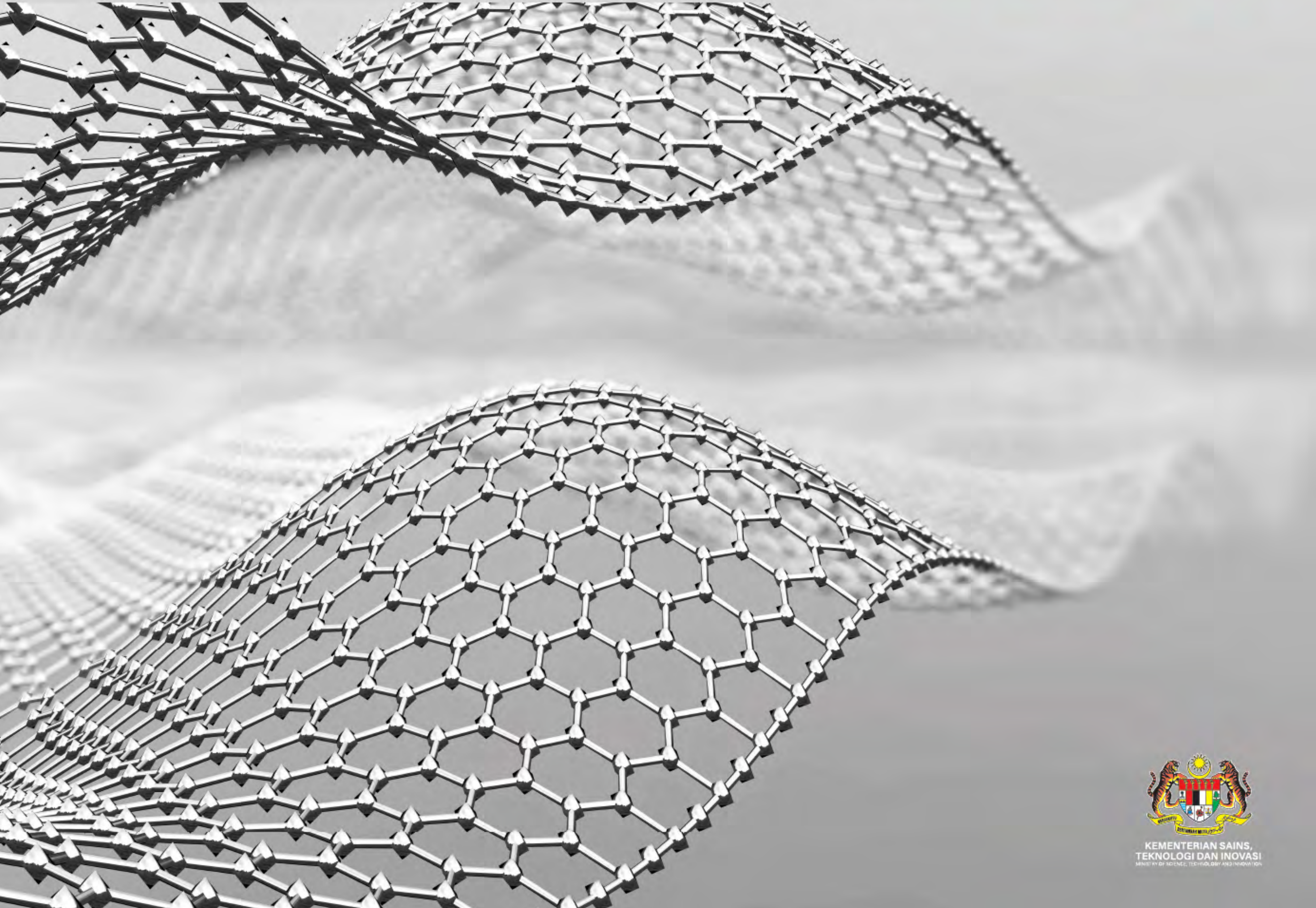
National Advanced Materials Technology Roadmap 2021-2030



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MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATION

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National Advanced Materials Technology Roadmap

2021-2030

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FOREWORD

Minister of Science, Technology & Innovation

YB Dato' Sri Dr. Adham Baba
Minister of Science, Technology & Innovation

During the High-Tech Nation Council meeting in December 2020, we aimed to champion existing and upcoming technologies that have the potential to be developed here in our country. Our aspirations lean towards high-tech national advancement, which in turn, would lead to rapid development through a strong base in science and technology. With all the reasons and rationales combined, MOSTI launched the 10-10 Malaysian Science, Technology, Innovation and Economy (MySTIE) Framework and National Policy on Science, Technology and Innovation (NPSTI) 2021-2030.

Advanced materials often form the core for many technological advances that turn far-fetched concepts into reality across industries. Be it disruptive or complementing technologies, innovations in materials could change socio-economic trends. It contributes to the increasing use of technology in day-to-day life, as well as creating industry-specific trends with the possibility of pushing lightweight and smart products into marketable products and services. Keeping track of new and emerging material developments, processes, and resultant products is crucial for growth in any industry.

A diverse team of industry experts in materials, plastics, polymers, petrochemicals, coatings, chemicals, and oil and gas can also help companies succeed in their focus industry. The mastery to produce better materials more quickly with less cost will ensure the country is at the forefront of innovative technology and products, as well as being an economic powerhouse.

At the same time, COVID-19 is accelerating the transformation of traditional producers to be more digitised, and adopt resilient approaches to production and logistics through higher connectivity, advanced analytics, automation, and advanced manufacturing technologies. Visionary leaders ensure that their transformation initiatives include developing new business models and ideally drive new digital native revenue streams. In this disrupted world, they would invest in strategic resilience while focusing on inclusive, comprehensive, and sticky business models, such as platforms and solutions.

Although challenging, these initiatives are richly rewarding particularly in opening much broader opportunities for long-term value creation for all stakeholders. Companies that provide value-added services on their platforms could rely on recurring revenue streams. We can now observe several trends transforming supply chains today from these efforts, including 3D printing, customisation at a mass scale, near-sourcing, and the digitalisation of operations.

Malaysia is very capable of designing the best initiatives to help promote the development of the necessary infrastructure and policies, but ensuring these initiatives will continuously be utilised, improved upon, and translated into real value requires our system to produce a sustainable supply of technocrats and innovators. The government, through MOSTI, has set aside RM100 million in funds for National Technology and Innovation Sandbox (NTIS) to fast-track the development and commercialisation of advanced projects, especially those with the highest potential to boost key sectors such as healthcare, manufacturing, agriculture, education, travel, and tourism.

NTIS value-adds Malaysia's capabilities and competitiveness in high-value chain sectors by promoting high-end research, innovations, and commercialisation. The country's dependency on technology and innovation from other countries will be reduced, thus increasing productivity, ensuring supply chain security, and improving the quality of life of the people. I hope this is the new dawn for Malaysia. History shows that Malaysia can recover after a crisis and will always come back stronger.

Advanced materials often form the core for many technology advances that are turning far-fetched concepts into reality across industries.

FOREWORD

Secretary General, Ministry of Science, Technology & Innovation

YBhg. Datuk Zainal Abidin bin Abu Hassan
Secretary General
Ministry of Science, Technology & Innovation (MOSTI)

As a result of the rapid growth in emerging technologies worldwide and the advancement in research and development, advanced materials have been identified as one of the components under Industry 4.0 that can potentially be a catalyst for economic growth across many industries. High-tech industrial sectors, such as automotive, aerospace, defence, medical, electronics, and energy, have relied on cutting-edge materials for many years. This reliance is even more apparent today. These industries are progressing by leaps and bounds, and many of their breakthroughs involved advanced materials in commercial applications.

The National Advanced Materials Technology Roadmap 2021-2030 is formulated to be the primary reference for various stakeholders from research institutions, government and government agencies, academicians, and the industry for a period of 10 years in tandem with 12MP. It identifies the types of advanced materials, major players, and potential business opportunities in the ecosystem. The mission of this roadmap is to accelerate the advanced materials technology and industry agenda towards making Malaysia a high-tech nation.

This roadmap advocates three national goals followed by 5 strategies and 15 initiatives for the benefit of all stakeholders.

We hope that this roadmap will create opportunities for Malaysia to be at the forefront of this new era of advanced materials, especially in utilising the availability of its natural resources and human capital development to create new opportunities for Malaysia in regards of advanced materials. On top of the available industry ecosystem, we can focus on the areas of utilising the available natural resources and human capital development for this industry. With everyone's involvement in fortifying the current ecosystem and developing new ones, Malaysia will move up the value chain and be more resilient and proactive.

A strong advanced materials industry would pave the way for Malaysia to be the primary destination for smart manufacturing globally and attract more high-tech investments. Enhanced productivity, job creation, innovation capacity, high-skilled talent pool and ultimately economic prosperity and societal well-being will strengthen Malaysia's competitiveness in the long run.

FOREWORD
CEO, MIGHT

YBhg. Datuk Dr. Mohd Yusoff Bin Sulaiman
President & CEO
MIGHT

Due to the COVID-19 pandemic, the world has gone through the most extraordinary global economic crisis since World War II. The past two years have been challenging for the world, but interestingly 2020 and 2021 have been a turning point for science, technology, and innovation (STI), where the world of R&D witnessed some of the most exciting works of the past few decades.

It is a time when both private and public players in the STI ecosystem work together to solve the crisis not only in the rapid development of vaccines but also in the rollout of digital technologies that would help lessen the impact of the pandemic on our lives.

The pandemic has accelerated trends already underway, opening access to scientific publications, increasing the use of digital tools, enhancing international STI collaborations, and spurring a variety of public-private partnerships.

Even amid the global pandemic, MIGHT — who has always been a catalyst in building and driving partnerships in technology — stands tall as a bridge that provides strategic advice and alliances to shape high technology. We are very honoured to be involved in the formulation of the National Advanced Materials Technology Roadmap 2021-2030.

Our country's focus on advanced materials is not new. The interest has intensified steadily since the 1970s, and we are now partaking in its global growth. We have the capability and capacity to leverage the technology to our advantage.

We at MIGHT are always up to the challenge of producing key industry roadmaps, and I hope that the National Advanced Materials Technology Roadmap 2021-2030 will serve as the impetus in opening new paths for the Malaysian industry.

EXECUTIVE SUMMARY

Advanced materials are paving the way in diversifying innovative advancements globally at a phenomenal pace. With the world marching towards higher levels of interconnectivity, the demand for advanced materials and products is set to continue. This industry is ready to grow at an accelerated speed to support technological innovations in various sectors such as healthcare, aerospace, automotive, and others.

The National Advanced Materials Technology Roadmap 2021-2030 outlines the performance of various materials, technological innovations, market's economic status, process technologies, key initiatives, and strategic partnerships to drive industrial transformation.

The most important feature of an advanced material is its key role in product design. It enhances component performance and subsequently improves the efficiency of the entire system and overall durability. We are now in the midst of materials revolution and over the next decade, rapid advancement in materials will have a massive impact on modern industrialisation.

Malaysia has come a long way from its dependence on commodities such as tin and rubber to become a base for manufacturing. Today, it is making great strides to emerge as one of the key players in advanced materials sector since the 1970s, when multi-national corporations (MNCs) began their operations in the country. A vast acceleration in the ability to create new advanced materials will power giant industries, from energy to manufacturing.

Advanced materials can be defined in numerous ways; the broadest definition is to refer to all materials that represent advances over the traditional materials, according to its purpose and goals.

In this roadmap, it is defined as:

> *"Novel or improved materials engineered for targeted and improved properties that provides a distinct advantage in (physical or functional) performance and application when compared to conventional materials which enable and provide technological innovation solutions and are sustainable to the economy, environment and society."*

Advanced materials help technological innovations and optimise the cost and efficiency of existing products. On a global scale, substantial evidence in recent years shows that both public and private organisations are willing to invest and dedicate resources to research and develop new materials that produce and commercialise better finished products. Currently, metamaterials hold the highest forecasted value among all the materials, followed by plastics.

Due to the increasing requirement and subsequent introduction of new materials to replace existing ones, advanced materials are constantly evolving and have prompted new innovations in the field of electronics, aerospace, automotive, coatings and paints, energy storage and more. Malaysia's advanced materials sector is positioned to spearhead the country into becoming a high-income, knowledge-based economy that will transform the country into a centre for regional or global manufacturing services.

Policies, initiatives and strategic plans are being set through the 10-10 MySTIE framework as strategic technology drivers. Globally, countries like China, Japan, Canada, South Korea, and the UK are active players in the advanced materials technology. Adopting the benchmark set by these countries in terms of best strategies, guidelines, and parameters may benefit Malaysia to advance further.

In developing this roadmap, six ground-breaking foresight research methods by MIGHT were applied. The methods namely Horizon Scanning, Interviews and Expert Panels, Scenario Analysis, MIGHT's F.I.R.S.T™ Matrix, Focus Group Workshops, and Wind Tunnelling were used to assess the current and future trends as well as identifying issues and challenges faced by the industry. This entire process involved up to 262 people from 60 organisations.

In addition, 778 surveys were also distributed to gather data and insights of the advanced materials scenario in Malaysia.

Surveys' Participating Industries

- Energy
- Medical & Healthcare
- Smart Technology
- Smart Cities & Transportations
- Water & Food
- Agriculture & Forestry
- Education
- Environment & Biodiversity

With the COVID-19 outbreak in early 2020, these efforts were mostly conducted virtually due to the Movement Control Order (MCO) enforced by the government.

Based on the data and findings gathered, a total of 3 goals, 5 strategies and 15 action plans are outlined in this industry-driven roadmap for Malaysia to capitalise on the availability of its natural resources and human capital development within the advanced materials ecosystem.

Three Goals For Malaysia In Becoming A High-Tech Nation By 2030:

GOAL 1	Nurturing world class capabilities and innovation culture in advanced materials.
GOAL 2	Strengthening Malaysia's competitiveness through balanced growth in economic and technology development in advanced materials.
GOAL 3	Intensifying the global connectedness by evolving into becoming the regional centre for production and services for advanced materials.

5 Strategies for Malaysia to achieve the goals

STRATEGY 1:

Accelerating materials innovation ecosystem via effective Policies and Regulations

The acceleration of advanced materials innovation ecosystem in Malaysia is crucial to increase opportunities for local innovators in securing a high-tech market and ensuring demand and supply securities. A comprehensive review on market policy is a step forward, which include the development of effective policies and regulations as well as attractive incentives such as import reduction for investors in the industry.

STRATEGY 2:

Enhancing the competitiveness of local industries via integrated Physical & Digital Infrastructure

The consolidation of Advanced Materials' COEs is vital to enhance the local industries' competitiveness as it will readily and easily allow players to leverage on existing physical and digital infrastructures. An integrated material informatics platform will accelerate the development of advanced materials for the research universities, institutions and local industries. The development and application for advanced materials industries can be further promoted by partnering with international players.

STRATEGY 3:

Empowering business sustainability via the establishment of a Consortium as a 'one-stop centre'

To empower business sustainability, a centralised consortium is proposed to govern multi-disciplinary and multi-stakeholder collaboration for greater coordination and facilitation in achieving innovation goals and strategic investments. The consortium can help to synchronise and address the gaps in the value chains, R&D funds and experts, industrial problems and technology updates, outreach as well as human capital development.

STRATEGY 4:

Enhancing Malaysia's capabilities in material development via conducive R&D&C&I activities

Malaysia's capabilities in material development can be strengthened via intensifying industry-led collaborative research, enhancing government co-funding in R&D&C&I works by the industries and leveraging on current COEs research facilities. A conducive R&D&C&I environment will manoeuvre the industry towards commercialisation and optimise the industries' development costs.

STRATEGY 5:

Nurturing world-class talent via strategic partnership

Nurturing local world-class talent is critical in building the confidence of researchers to collaborate with the industry in developing advanced materials applications. This strategy can be achieved by increasing the participations of IHL researchers in the industry, getting international organisations to collaborate and partner with local organisations and developing local talent in critical areas of expertise, such as material informatics.

Two priorities and four game-changers in transforming Malaysia to become a high-tech nation have been identified from the roadmap's strategies and action plans.

PRIORITIES

1 

ESTABLISHMENT OF NATIONAL ADVANCED MATERIALS CONSORTIUM (NAMC)

2 

CONSOLIDATION OF ADVANCED MATERIALS CENTRES OF EXCELLENCE (COEs)

NAMC, co-chaired by the ministry and industry, shall act as an advisor to the government in monitoring the roadmap implementation. This consortium will govern multi-disciplinary and multi-stakeholder collaborations, synchronise and address the gaps in the value chains, R&D&C&I funds and experts, industrial problems and technology updates as well as outreach and human capital development. In addition, NAMC will be a referral centre for business facilitation, providing assistance to create networks and engagement for early adopters in the industry.

The consolidation of COEs under National COE (NCOE) will consist of integrated Physical and Digital Infrastructures. The NCOE shall report to NAMC and will leverage on existing physical centres that house crucial information on infrastructure for material development, analysis, sustainable production techniques, testing, quality verification and certification.

NCOE will host a material informatics platform that can accelerate the deployment of advanced materials faster and cheaper as compared to traditional methods. This platform will benefit all the public-private stakeholders in developing new materials to fulfil technology performance requirement, hence uplifting local industries innovation capabilities and competitiveness. Establishment of this industrial databank for the local advanced materials industries is vital to provide and store information of numerous material research activities.

In efforts to further upsurge the industry, graphene, nitinol, rare earth and microcrystalline cellulose polymer (MCC) have been identified as the four game-changers, through a specially designed programme to make significant contributions to the development of Malaysia's advanced materials industry.

GAME CHANGERS

1. GRAPHENE
2. NITINOL
3. RARE EARTH
4. MICROCRYSTALLINE CELLULOSE POLYMER

The programme will act as a catalyst in developing the advanced materials ecosystem in Malaysia. Ownership of IPs, manufacturing capability, raw materials, market readiness and cross cutting applications of these advanced materials are among the determining factors considered for the selection. Synergy in multi-stakeholders' participation will reduce the import dependency of advanced materials in crucial economic sectors in Malaysia while at the same time contribute to the nation's income generation and job creation as well as enhance the sustainability of local businesses in the industry.

Innovations in advanced materials underpin all manufacturing sectors and are essential to Malaysia's economic growth. These innovations are meant not only to solve technological challenges, but in a far wider sense, a long-term vision for a sustainable new economy with social dimensions.

Unyielding commitment from stakeholders and close monitoring by relevant agencies will serve as an impetus for Malaysia to become a high technology nation and benefit future generations.

ABBREVIATIONS

#

10-10 MySTIE	10-10 Malaysian Science, Technology, Innovation and Economy Framework
11MP	Eleventh Malaysia Plan
12MP	Twelfth Malaysia Plan
2D	Two dimensional
3D	Three dimensional
4IR	Fourth Industrial Revolution

A

AC	Activated Carbon
ACM	Advanced Composite Manufacturing
ADFIM	Association of Development Finance Institutions of Malaysia
AELB	Atomic Energy Licensing Board
AFP	Automated Fibre Placement
AHSS	Advanced High Strength Steel
AI	Artificial Intelligence
AL	Advanced Aluminum Alloys
ALPER	Advanced Lightning and Power Energy Research
AMIC	Aerospace Malaysia Innovation Centre
AMTEC	Advanced Membrane Technology Research Centre
ANM	Nuclear Malaysia
AP	Asia Pacific Region
API	Active Pharmaceutical Ingredients
AR	Argentina
ASM	Academy of Science Malaysia
AT	Austria
ATL	Automated Tape Laying
AU	Australia

B

BCF	Biotechnology and Commercialisation Fund
BNM	Bank Negara Malaysia
BNNTs	Boron Nitride Nanotubes
BR	Brazil
Bio-MEG	Bio-mono ethylene glycol

C

CA	Canada
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CAPEX	Capital Expenditure
CBU	Complete Built-Up
CF	Carbon Fibre
CFRP	Carbon Fibre Reinforced Polymer
CIP	Cradle Investment Programme
CL	Chile
CN	China
CNT	Carbon Nanotube
CO_2	Carbon Dioxide
COE	Centre of Excellence
COVID-19	Coronavirus Disease 2019
CRDF	Commercialisation of R&D Fund
CREST	Collaborative Research in Engineering, Science and Technology Centre
CTRM	Composites Technology Research Malaysia
CVD	Chemical Vapour Deposition
Ce	Cerium

D

DDI	Domestic Direct Investment
DE	Germany
DLT	Distributed Ledger Technology
DOE	Department of Environment Malaysia
DOSM	Department of Statistics Malaysia
DWNTs	Double-Walled Nanotubes

E

E&E	Electrical and Electronic
EC	Ecuador
EG	Egypt
EMI	Electromagnetic Interference
EP	European Patent Office
EPU	Economic Planning Unit
ES	Spain
ESD	Electrostatic Discharge
EU	European Union
EV	Electrical Vehicle

F

F.I.R.S.T™	Funding and Finance, Infrastructure, Regulations and Policies, Skills and Talents, and Technology
FDI	Foreign Direct Investment
FIC	Fast Interceptor Craft
FLG	Few-Layer Graphene
FMCGs	Fast-Moving Consumer Goods
FMM	Federation of Malaysian Manufacturers
FR	France

G

GaN	Gallium Nitride
GB	United Kingdom
GDP	Gross Domestic Product
GE	General Electric
GFRP	Glass Fibre Reinforced Polymer
GLC	Government Linked Company
GNI	Gross National Income
GNP	Graphene Nanoplatelets
GO	Graphene Oxide
GR	Greece
GTFS	Green Technology Financing Scheme

H

HDPE	High-Density Polyethylene
HRDF	Human Resource Development Fund
HTF-NIA	High-Tech Facility - National Investment Aspirations
HU	Hungary

I

IAMM	Islamic Arts Museum Malaysia
ICBP	Indochine Bio Plastiques (ICBP) Sdn. Bhd.
ID	Indonesia
IEM	The Institution of Engineers, Malaysia
IHL	Institutes of Higher Learning
IIoT	Industrial Internet of Things
IIUM	International Islamic University Malaysia
IL	Israel
IMM	Institute of Materials Malaysia
IMO	International Maritime Organisation
IN	India
INTROP	Institute of Tropical Forestry and Forest Product
IP	Intellectual Property
IT	Italy
ITMA	Institute of Advanced Technology
Industry 4WRD	National Policy on Industry 4.0
IoT	Internet of Things

J

JMG	Mineral and Geoscience Department
JP	Japan
JPM	Prime Minister's Department

K

KASA	Ministry of Environment and Water Malaysia
KeTSA	Ministry of Energy and Natural Resources Malaysia
KKMM	Ministry of Communications and Multimedia Malaysia
KPI	Key Performance Indicator
KPKT	Ministry of Housing and Local Government Malaysia
KPLB	Ministry of Rural Development Malaysia
KR	Republic of Korea
KYS	Kolej Yayasan Saad

ABBREVIATIONS

L

LAMP	Lynas Advanced Material Plant
LCP	Liquid Crystal Polymers
LMR	Lithium-and Manganese-Rich
LNMO	Lithium-Nickel-Manganese Oxide
LOHCs	Liquid Organic Hydrogen Carriers
LSSPV	Large Scale Solar PV
LT	Lithuania
LTKN	National Kenaf and Tobacco Board of Malaysia
LV	Latvia
Li	Lithium
LiDAR	Light Detection and Ranging
Ln	Lanthanum

M

MAFI	Ministry of Agriculture and Food Industries Malaysia
MARA	Majlis Amanah Rakyat
MARDI	Malaysian Agricultural Research and Development Institute
MARii	Malaysia Automotive, Robotics and IoT Institute
MATRADE	Malaysia External Trade Development Corporation
MBDC	Malaysia Bioeconomy Development Corporation
MBOT	Malaysia Board of Technologists
MCC	Microcrystalline Cellulose
MCMC	Malaysian Communications and Multimedia Commission
MCO	Movement Control Order
MD	Republic of Moldova
MDA	Medical Device Authority
MDEC	Malaysia Digital Economy Corporation
MDF	Market Development Fund
MDV	MDV Berhad
MEDAC	Ministry Of Entrepreneur Development And Cooperatives Malaysia
MGCC	Malaysian-German Chamber of Commerce and Industry
MGE	Materials Genome Engineering
MGTC	Malaysian Green Technology and Climate Change Corporation
MIDA	Malaysian Investment Development Authority
MIDF	Malaysia Industrial Development Finance Berhad
MIG	MIGHT's Interest Group
MIGHT	Malaysian Industry-Government Group for High Technology
MIM	Metal Injection Moulding
MINDEF	Ministry of Defence Malaysia
MISIF	Malaysian Iron and Steel Industry Federation
MITI	Ministry of International Trade and Industry Malaysia
MLG	Multilayer Graphene
MNC	Multinational Corporation
MOF	Ministry of Finance Malaysia
MOFs	Metal Organic Frameworks
MOH	Ministry of Health Malaysia
MOHA	Ministry of Home Affairs Malaysia
MOHE	Ministry of Higher Education Malaysia
MOHR	Ministry of Human Resource Malaysia
MOSTI	Ministry of Science, Technology and Innovation Malaysia
MOT	Ministry of Transport Malaysia
MPC	Malaysian Productivity Corporation
MQA	Malaysian Qualifications Agency
MRI	Magnetic Resonance Imaging
MRO	Maintenance, Repair & Overhaul
MSW	Municipal Solid Waste
MTCMS	Marine Technology Company Mega Salutes
MTDC	Malaysian Technology Development Corporation
MTEG	Materials Technology Group
MTSF	Malaysia Toray Science Foundation
MWNTs	Multiwalled Nanotubes
MX	Mexico
MY	Malaysia

N

NAICO	National Aerospace Industry Coordinating Office
NAMC	National Advanced Material Consortium
NAP	National Automotive Policy
NCOE	National Advanced Material Centre of Excellences
NEM	Net Energy Metering
NIST	National Institute of Standards and Technology
NMC	Nickel-Manganese-Cobalt
NOSS	National Occupational Skills Standard
NP	Nanoparticles
NPP3	National Physical Plan 3
NPSTI	National Policy on Science Technology and Innovation
NTIS	National Technology and Innovation Sandbox
NUP2	National Urbanisation Policy 2
Nd	Neodymium

O

ODM	Original Design Manufacturer
OEM	Original Equipment Manufacturer
OOA	Out-of Autoclave
OPEX	Operating Expenditure
OSV	Off-shore Vessel

P

PA	Polyamide
P-type	Porous Particles
PBAT	Polybutylene adipate-co-terephthalate
PCMs	Phase-Change Materials
PDCA	Plan-Do-Check-Act
PE	Peru
PET	Polyethylene Terephthalate
PHA	Polyhydroxyalkanoate
PL	Poland
PNF	Polyethylene Furanoate
POC	Proof of Concept
PP	Polypropylene
PTFE	Polytetrafluoroethylene
PV	Photovoltaic
Pr	Praseodymium

R

R&D	Research and Development
R&D&C&I	Research, Development, Commercialisation and Innovation
R&T	Research and Technology
RDF	Refuse-Derived Fuel
RE	Rare Earth
REE	Rare Earth Element
REO	Rare Earth Oxide
RFID	Radio-Frequency Identification
RMK12	Rancangan Malaysia Ke-12
RP	Reinforced Polymer
RPA	Robotics Process Automation
RU	Russian Federation
RUI	Research University & Institution
rGO	Reduced Graphene Oxide

S

S-type	Spherical Particles
SA	Saudi Arabia
SCC	Sabah Credit Corporation
SDAICO	Selangor Darul Ehsan Aerospace Coordinating Office
SDB	Sabah Development Bank Berhad
SDG	Sustainable Development Goal
SEDA	Sustainable Energy Authority Development Malaysia
SFDT	Soft Financing Scheme for Digital and Technology
SG	Singapore
SI	Slovenia
SiC	Silicon Carbide
SIRIM	Standard and Industrial Research Institute of Malaysia
SIRIM AMREC	SIRIM Advanced Materials Research Centre
SMART	Specific, Measurable, Attainable, Realistic and Timeliness
SMAs	Shape Memory Alloys
SMC	Shape Memory Composites
SME	Shape Memory Effect

ABBREVIATIONS

SMPs	Shape Memory Polymers
SOP	Standard Operating Procedure
SRF	Solid Recovered Fuel
SSBs	Solid State Batteries
STI	Science, Technology and Innovation
STRG	Science and Technology Research Grant
STRIDE	Science & Technology Research Institute for Defence
SWNTs	Single-Walled Nanotubes

T

TCA	Technology Commercialisation Accelerator
TKSU	Timbalan Ketua Setiausaha
TNB	Tenaga Nasional Berhad
TPM	Technology Park Malaysia
TRGS	Trans-disciplinary Research Grant Scheme
TRIZ	Theory of Inventive Problem Solving
TRL	Technology Readiness Level
TSV	Terengganu Silica Valley
TV	Television
Ti	Titanium

U

UiTM	Universiti Teknologi Mara
UK	United Kingdom
UKM	Univerisiti Kebangsaan Malaysia
UM	Universiti Malaya
UMK	Universiti Malaysia Kelantan
UMP	Universiti Malaysia Pahang
UMW	United Motor Works
UniMAP	Universiti Malaysia Perlis
UNITEN	Universiti Tenaga Nasional
UPM	Universiti Putra Malaysia
USA/US	United States of America
USFDA	US Food and Drug Administration Agency
USM	Universiti Sains Malaysia
UTHM	Universiti Tun Hussein Onn Malaysia
UTM	Universiti Teknologi Malaysia

V

VAV	Vacuumshmeitze
VN	Vietnam

W

WIPNET	Research Centre of Excellence for Wireless and Photonics Network
WIPO/WO	World Intellectual Property Organization
WPC	Wood Plastic Composite

Y

Y	Yttrium

Z

ZA	South Africa

CONTENTS

CHAPTER LIST

CHAPTER

1 NATIONAL ADVANCED MATERIALS TECHNOLOGY ROADMAP 2021-2030

THE AGE OF ADVANCED MATERIALS
materials characteristics can now be engineered and designed for their intended functions

Introduction

The emergence of new technologies and materials is always closely connected to human civilisation and socio-economy. As new technological capabilities and findings from advanced research progress, we have arrived at The Age of Advanced Materials, where specific materials characteristics can be engineered and designed for their intended functions. Nanotechnology is a pivotal example involving applications of advanced materials with large numbers of nanomaterials used in consumer, industrial, and medical applications such as imaging, targeted drug delivery, nanorobots for surgery, and cell repair. It is also gaining traction in the automotive sector due to the rising awareness of efficient vehicles and reducing carbon footprint.

In modern history, the change from an agrarian economy to one dominated by technology and machine manufacturing started during the Industrial Revolution in the 18th century. During this era, cities and industries grew rapidly while significantly contributing to nations' economies. The main features in the Industrial Revolution included the use of new basic materials (mainly iron and steel), the use of new energy sources (such as coal, steam engine, electricity, and petroleum) and the increasing application of science to industry. These technological changes tremendously increased the use of natural resources, and the mass production of steel is one of the key advancements behind the Second Industrial Revolution.

Sweeping changes brought about by digital computing marks the Third Industrial Revolution, also known as the Digital Revolution — during which the shift from analogue and mechanical electronic technology to pervasive digital technology dramatically disrupted industries, especially global communications and energy. It was also the starting point of the digitalisation era where mainframe computing, personal computing, and the Internet were introduced.

Currently, the world is at the emergence of the Fourth Industrial Revolution, known as 4IR, where cyber-physical interconnections have become a reality. Autonomous processes, artificial intelligence, big data analytics, and the Internet of things (IoT) are just among the

#Quick Fact

In Malaysia, the advanced materials industries started in the 1970s, when foreign firms such as Intel, AMD, HP, Hitachi and National began their operations between 1971 and 1974.

few technologies that require more advanced materials with distinct performances compared to conventional materials — these technologies are deemed faster, lighter, highly durable, and highly reliable to cope with new and more advanced applications.

In 2010, two physicists Sir Andre K. Geim and Sir Konstantin Novoselov were awarded the Nobel Prize in Physics for their research in graphene. The study found that graphene is the world's thinnest, strongest, and most conductive material for electricity and heat. The superior properties of the material garnered enormous attention from researchers and businesses around the globe, making it useful in cross-sector applications. It carries a substantial potential to revolutionise entire industries, such as energy, electrical, automotive, and more.

Technologically advanced countries are now focused on mastering and developing advanced manufacturing capabilities by transforming the industry onto the next technology frontier through higher investments in high-tech infrastructure and providing quality education, which will raise their economic wellbeing.

The continued existence of traditional and modern materials is in tandem with new emerging technologies in many sectors and applications. In Malaysia, *Hibiscus cannabinus L* or kenaf, first introduced in 2010, is fast becoming the country's third industrial crop after palm oil and rubber as an alternative to tobacco. Kenaf was introduced as the new local natural fibre composite and helps provide high income for smallholders. The National Kenaf and Tobacco Board of Malaysia (LKTN) has allocated 2,000 hectares for smallholders to cultivate kenaf — the global market is expected to reach $854 million by 2025.

Roadmap Background

Advanced materials play a very significant role in transforming the global manufacturing industry. It encompasses all sectors including electronics and electrical, civil engineering and construction, machinery and equipment, medical devices, chemicals, aerospace, as well as automotive. Through various modifications, the quality of physical and functional performance of materials is increased — including high strength to weight ratio, superconductivity, hydrophobicity, hydrophilicity, high thermal resistivity, chemical resistance, and many more. One of the signs of progress in materials development is to enhance the efficiency of renewable energy generation and storage as well as developing light materials to reduce energy consumption. Nanomaterials and functionally graded materials have a crucial role in increasing components' strength to weight ratio to reduce CO_2 emissions.

The growth of the advanced materials industry can be ascertained through the increasing number of research and development activities in developing regions. The US government has invested over $250 million in new R&D and innovation infrastructure to anchor the use of advanced materials in existing and emerging industrial sectors in 2011. In 2015, China launched the 'Advanced Materials Science & Technology in China: A Roadmap to 2050' as their strategic document and funded $150 million in the Materials Genome Engineering (MGE) project in 2016. Robust frameworks and supports in developing advanced materials ecosystems have also been initiated in other countries such as Canada, Japan, Germany and other EU countries.

In Malaysia, the advanced materials industries started in the 1970s, when MNCs such as Intel, AMD, HP, Hitachi, and National began their operations between 1971 and 1974. Since then, increasing consumption of consumer goods and expanding applications of advanced materials in areas such as healthcare, aerospace, automotive, and others are envisioned to bolster the growth of the advanced materials market in the country. The rise of the composites industry started after the launch of the National Aerospace Blueprint 1997. It charted the development of composites materials to transform Malaysia's aerospace industry into a dynamic regional and international aerospace player.

Kenaf, fast becoming the country's third industrial crop after palm oil and rubber, is seen as an alternative to tobacco after being introduced as the new local natural fibre composite.

The blueprint recommended maintaining National Advanced Composites Register, establishing National Advanced Composites Advisory Committee, introducing Composites Procurement Programme and Regional Aerospace Composites Centre, as well as expanding the number of key domestic players in advanced composites. As a continuation, the second blueprint, the Malaysia Aerospace Industry Blueprint 2030, proposed an initiative to attract foreign direct investment from raw material suppliers to set up warehouse in the country as a regional hub. As an outcome of the blueprint, the number of domestic players in advanced composites has increased and expanded to other sectors such as maritime, defence, security, and construction.

Since then, Malaysia has achieved various milestones in the advanced materials sector. In 2011, NanoMalaysia Berhad was incorporated under the Ministry of Science, Technology and Innovation (MOSTI) to act as a business entity entrusted with nanotechnology commercialisation activities and launched the National Graphene Action Plans 2020. Advanced materials technology was also identified as one of the enabling technologies to enhance the Industry 4.0 agenda through the National Policy on Industry 4.0 (Industry 4WRD) launched by the Ministry of International Trade and Industry (MITI) in 2018.

MOSTI launched the National Policy on Science, Technology and Innovation (NPSTI) 2021-2030 and 10-10 Malaysian Science, Technology, Innovation and Economy (MySTIE) Framework in December 2020 to propel Malaysia into a knowledge-intensive economy with the advanced materials sector as its key driver. Soon after the launch, in support of high-tech and innovation-driven SMEs affected by COVID-19, Bank Negara Malaysia introduced the High Tech Facility - National Investment Aspirations (HTF-NIA) during the National Budget 2021 announcement to revitalise the nation's innovation capacity. This initiative is launched for the high technology business and services sector as well as R&D driven firms in advanced materials to ensure its competitiveness globally.

Apart from undergoing a fast-moving expansion over the past few years, the automotive and aerospace industries have witnessed significant growth with the support of advanced materials, especially in the Asian region. Additionally, adopting cutting-edge technologies that hinge on this industry on a larger scale and the abundance of mineral resources accessible here are helping drive the market demand for advanced materials. On account of these factors, MOSTI embarks on developing the **National Advanced Materials Technology Roadmap 2021-2030** for the future of national economic growth. A series of stakeholders' engagements were held to gather insights and inputs from the local industry players and universities. Subsequently, MOSTI requested one of its agencies, MIGHT, to develop a roadmap aligned with national strategic long-term goals with a specific focus on economic growth.

In this roadmap, we discuss the overview of the types of advanced materials that are available both locally and globally, their growth, role and potential in transforming Malaysia into a knowledge-intensive economy through various socio-economic driver technologies — such as medical and healthcare, agriculture and forestry, as well as environment and biodiversity. With the rapid expansion in manufacturing activities and industrialisation taking place, Malaysia is also anticipating the growth of this industry's market in the next decade.

Roadmap Objectives

The objectives of the National Advanced Materials Technology Roadmap 2021-2030 have been set as follows:

1. To analyse the nation's goals and prioritisation in relation to advanced materials.
2. To prepare proposals and implement strategic plans that have been identified in the national roadmap to develop the advanced materials technology industry in Malaysia.
3. To identify the key sectors that will drive the initiatives to accelerate the growth of the advanced materials industry.

Scope

The National Advanced Materials Technology Roadmap 2021-2030 was prepared in accordance with the **National 4IR Policy**, **National Policy on Science, Technology and Innovation (NPSTI) 2021-2030** and **10-10 Malaysian Science, Technology, Innovation and Economy (MySTIE) Framework.** This roadmap focuses on the development of the national advanced materials technology directions, targets, and goals for the period of 2021-2030.

#blueprints

- National Aerospace Blueprint 1997
- Malaysia Aerospace Industry Blueprint 2030
- National Graphene Action Plan 2020
- National Policy on Industry 4.0 (Industry 4WRD)
- National Policy on Science, Technology and Innovation (NPSTI) 2021-2030
- 10-10 Malaysian Science, Technology, Innovation and Economy (MySTIE) Framework
- National 4IR Policy
- **National Advanced Materials Technology Roadmap 2021-2030**

CHAPTER

2 OVERVIEW OF ADVANCED MATERIALS

Advanced materials are primarily defined as new and improved materials that provide a unique advantage in performance. However, it holds different definitions to different organisations depending on the purpose and goals of the respective institutions in using the advanced materials. Therefore, to achieve the objectives of this roadmap, the following definition is championed. It highlights the distinct types of advanced materials and their way forward in various applications in Malaysia, as shown in Table 2.1.

Malaysian Definition for Advanced Materials

ADVANCED MATERIALS:

"Novel or improved materials engineered for targeted and improved properties, that provide a distinct advantage in (physical or functional) performance and application when compared to conventional materials, which enable and provide innovative technological solutions and sustainability to the economy, environment, and society."

Table 2.1 Malaysian Definition for Advanced Materials

(This definition is a result of numerous engagements and was agreed upon by the Technical Committee of this roadmap.)

Source: MIGHT Analysis

Global Overview of Advanced Materials

Advanced materials provide a vast scope of research and potential applications — the two main factors that allow advanced materials to make innovative advancements in different markets. With rapid industrialisation happening across the world, the demand for advanced materials is increasing globally. Besides the **growing activity of research and development of advanced materials** in many regions, its **expanding applications in different sectors** like healthcare, aerospace, and automotive are among the main drivers for the development of the global advanced materials market.

These two factors are summarised in the advanced materials system outlined in the report, 'Reigniting Growth: Advanced Materials Systems' published by Deloitte Touche Tohmatsu Limited (DTTL) Global Manufacturing Industry Group in 2012. The system, described as a new approach for manufacturing sectors to pursue opportunities in large markets, is enabled by materials technologies, wherein innovation moves beyond the frontier of new molecules and materials. It can promote growth, value creation, and innovation renewal by delivering functional solutions to markets and customers.

Figure 2.1 demonstrates a potential advanced materials ecosystem, showing relationships and possible value-creation opportunities. It primarily highlights three stages, namely **material and process discovery, material component development**, and **system integration**, showcasing how these three steps correlate with each other while also acknowledging the key players involved to ensure the system is effective.

Materials and process discovery outlines several sources in developing novelty or improved materials. Entities like research universities and institutions (RUIs) and national labs may succeed in formulating new compositions of matter and processes. On the other hand, **material component development** involves a few players focusing on the commercial development of novel materials. These include startup companies that develop system components (or even complete systems). System components incorporate new materials and technologies into wider solutions. This space consists of independent engineering and design firms that contract or engage with system integrators to bridge gaps in incorporating a solution in the market.

System or product manufacturers (which often involve large OEMs for industrial products) would then subsume **system integration** activities like energy, agriculture, and transportation. The system integration also includes any other players that help transition materials from business to consumer. In this ecosystem, it is not only crucial for the entities to determine value creation and capture it, but their interactions are critical as well. Interactions between these organisations allow key players to have a more distinct view, allowing them to go beyond only moving upstream or downstream of their positions along the chain.

This advanced materials system establishes networks that integrate different channels while optimising all components in the value system — creating an ecosystem that encourages and nurtures new partnerships, avenues, and strategies catered to the market's needs. Even though this system is not a new pursuit in this industry, it acts as a distinct guideline to steer future innovation.

The expansion of the system opens doors to an increasing number of companies and startups. Indeed, the global economy could use a growth engine in this field as society will continue to demand solutions or products that provide answers to problems and establish a durable market for advanced materials for the years to come.

Simplified View of a Potential Advanced Materials Systems Ecosystem

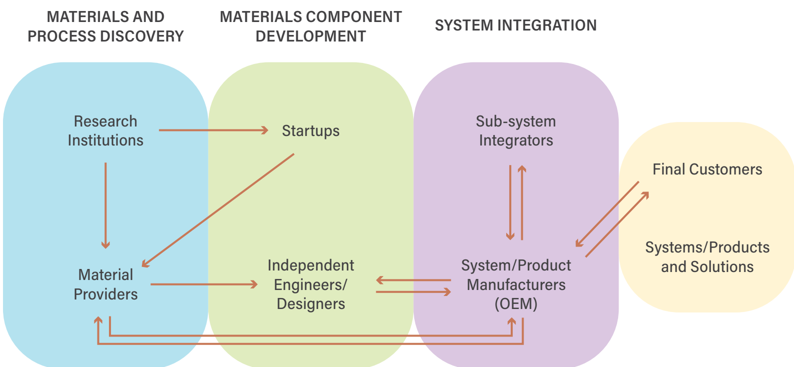

Figure 2.1:
Simplified View of a Potential Advanced Materials Systems Ecosystem
Source:
Deloitte Reigniting Growth Advanced Materials System, Deloitte Touche Tohmatsu Limited ("DTTL")

Market Value of Advanced Materials

The market value of advanced materials is gathered in Table 2.2. Among all the materials, metamaterials hold the highest forecasted value at $5,900 billion by 2028 and had the second highest market value between 2014 and 2020 at $448 billion. Plastics come in with the second highest forecasted market value at $754 billion by 2027. From 2014 until 2020, plastics held the highest market value at $569 billion.

The market shows that while plastics-related technologies and products are mature, they still possess a high potential to be further developed and will continue to have high demand in the future. Meanwhile, metamaterials-related technologies and products are still at the development stage. They will be the key material for advanced technologies and applications

Forecasted Value

Materials	Specifics	Market Value (Billion USD)															Highest Value Forecasted (Billion USD)
		2014	2015	2016	2017	2018	2019	2020	2021*	2022*	2023*	2024*	2025*	2026*	2027*	2028*	
Metamaterials			308			448					1,800		2,500			5,900	5,900
Plastics						523	569						721		754		754
Composite Materials			67		77		89								181		181
Lightweight Materials	Metals				96						143						143
Plastic Recycling							34								80		80
Lightweight Materials	Composites				39						63						63
Technical Ceramics			57	62													62
3D Printing Products and Services								13		26		41					41
Advanced Composites					23					38							38
Lightweight Materials	Plastics				24						36.9						37
Matrix for Carbon Composite	Polymer					16											16
CNT						4.47								15			15
Biodegradable Plastics						3.0					6.1				12		12
Biodegradable Plastic Packaging							4.7						12				12
Electroceramics				8.3						12							12
Post-Consumer Recycled Plastics							7.7					10					10
Composite Manufacturing Equipment						6.1					9.0						9
Nanocomposites							4.1					8.5					8.5
Matrix For Carbon Composite	Ceramics					4.7											4.7

continued next page

Materials	Specifics	Market Value (Billion USD) 2014	2015	2016	2017	2018	2019	2020	2021*	2022*	2023*	2024*	2025*	2026*	2027*	2028*	Highest Value Forecasted (Billion USD)
Ceramic Fibres						1.6				2	2.2	2.4	2.6		3.2		3.2
Graphene-Based Products			0.002						0.31				2.5				2.5
Recycled Plastic and Waste to Oil		0.54										1.97					1.97
Matrix for Carbon Composite	Hybrid					1.2											1.2
Graphene							0.079								1.1		1.1
Matrix for Carbon Composite	Metal					0.82											0.82
Graphene Nanocomposites						0.05										0.8	0.8
Nanocellulose								0.3					0.78				0.78
CFRP (Thermoplastic)		0.25	0.275							0.56	0.62	0.7	0.78				0.78
Polymer Delivered Ceramics					0.44					0.71							0.71
Transparent Ceramics				0.19						0.55							0.55
3D Printed Technical Ceramics			0.12	0.14						0.54							0.54
Graphene Batteries							0.049								0.4		0.4
Graphene-Enhanced Composites	Polymer Composites				0.07						0.32						0.32
Graphene Nanoplatelets				0.12									0.21				0.21
Graphene Composites					0.007	0.009								0.11			0.11
Advanced Ceramics and Nanoceramic Powder						0.16					0.025						0.025
Graphene-Enhanced Composites	Ceramic Composites				0.005						0.02						0.02
Graphene-Enhanced Composites	Metal Composites				0.003						0.013						0.013

Table 2.2
Market Value of Materials
Source: Statista

in the future, such as 5G/6G, Light Detection and Ranging (LiDAR) for autonomous vehicles, and others. Despite so much hype, the highest forecasted market value for graphene is only at $2.5 billion in 2025. While graphene is dubbed as a super material, it has yet to live up to its commercial expectations due to the high cost of production, the environmental impacts of graphite mining, and inconsistencies in quality. Continuous R&D work needs to be carried out in overcoming those challenges before graphene can be adopted widely by the industry and have higher market value.

#Quick Fact

Metamaterials-related technologies and products will be the key elements for advanced technologies and applications in the future

Malaysia's Overview of Advanced Materials

Given the great potential of advanced materials, the Malaysian government has directed many efforts towards collaborative research activities between organisations and industries. These include constant knowledge sharing sessions and programmes among industry experts, researchers, and scientists from various backgrounds, to ensure a continuous sharing of knowledge and updates on new advances in advanced materials that will not only solve modern day problems but also achieve desired commercialisation impacts. Furthermore, as stipulated in the national strategic documents such as National 4IR Policy, Industry 4WRD and 10-10 MySTIE, further development of research and applications will be given priority as advanced materials is one of the most strategic technology areas of the future. Figure 2.2 highlights the key players involved and the current ecosystem of advanced materials in Malaysia.

In Malaysia, most of the raw materials derived from rice husk, palm, kenaf, rice straw, silica, and others, are locally produced by companies with appropriate manufacturing expertise. These raw materials are then further extracted through production processes such as polymerisation, catalysis, or nanomanufacturing to produce intermediate materials. Finally, with the help of modern technology — namely 3D printing, injection moulding, hot press forming, and several others — these intermediate materials are converted to advanced materials for numerous applications in various fields.

Figure 2.3 highlights the value chain of the composites industry in Malaysia, which is an example of a mature advanced materials ecosystem developed locally.

Each key player pitches in something important to the ecosystem, and just like the global overview of advanced materials, an integrated system is the way forward. It opens new doors in research development, training and education, testing and consultancy institutions while enabling the possibilities to enhance various solutions to tackle different problems concerning advanced materials in the future.

A coordination platform or a consortium between advanced materials industries, academia, and government could be developed. It will be an avenue for industry players to raise their problems regarding product quality and availability, lack of skills and talents, among others. It can also be a platform where researchers can provide solutions, and at the same time, are assured that their research works are commercialised. Thus, it can be the key to advancing research and technology while providing the market with new products and new technology. Meanwhile, government agencies will be the neutral parties that ensure the partnership benefits all.

Advanced Materials Ecosystem in Malaysia

RAW MATERIAL	INTERMEDIATE MATERIAL	TECHNOLOGY	ADVANCED MATERIALS APPLICATIONS
Advanced Composites • Hydrocarbon • Polymers • Petroleum pitch	• Carbon fibre • Polymeric resins • Kevlar	• **Fibre Placement** • **Auto-tape Laying** • **3D Printing**	• Aerostructures • Rail & rolling stocks • Constructions • Automotive panels
Carbon/Graphene • Graphite • Carbon rich compounds	• Graphene nanoplatelets • Carbon nanotubes • Nanofluids • Additives • Rubber additives	• **CVD** • **Inkjet Printing** • **Electrolyte Exfoliation** • **Microwave Exfoliation**	• Carbon capture • Graphene nanolubricants • Conductive inks • Lithium-ion battery anodes/ultracapacitors • Rubber products
Metal/Alloys • Ore • Coke • Limestone	• Metal-based battery materials • AHSS • Heat resistant alloys • Porous nickel-titanium • Shape memory alloys	• **Hot Press Forming** • **Metal 3D-Printing** • **Injection Moulding**	• EV body structure • Metal-based battery • Medical & dental implants
Polymer • Crude oil • Natural gas	• Adhesives • Catalysts • Active pharmaceutical ingredients (API)	• **Thermoplastic**	• Specialty chemical • Engineered polymer • Dielectric thermal conducting coolants
Silica • Sand • Rice husk	• Silica aerogel	• **Infused Thermal**	• Advanced insulator • Advanced industrial glasses • Semiconductors
Rare Earth • Secondary rare earth phosphate minerals	• Rare earth oxides	• **Extraction/Purification**	• Power magnet • Motor • Batteries • Optical • Hard disk
Bio-based Materials • Kenaf fibre • Rice husk/straws • Oil palm biomass • Tapioca starch	• Kenaf non-woven mat • Kenaf woven mat • Microcrystalline cellulose • Nanocellulose	• **Non-woven Processing** • **Woven Processing** • **Cellulose Nanofibrillation**	• Bio Composites • Biodegradable Packaging • Bioplastics • Bio-industrial Products • Industrial Building System (IBS) • Green Concrete (Kenafcrete) • Pharmaceutical

MINISTRIES & AGENCIES

FINANCIAL INSTITUTIONS

R&D / EDUCATION/ TRAINING

Figure 2.2:
Advanced Materials Ecosystem in Malaysia
Source: MIGHT Analysis

Malaysia Composites Value Chain Ecosystem

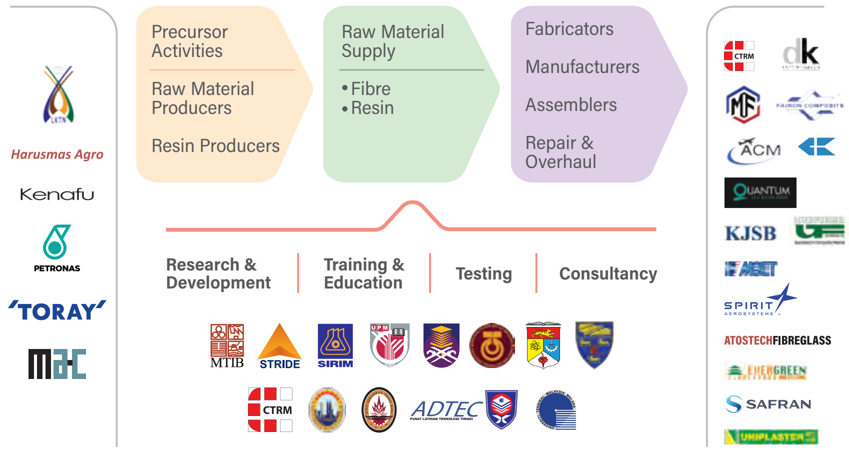

Figure 2.3:
Malaysia Composites Value Chain Ecosystem
Source: MIGHT Analysis

Malaysia's IP Overview of Advanced Materials

With the number of patents filed, it is apparent that this industry is growing in Malaysia — composites are dominating the number of patents with 135 patents filed (71 granted, 64 pending) since 2010 — further proving the maturity of the composites industry in Malaysia.

The second most filed patent is on graphene/carbon materials, with 64 patents filed (30 granted, 34 pending). The growth of graphene and carbon materials are most likely due to the innovation of the exfoliation method discovered in Manchester in 2008 that led to a Nobel Prize award in 2010.

Nanotechnology, particularly in the graphene industry, is another factor contributing to the rise of patents in advanced materials, mainly from the introduction of the National Graphene Action Plan 2020 by NanoMalaysia in July 2014. It helped boost the involvement of Malaysian inventors in the graphene industry, which saw an increase in the number of innovations filed for patent. The continuous rise in research and development of advanced materials in Malaysia by competent players will further expand and allow the advanced materials market to flourish.

Import and Export of Advanced Materials in Malaysia

There is a trade deficit in Malaysia where the import records of commodities related to advanced materials outweigh the export records. Moreover, with the current impact of the COVID-19 pandemic affecting local material production, the trade deficit rate is expected to grow. The upcoming chapters in this roadmap will discuss the way forward and efforts to close the highlighted trade deficit.

Rare earth elements (REE) are economically challenging to obtain because they rarely occur in concentrated forms. They are used as critical components in many modern-day technological devices and everyday electronics — leading to a shortage of REEs for production purposes. The value of rare earth imports into Malaysia totalled $97 million in 2019 — Australia is the primary source of RE related commodities for Malaysia, which accounts for 76% of total RE imports into Malaysia in 2019 at $74 million. As for exports, Malaysia totalled $28 million in 2019, with most exports to Indonesia and India in 2019 at an approximate value of $6 million each.

Composites related commodities include commodities that have composites in their production — such as glass fibres, carbon fibres, helicopters, aeroplanes, spacecraft, aircraft parts, composite plates, and marine vessels. The value of composites related commodities imports into Malaysia totalled $3.4 billion in 2019, and its cumulative import value from 2012 to 2019 amounted to $32 billion (in 2019, aircraft parts account for 92% of total composites imports at $3.1 billion). The value of composites related commodities exports from Malaysia totalled $2.7 billion in 2019. Its cumulative export value from 2012 to 2019 amounted to $15 billion (in 2019, aircraft parts accounted for 78% of total composites exports at $2.1 billion).

Table 2.3 summarises the commodities related to advanced materials that were imported/exported by Malaysia.

Rare earth elements (REE) are economically challenging to obtain because they rarely occur in concentrated forms. They are used as critical components in many modern-day technological devices and everyday electronics — leading to a shortage of REEs for production purposes.

Malaysia's Import and Export of Advanced Materials

No.	Materials	Import	Export
1	Ferro-manganese	●	●
2	Ferro-chromium & ferro-silico-chromium	●	○
3	Ferro-nickel	●	●
4	Ferro-titanium & ferro-silico-titanium	●	●
5	Ferro-vanadium	●	●
6	Nickel powders & flakes	●	●
7	Nickel bars, rods, profiles & wire	●	●
8	Nickel-alloy bars, rods, profiles & wire	●	●
9	Precious metal ores & concentrates (other than silver ores & concentrates)	●	●
10	Zirconium ores & concentrates	●	●
11	Thorium ores & concentrates	●	●
12	Other mineral substances	●	●
13	Cerium compounds	●	●
14	Scandium & yttrium	●	●
15	Ground apatite	●	○
16	Molybdates (molybdenum content)	●	●
17	Radioactive chemical elements & isotopes	●	●
18	Plastic monofilament	●	●
19	Natural graphite	●	●
20	Artificial graphite	●	●
21	Activated carbon	●	●
22	Carbon fibre	●	●
23	Glass fibre	●	●
24	Natural fibre	●	●
25	Silicon carbides	●	●
26	Epoxide resins, polycarbonates, alkyd resins, polyallyl esters & other polyesters	●	●

No.	Products	Import	Export
1	Electro-magnets; permanent magnets of metal	●	●
2	Electric motors & generators	●	●
3	Primary (manganese, silverlithium, air-zinc) & secondary batteries (nickel, lithium-ion, cadmium, metal-hydride)	●	●
4	Machinery parts	●	●
5	Electro-cardiographs	●	●
6	Ultrasonic scanning apparatus	●	●
7	Magnetic resonance imaging apparatus	●	●
8	Instruments & appliances used in medical, surgical, dental or veterinary sciences, including scintigraphic apparatus	●	●
9	Artificial teeth	●	●
10	Other dental fittings	●	●
11	Orthopaedic or fracture appliances	●	●
12	Artificial joints	●	●
13	Hearing aids	●	●
14	Pacemakers for stimulating heart muscles	●	●
15	Medical appliances	●	●
16	Vessels for yachts, rowing boats & canoes, inflatable & other than inflatable	●	●
17	Lifeboats	●	●
18	Helicopters	●	●
19	Aeroplanes & other aircraft	●	●
20	Sound recording or reproducing apparatus using magnetic, optical or semiconductor media	●	●
21	Diodes, other than photosensitive or light-emitting diodes (LED)	●	●
22	Transistors, other than photosensitive transistors	●	●
23	Other transistors	●	●
24	Thyristors, diacs & triacs	●	●
25	Light-emitting diodes (LED)	●	●
26	Other semiconductor devices	●	●
27	Mounted piezo-electric crystals	●	●
28	Parts for diodes, transistors & similar semiconductor devices	●	●

Import/Export: ● Available ○ Not Available

Table 2.3: Malaysia's Import and Export of Advanced Materials
Source: MATRADE

Taxonomy of Advanced Materials

Taxonomy of advanced materials allows the comprehensive analyses on the types of advanced materials present and the possible ways these advanced materials can be defined and classified. Numerous data and analyses are derived to ensure effective classifications. It places importance on helping future organisations recognise and advance the existing knowledge of this field. Varying physical and chemical properties alongside the type of expertise required for advanced materials to be developed are some of the deciding factors that play a part in this taxonomy. Hence, there are three attributes to classify advanced materials: **surfaces, structures**, and **future material platforms**, as highlighted in Figure 2.4.

Taxonomy of Advanced Materials

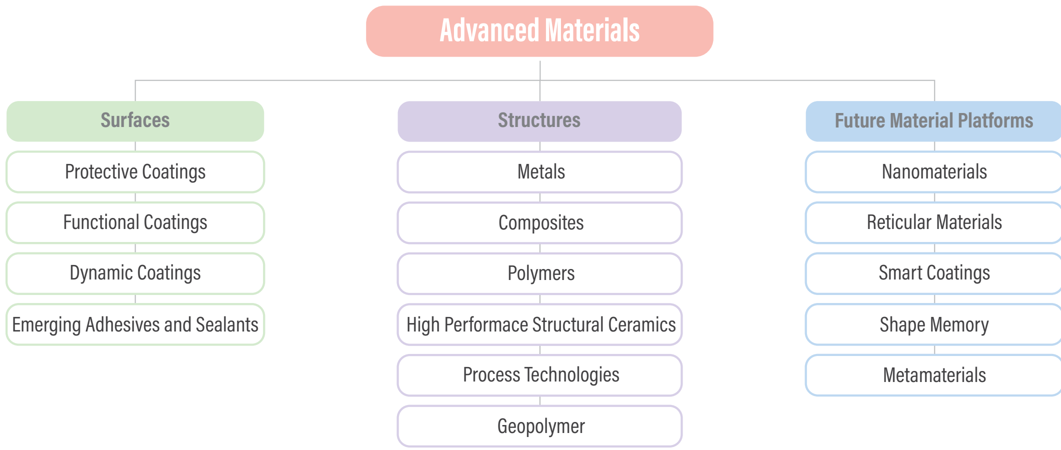

Figure 2.4: Taxonomy of Advanced Materials
Source: MIGHT Analysis

Surfaces

To fully comprehend the surfaces involved in advanced materials, in-depth knowledge of the entire process chain is required — from early manufacturing processes to end-user applications. Surface types are important as they can radically improve the properties and functionality of the advanced materials in question, reducing costs, improving efficiency, or providing entirely new functionalities. Further explanations on the types of surfaces and the attributes they hold are discussed.

i. Protective Coatings

Protective coatings assist in increasing the lifetime of products while also reducing maintenance costs by fighting off degradation mechanisms.

Type of Coating	Attributes
Anti-corrosion	Inhibits the corrosion process.
Anti-fouling	Inhibits the building up of unwanted material.
Anti-wear	Reduces wear, degradation and abrasion.
Low friction	Reduces friction-induced heating and damage.
Flame retarding	Reduces possibility of catching fire and inhibits combustion.
Thermal insulating	Reduces heat transfer between thermal contact objects or in the range of radiative influence.

ii. Functional Coatings

Functional coatings add on more valued functionalities that work beyond protective and decorative functions.

Type of Coating	Attributes
Anti-corrosion	Inhibits the corrosion process.
Anti-fouling	Inhibits the building up of unwanted material.
Anti-wear	Reduces wear, degradation and abrasion.
Low friction	Reduces friction-induced heating and damage.

iii. Dynamic Coatings

Dynamic coatings provide functionalities that allow change of properties to adhere to the environment or user stimuli such as light, voltage, pH, temperature, or humidity.

Type of Coating	Attributes
Damage sensing	Alerts users of rupture by changing colour, emitting light or smell.
Chemical sensing	Detects chemicals and alerts users by changing colour or emitting light.
Mechanical sensing	Contains conductive elements that change conductivity in response to strain, deformation, or fatigue.
Switchable friction	Shifts surface topography between high and low friction in response to triggers in pH, light, or temperature.
Switchable transmittance	Shifts solar radiation transmittance in response to triggers in voltage, temperature, or light.
Switchable adhesion	Shifts surface topography to reach adhesive and non-adhesive states in response to pH, humidity, or temperature triggers.
Switchable hydrophobicity	Shifts surface energy between hydrophilic and hydrophobic states in response to triggers in pH, light, or temperature.

iv. Emerging Adhesives and Sealants

Emerging adhesives and sealants can open doors to new applications and innovate performances and sustainability over incumbent solutions in the future.

Figure 2.5 (page 18) highlights and summarises the compositions present in the previously discussed coatings and the value-added properties they hold as advanced materials, each tackling and solving various applications.

Structures

In many applications, the common engineering materials in the structural department may reach their limits, and new developments are required to fulfil increasing demands on enhanced engineering materials. The performance of these materials can be improved by combining different materials to achieve better properties than a single constituent or by shaping the material or constituents into a specific structure. The interaction between material and structure may arise on different length scales, such as micro-, meso-, or macro scale, and offers possible applications in diverse fields. We dive deeper into the types of advanced materials in structures and their properties below.

i. Composites

Composites highlight desirable physical and chemical properties that include lightweight, high elasticity, high strength, etc. They usually exhibit low density while occupying a large volume, which includes nanomaterial fillers that impart electrical, thermal, and other functional properties.

Type of Composites	Properties
Fibre-reinforced plastics	Polymer matrix that incorporates carbon, glass, aramid, or other fibres which includes carbon fibre, carbon fibre reinforced plastics (CFRPs), sizing, and resin.
Metal matrix composites	Metals containing fillers such as fibres or particles.
Ceramic matrix composites	Ceramics containing fillers, such as fibres or particles.
Nanocomposites	Any matrix with nanomaterial fillers to add functionality or mechanical reinforcement.

ii. Polymer

Polymers essentially consist of two-component materials, the matrix material or polymer and the fibre. Matrix materials generally exhibit low-strength and low-modulus components, whereas fibre generally shows relatively high-strength and high-modulus components.

Type of Polymers	Properties
High-performance thermoplastics (HPTPs)	Thermoplastics with melting points above 150°C that contribute to high strength and chemical robustness.
Recyclable thermosets	Thermoset resins that can return to liquid, uncured form, which enables reuse and recycle.
Fast-curing thermosets	Thermosets with rapid cure cycles.

iii. Ceramics

Ceramics such as aluminium oxide, silicon carbide, and boron nitride are generally high-performance structures that display favourable properties concerning stiffness, hardness, lightweight, and high-temperature stability. However, despite that, there are certain disadvantages, including high processing costs and unpredictable brittle failure.

iv. Metals

Metals in advanced materials are the combination of metal elements manufactured for unique or extreme features, including high thermal resistance, electrical conductivity, and mechanical strength with relatively low cost.

Type of Metals	Properties
Advanced high-strength steel (AHSS)	Provides high strength, temperature performance, and low cost.
Advanced aluminium alloys	Provides high mechanical and thermal performance based on new composition and microstructures.
Titanium	Provides high strength and high-temperature performance comparable to AHSS at a lower weight but much higher cost.
Other advanced alloys	Based on magnesium, nickel, cobalt-chrome, and other metals.

v. Concretes

Concretes with regard to advanced materials are changing the narrative of the construction industry. Concretes leave a low carbon footprint due to the various waste materials incorporated in concrete materials. High performance is observed with its preservation of certain required properties and resistance to environmental action necessary for the sustainability of our civilisation.

vi. Aerogels

Aerogels are comprised of materials like silica, polyamide, etc. These materials are highly porous, lightweight materials with high surface areas and high insulation making aerogels ideal for many applications, such as thermal and acoustic insulators, adsorbents, filters, catalyst supports, and electrodes for hydrogen and electrical storage.

vii. Phase-Change Materials

Phase-change materials (PCMs) are substances that can accurately manage temperature control by absorbing or releasing large amounts of heat when they go through a change in their physical state, i.e. from solid to liquid and vice versa.

vii. Geopolymer

Geopolymers are chains or networks of mineral molecules linked with covalent bonds, and these geopolymers have proven to possess excellent physical and mechanical properties and durability. Hence, geopolymers are often used as binders in concrete, coating material, and masonry units.

Figure 2.6 (page 19) highlights and summarises the various structures that are involved in the advanced materials industry and the respective properties in different applications.

Future Material Platforms

With regard to the future of the advanced materials field, it is imperative to ensure that new advanced materials platforms tackle problems in the status quo — mainly in these three broad industrial and societal needs: sustainability and materials security, materials for energy, and high-value markets. Most important future materials developments will enable new designs and deliver improved performance that will provide value. With the assistance from nanotechnology and meta technology, to name a few, the following applications can be fulfilled.

i. Nanomaterials

Nanomaterials are materials possessing, at minimum, one external dimension measuring 1-100nm. Nanomaterials are created through combustion as by-products or design engineering with tweaks to the physical and chemical properties compared to their bulk counterparts.

Type of Nanomaterials	Attributes / Properties
Single-walled nanotubes (SWNTs)	Nanotube walls consist of one carbon layer. Very expensive but useful for electronic applications.
Double-walled nanotubes (DWNTs)	Nanotube walls consist of two carbon layers. Intermediate in price and performance, commonly used in applications that call for electrical or thermal performance, at a moderate cost.
Multiwalled nanotubes (MWNTs)	Nanotube walls consist of several to several tens of carbon layers. Cheapest and used for structural applications.
Graphene nanoplatelets (GNPs)	Consists of discs of graphene, and the thickness transcends to hundreds of layers thick.
Graphene oxide (GO)	Similar in form factor to GNPs but chemically similar to graphite oxide rather than graphite.
Graphene films	Uniform, usually monolayer films of graphene across a surface.

ii. Metamaterials

Metamaterials are composite materials, and they consist of arrays of small metallic resonators structured from a microstructure or nanostructure superlattice that can achieve electromagnetic properties.

Type of Metamaterials	Attributes / Properties
Optical metamaterials	Enables patterned internal structures to modify how they interact with electric and magnetic fields and electromagnetic radiation at specific frequencies and may have zero or negative permittivity and permeability.
Acoustic metamaterials	Enables patterned internal structures to modify how they interact with sound and vibration at specific frequencies and may have zero or effective negative elasticity and bulk modulus.
Mechanical metamaterials	Enables patterned internal structures to modify mechanical properties; enabling negative Poisson's ratio or elastic modulus or near-zero shear modulus.
Surface/texture metamaterials	Enables patterned surfaces to modify interfacial properties like friction, adhesion, surface energy, reflectivity, and absorption.

iii. Shape Memory Materials

Shape memory materials enable changes in length or volume to adapt to the surrounding temperature, light, or voltage. As a result, these materials are able to retrieve their original shapes reacting to the presence of the right stimuli.

Type of Shape Memory Materials	Attributes / Properties
Shape memory alloys (SMAs)	Deforms in response to changes in temperature, generally via shifts between austenitic and martensitic phases.
Shape memory polymers (SMPs)	Deforms in response to changes in temperature, exposure to light, or changes in a chemical environment, generally via shifts between amorphous and crystalline or semi-crystalline phases.
Shape memory composites (SMCs)	Deforms in response to changes in temperature, changes in chemical environment or exposure to electric or magnetic fields; fillers may include CNTs, carbon fibre, nickel, and metal nanoparticles.

iv. Metal Organic Frameworks (MOFs)

Metal organic frameworks are crystalline, highly porous, sponge-like materials that are used to capture, store, and deliver gases. They are made up of two components: metal ions and organic molecules known as linkers. Their bespoke and flexible designs create new opportunities for safer, high-capacity gas separation, storage, and delivery.

Figure 2.7 showcases the types of future material platforms in the advanced materials field and the various applications discussed.

Advanced Materials - Types of Surfaces

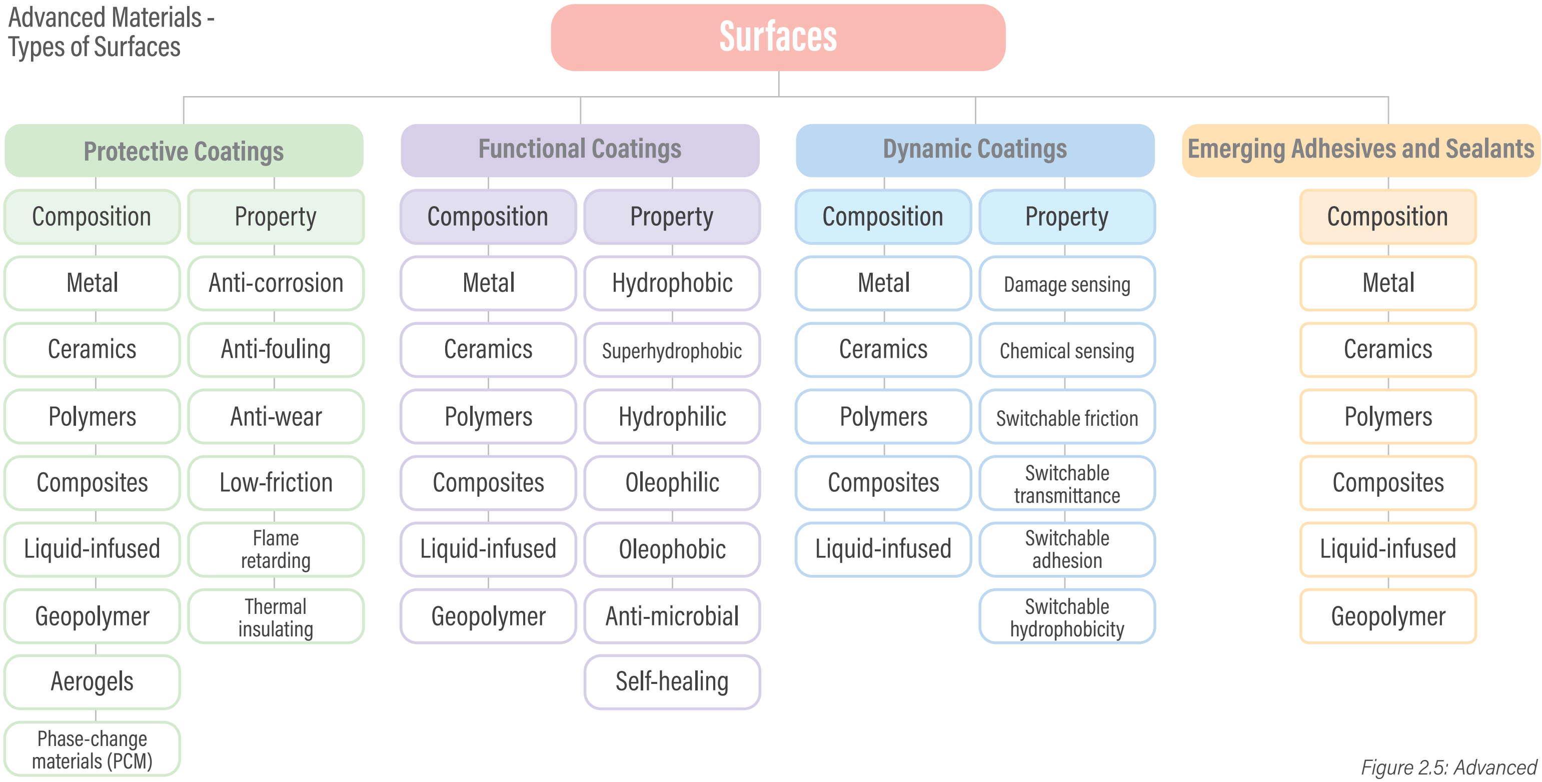

Figure 2.5: Advanced Materials - Types of Surfaces
Source: MIGHT Analysis

Advanced Materials - Types of Structures

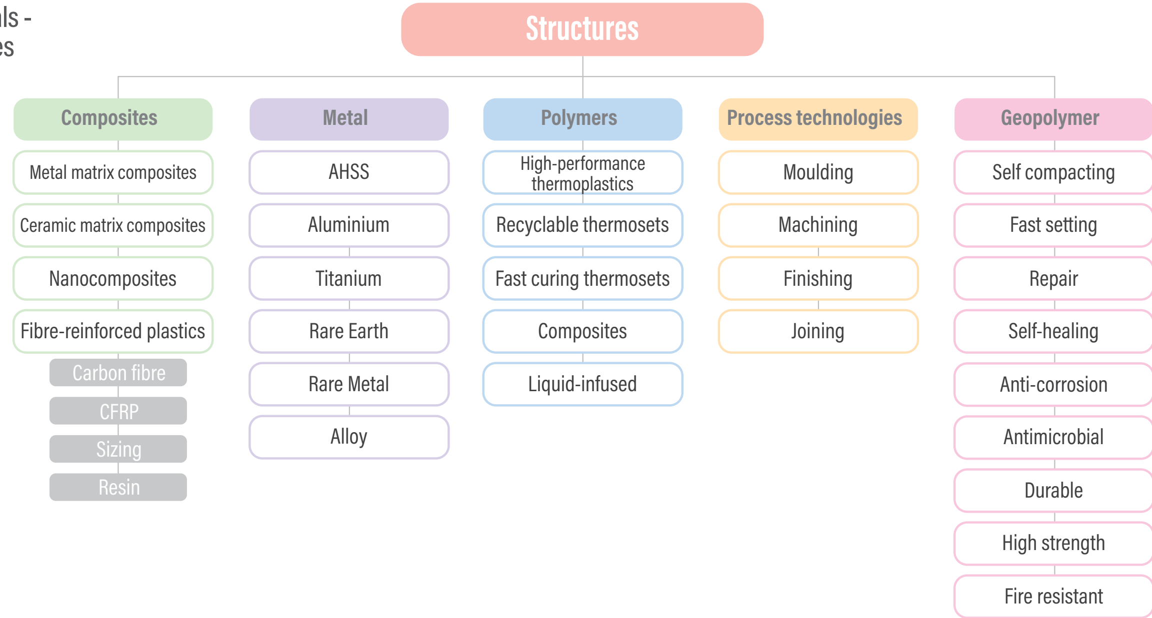

Figure 2.6: Advanced Materials - Types of Structures Source: MIGHT Analysis

Advanced Materials - Types of Future Material Platforms

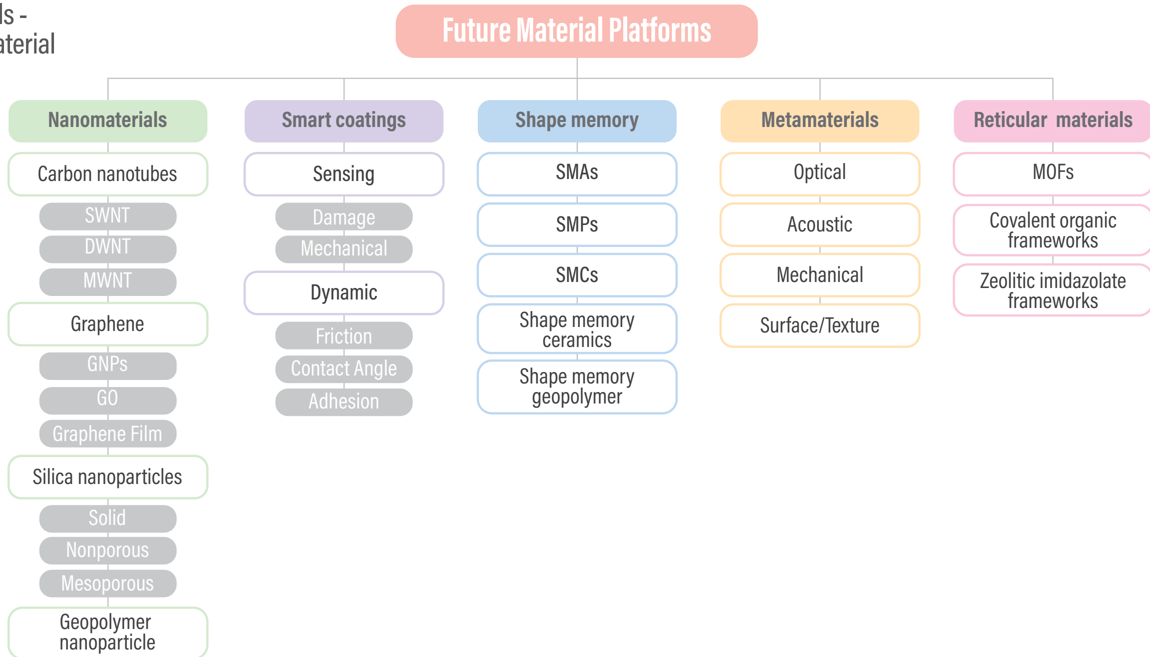

Figure 2.7: Advanced Materials - Types of Future Material Platforms Source: MIGHT Analysis

Potential Advanced Materials Industrialisation in Malaysia

The types of advanced materials discussed in the previous segment play a vital role in various applications in Malaysia and they hold the potential of driving Malaysia's economy to greater heights. They are not only economically feasible but also sustainable and environmentally friendly. An effective way forward to ensure that the advanced materials industry is developed and commercialised within a particular time frame is very much needed. Figure 2.8 highlights the short-term, medium-term and long-term for the types of advanced materials to potentially affect the industry in Malaysia by a substantial amount. It is apparent that chemicals and composites have a high impact on Malaysia's advanced materials industry within the next few years. Rare earth elements and advanced recycling are two industries to impact Malaysia's market in the long run.

With the current rate of industrialisation, advanced materials engineering has transformed tremendously. This section further expands on how the listed types of advanced materials in Figure 2.8 impact Malaysia's market and their potential for industrialisation. The key industries impacted and development opportunities are also highlighted accordingly.

I. Carbon-based Materials

Outlook:

Carbon-based materials have a vast scope when it comes to application in various sectors. The four main types of carbon-based materials include graphene, carbon nanotubes (CNT), activated carbon (AC), and carbon fibre (CF), each possesses subtypes that have interchangeable usage areas. Figure 2.9 highlights the four types of carbon materials and their subtypes.

Key Industries Impacted:

Carbon-based materials extend to many different applications. For example, graphene potentially impacts all industries in both short-term opportunities such as electronics, automotive, and aerospace as well as long-term opportunities such as healthcare and defence sectors. Malaysia's rubber industry will be among those to benefit from the domestic production of

Materials and Technology Mapping

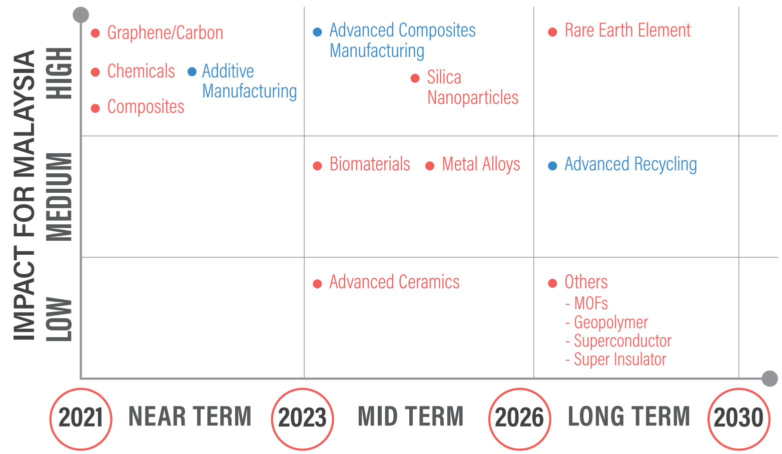

Figure 2.8: Materials and Technology Mapping
Source: MIGHT Analysis

Carbon-Based Material

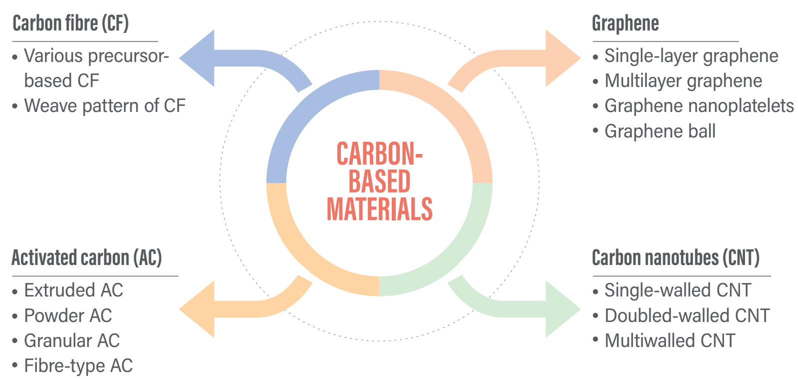

Figure 2.9: Carbon-Based Materials
Source: MIGHT Analysis

a high-performance functional carbon fibre filler that can be used for compounding. The four types of carbon-based materials mentioned previously have very specific properties that target unique applications of various sectors, which include the medical, aerospace, automotive, shipbuilding, and electrical and electronic sectors.

Opportunities for Development:

The renewable energy sector in Malaysia is continuously expanding each year. The main challenge associated with renewable energy is its need for an economical way to store electricity in an adequate capacity that can provide uninterrupted supply — or in the case of electric vehicles (EV), to enable rapid recharge after the EV has travelled a certain distance. Carbon nanotechnology has been playing an important role in the advancement of high-performance supercapacitors, and these supercapacitors improved recharge time as well as the capacity of renewable energy. Extensive research and development with regard to carbon nanotechnology, especially in low-cost mass manufacturing technology, is needed as it would pave more paths for clean energy to flourish.

II. Composites

Outlook:

The importance of composites to Malaysia's advanced materials field became apparent and prominent in conjunction with the Third Industrial Master Plan (IMP3) that was launched in 2006. Numerous policies were introduced to promote the composites industry such as the Malaysia Composite Industry Report, the National Aerospace Blueprint 1997, the National Automotive Policy 2020 and the Malaysian Aerospace Industry Blueprint 2030. These plans initiated public and private institutes engagement with composites, which included the Composite Technology Research Malaysia (CTRM), Aerospace Composites Malaysia (ACM), and Aerospace Malaysia Innovation Centre (AMIC).

Key Industries Impacted:

The composites industry in Malaysia is forecasted to provide a turnover of RM3.5 billion with its wide range of applications in Malaysia which extends from utilities and consumer products to high tech applications such as marine, rail, automotive, aerospace, oil and gas, and construction. Demands from the aerospace and automobile industries for fibre reinforced composites have grown significantly over the recent years because of their low weight, high strength, corrosion resistance, flexibility in design, and cost-effectiveness. Figure 2.10 presents the composite applications in various sectors.

Opportunities for Development:

Usage of glass fibre and carbon fibre is extensive in the aerospace and automotive industry in Malaysia. However, there are several drawbacks in using these materials, such as poor recycling properties, high energy consumption in production, pose a health risk, and are non-biodegradable. Hence, a more renewable and sustainable alternative is required to reduce weight and cost to maintain performance. With the abundance of bio-based materials in Malaysia, the automotive industry could leverage this technology to solve the end-of-life issue for vehicles by producing lightweight, high performance, and biodegradable components that promote recycling and renewable materials. In addition, Malaysia should also focus on material certification for highly regulated sectors such as aerospace to ensure the sustainability of local industries.

Composite Applications in Malaysia

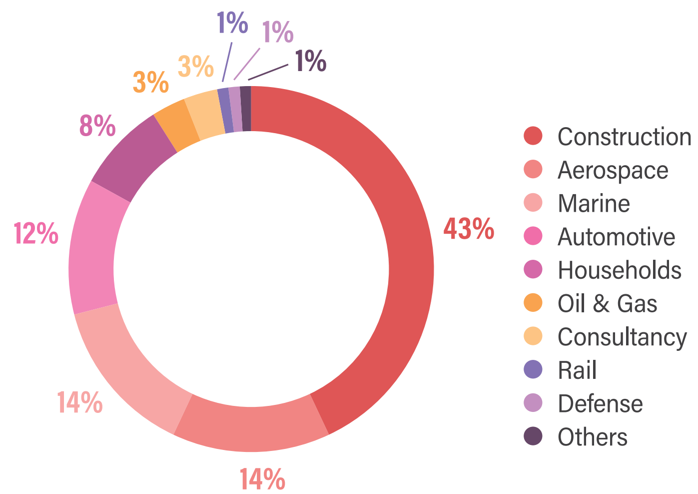

Figure 2.10: Composite Applications in Malaysia
Source: MIGHT Analysis 2014

III. Advanced Composites Manufacturing

Outlook:

Compared to other advanced materials industry, composite manufacturing is undergoing a slow revolution due to the sluggish transition from skilled manual labour to manufacturing automation. Nanotechnology, out of autoclave (OOA) curing, automated tape laying (ATL), automated fibre placement (AFP), and composite recycling are the emerging technologies in the composite manufacturing sector, with 3D printing being widely popular. The industry needs to keep abreast with the necessary skills and create more collaboration. As these technologies come to market, Malaysia will need to play a critical role to upskill existing supply chain participants. Fundamentally, the manufacturing methods mentioned above are different for different end products. Therefore, companies need to have an in-depth understanding of the practices to help them determine suitable manufacturing processes for them.

Key Industries Impacted:

The aerospace industry can leverage this technology to develop new avenues for seats and overhead bins in planes. Thermoplastic technology allows the automobile industry to produce lightweight, high-performance parts for both structural and semi-structural uses. In the medical field, this technology opens doors to lower cost composites in prosthetics and instruments. Thermoplastic processing enables cost reduction and better performance that will drive a more robust composite manufacturing adoption.

Opportunities for Development:

As acknowledged, the use of these techniques and the design of these components are still under development. Therefore, Malaysia has to invest in consortia efforts that focus on building best practices, proving the scalability of these techniques, and spreading knowledge to key stakeholders for this sector to flourish. Overall, emerging manufacturing methods, whether partial automation, full automation, or novel, offer various new options for manufacturers to grow the composites market.

#Quick Fact

Emerging technologies in composite manufacturing sector:

- Nanotechnology
- Out of Autoclave (OOA) Curing
- Automated Tape Laying (ATL)
- Automated Fibre Placement (AFP)
- Composite Recycling
- 3D Printing

IV. Chemicals

Outlook:

In 2019, the total approved investment for chemicals was RM3.6 billion, with 60% of the total being foreign investments. Although it is a well-established sector, it still requires significant innovation due to the challenges in energy, shifting feedstock, resource disruption, the sustainability imperative, and the rising demand from consumers for customisation.

Key Industries Impacted:

Malaysia is abundant in natural resources required for chemical products. This wealth significantly impacts the manufacturing of various finished goods such as electrical and electronics, plastic products, agriculture, automotive, construction, oil and gas, medical, and consumer products.

Opportunities for Development:

Innovation to develop higher value-added products in advanced chemical materials is crucial because Malaysia can be a competitive nation in the chemical industry. This goal can be accomplished through knowledge transfer and international collaborations, particularly in the safe handling of chemicals without compromising environmental impact. The table below summarises the example of chemical products by industry segments.

Example of Chemical Products by Industry Segment

Industry Segment	Product
Commodity inorganic chemical	Ammonia, chlorine, phosphates, etc.
Commodity organic chemical	Propylene, ethylene oxides, methanol, xylenes, etc.
Commodity polymers	Polypropylene, polyethylene terephthalate, etc.
Specialty organic chemicals	Surfactants, coatings additives cosmetics, food additives, paper additives, etc.
Specialty polymers	Engineering polymers, coatings, adhesives, etc.
Consumable chemicals	Agrochemicals, water chemicals, process chemicals, cleaning chemicals, etc.

Table 2.4: Example of Chemical Products by Industry Segment Source: MIGHT Analysis

V. Silica-based

Outlook:

Silica-based advanced materials, particularly silica nanoparticles, are projected to achieve $50 billion in the global market by 2027 — making this technology appear more substantial in general employment and the economy. Malaysia is the world's sixth-largest exporter of processed silica sand; approximately 148.4 million tonnes of silica sand reserves are located in Johor, Perak, Terengganu, Kelantan, Sabah, and Sarawak.

Key Industries Impacted:

Silica can impact many industry in Malaysia with its vast applications that include industry sectors like solar PV, automotive, and semiconductors. Furthermore, it holds long term implications in the water and agricultural treatment industry, whereas, in the healthcare sector, this material appears to be the slowest to emerge.

Opportunities for Development:

With more breakthroughs from academic research, silica-based advanced materials can create more avenues in agriculture, coatings, and drugs. Malaysia can use this opportunity to build a supply chain for customised and functionalised silica particles by developing the technology domestically through a partnership with NanoMalaysia. Furthermore, being one of the largest producers and exporters of rubber, Malaysia can further explore the development of silica nanotechnology to enhance vulcanised rubber's mechanical strength further.

VI. Rare Earth Elements

Outlook:

Rare earth elements have been a significant export for Malaysia due to it having the largest single light rare earth separation facility in the world. With a considerable supply of heavy rare earths, this country can attract specialised refining and fabricating vendors to cover the entire spectrum of rare earth enabled products. There is potential for a total domestic rare earth supply chain considering the future global and regional demands for rare earths. Nuclear Malaysia (ANM) plays an essential role in providing the technology for infrastructure development in the REE industry ecosystem. Developing the local upstream industries will attract FDIs and DDIs in many sectors, including energy, mobility, electrical and electronics, and defence.

Key Industries Impacted:

REE applications only require a small amount of REE to boost the materials, equipment and process performances. For example, yttrium (Y) is used in E&E industries, e.g. for producing lasers, displays (TVs and computers), and microwave filters. Lanthanum (La) is used in oil refining processes in hybrid-car batteries and camera lenses. Meanwhile, cerium (Ce) is used in cars' catalytic converters, oil refining processes, glass-lens production, and neodymium (Nd) is used in computer hard drives, cell phones, and high-power production magnets for wind turbines.

Opportunities for Development:

Malaysia is blessed with an abundance of raw REE materials, and with good implementation plans, Malaysia can develop its REE industry ecosystem. Alongside ANM's roadmap for research and development in REE extraction, it concludes with establishing the National Rare Earth Extraction Research Centre in Malaysia. The National Mineral Industry Transformation Plan 2021-2030 targets Malaysia as an important hub for developing the mineral industry. The study conducted by the Mineral and Geoscience Department (JMG) has estimated the value of the country's mineral resources at RM4.11 trillion, comprising metallic minerals worth RM1.03 trillion, non-metallic minerals worth RM2.96 trillion, and energy minerals worth RM0.12 trillion. The government has allocated a total of RM87.2 million to develop this industry. Table 2.5 summarises the types of REE and the global players of the REE industry.

Global Players in REE Ecosystem

MINING	SEPARATION	METAL	ALLOY	MAGNET	COMPONENT	OEM
CN	CN	CN	CN	CN	CN	CN
AU	MY	VN	JP	JP	JP	JP
US	CN	CN	CN	CN	US	US
	BR	GB	GB	DE	EU	EU
	CA					
LYNAS RARE EARTH LIMITED	LAMP	LYNAS PARTNERS	ALLOY	MAGNET	COMPONENT	ODM / OEM

MARKET LEADERS IN APPLICATIONS

- Oxford Instruments
- Scientific Magnets
- Siemens Medical Solutions
- Vacuumschmelze (VAC)
- Hitachi Medical Systems
- Toshiba Medical Systems
- Furukawa Electric
- ShinEtsu

Table 2.5: Global Players in REE Ecosystem
Source: MIGHT Analysis

VII. Metals / Alloys

Outlook:

The iron and steel industry contributed 2.9% to Malaysia's GDP in 2016. It was projected to generate up to 6.5% of GDP growth and offer up to 225,000 job opportunities in 2020 with export destinations including Mexico, the Republic of Indonesia, Thailand, India, and Singapore. According to the World Steel Association (World Steel), based on the projection between MISIF and World Steel in data modelling using locally sourced data and inputs, Malaysia's apparent steel consumption will approach 12.4 million MT by 2025.

Key Industries Impacted:

Metals/alloys as advanced materials have a high impact on various industries such as automotive, aerospace, electrical and electronic, energy, oil and gas, amongst others. This impact aids the development of future technologies like energy storage, coatings, high heat resistance components, parts for automotive and aerospace, and fast charging technology.

Opportunities for Development:

Advanced high strength steel (AHSS) is among the potentials in the automotive sector as it plays a vital role in reducing the weight of vehicles. The high specific energy and good loading capability of lithium metal batteries enable rechargeable batteries in the future, improving the application of coatings to reduce dendrite growth.

Additionally, the ability for metal-based supercapacitors to enable fast charging performance allows new possible applications. For example, advanced heat resistance alloys such as nickel-based alloy / cobalt-based alloy provide a wide range of applications across sectors with their ability to retain their strength even after a long period of heat exposure. Generally, these superalloys can be used in extreme environments like high-temperature fasteners, high-pressure vessels, boilers, turbocharger rotors, and turbine blades.

VIII. Bio-based Materials

Outlook:

Bio-based materials have the potential to extend to a wide range of applications from the nano-scale to the macro-scale, especially in biomedical applications, which include therapeutic delivery, immunotherapy, bioimaging, and regenerative engineering. However, advanced bio-based materials must tackle the limited control over biophysical and biochemical characteristics that hamper their utility for biomedical applications. Nevertheless, the advancement in biomaterial engineering is promising and represents opportunities in utilising bio-based materials, namely for the medical revolution.

Besides biomedical, Malaysia has one of the highest biomass availabilities of any country in the world. However, we are treading this privilege cautiously when it comes to advanced bioplastics. The techniques to produce these materials from waste are still at their pioneer stage, and there is a long track record of failures in waste-based plastics. Besides requiring effective coordination between stakeholders and strong support during the research phase up to the production stage, funding is also crucial for successful commercialisation.

Key Industries Impacted:

Given that packaging is the dominant application of these materials, and Malaysia has launched Malaysia's Roadmap Towards Zero Single-Use Plastics 2018-2030 roadmap in 2020, the local bioplastic industry will see a surge in its market. Furthermore, the growth of these bioplastics could impact the palm industry, palm oil and palm waste (such as fronds and empty fruit bunches), as they could be feedstock materials for these bioplastics.

Opportunities for Development:

Malaysia's key players, such as Free The Seed and ICBP, are ready to bring the industry to the next level. However, there is still real work to be done in the production processes of these materials; this includes scaling up existing operations and discovering new routes. Extensive research is also required in characterising these materials and developing new products and formulations. For instance, a polymer like polyhydroxyalkanoate (PHA) has more than 20 varieties, all of which have different properties and may be suitable for various applications — hence proper characterisation is important to ensure its use to its fullest potential.

IX. Additive Manufacturing

Outlook:

At present, 3D printing is creating opportunities by bringing advanced production of high-value parts in Malaysia — concurrently creating jobs, supporting the economy, and also helping to protect national interest by domestically producing critical components for aerospace, defence, and medical applications. Also, aluminium and steel powder products seem to benefit important local sectors, i.e., automotive, consumer products, healthcare, aerospace (tooling), and defence.

Key Industries Impacted:

Metal 3D printing can enable the production of tools and end-use products with comparable mechanical properties to traditional manufacturing. In addition, it cuts down material waste and lead time while offering more design and production flexibility to users. Over the next decade, metal 3D printing will become a core technology in the medical, aerospace, and heavy industries. As a result, it will redistribute manufacturing, bringing it closer to where parts are used. Although this creates an opportunity for Malaysia to substantially prosper in areas such as aerospace, it however will also create risks for other industries that might eventually move out of Malaysia.

Opportunities for Development:

Manufacturing industries should take up this technology as it is aligned with the initiatives highlighted in the National Policy on Industry 4.0 (Industry 4WRD), and we have key players like Technology Park Malaysia, Nitium Technology, and Oryx Advanced Materials, who are among the R&D&C&I adopters and raw material suppliers in Malaysia. To build a practical 3D printing ecosystem, Malaysia should invest in centres of excellence that attract global printer companies and assist in developing the skills needed in the workforce to design printed parts and operate the printers.

X. Advanced Ceramics

Outlook:

Progress rates for advanced ceramic materials are slow, with only limited key players. A targeted technology supply chain building programme could bolster Malaysia's domestic aerospace and defence sector; however, the overall impact on the economy and employment would be limited. Fibre innovation could change this field due to the cost reduction and promising developments from startups like Advanced Ceramic Fibers and Free Form Fibers.

Key Industries Impacted:

The high costs and availability implications of ceramics only allow Malaysia's aerospace and defence industry to utilise these advanced materials but remain a challenge for the automotive and energy sector.

Opportunities for Development:

Extensive research in the production of ceramics composites that lowers the cost, energy, and time needed to produce these materials would make them not only suitable for more applications, but possibilities for issues on reliability and design would also prevail. Hence, it is crucial to have more technology transfer programmes that encourage aerospace and defence OEMs to set up productions in Malaysia.

Advanced Recycling Opportunities by ReDisCoveR Project

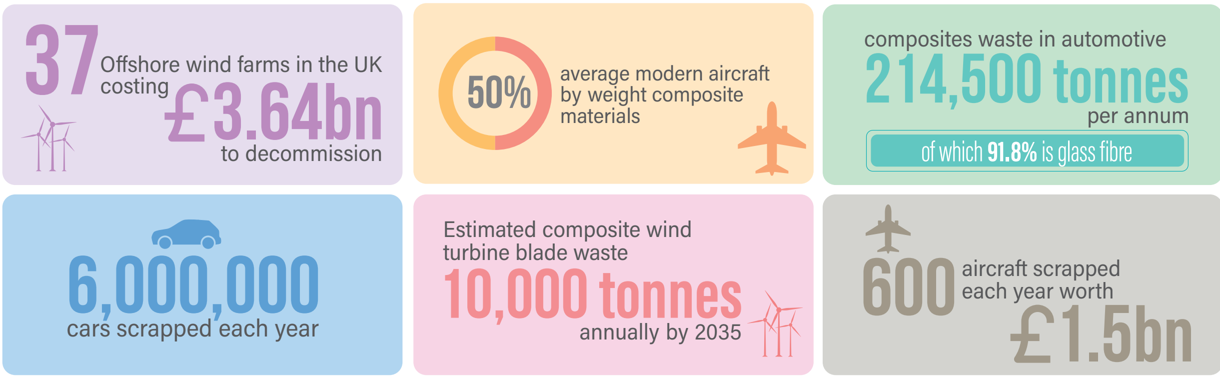

Figure 2.11: Advanced Recycling Opportunities by ReDisCoveR Project
Source: National Composites Centre UK

XI. Advanced Recycling

Outlook:

Advanced recycling is a complementary approach to mechanical recycling to help us meet the growing demand for composite materials. With stricter environmental regulations, we need to develop a more durable solution. Processes like chemical recycling, pyrolysis, and gasification are used to turn plastic polymers back into individual monomers allowing materials to be reused in various ways. About 12,000 commercial aircraft are estimated to reach the end of their service in the next two decades, and the number is currently increasing due to the COVID-19 pandemic.

About six million cars are scrapped each year globally, while a higher percentage of composites are embedded in mass-produced vehicles due to the development of high-volume thermoplastic technologies. Various methods have been explored and developed, which include mechanical, thermal, and chemical recycling approaches. They are highly dependent on the type of materials being recycled and their intended reuse application. The energy demand involved in the recycling process also ranks in that order from lowest to highest. Figure 2.11 summarises the types of waste that need to be addressed concerning advanced recycling by the ReDisCoveR project (a project established to interrogate the major challenges faced by composite materials at end-of-life) carried out in the United Kingdom.

The plastic recycling and manufacturing industry in Malaysia has an economic value of RM30 billion. Even though the government permanently banned plastic scrap import in October 2018, it has lightened the ban by limiting the import to only quality and clean plastic, with strict regulations. There are restrictions on importation from developed countries such as the United States, Korea, Japan, and European countries. Signatories to the Basel Convention, which came into force on 1st January 2021, means Malaysia may only trade plastic waste if they are clean, sorted, and easy to recycle.

Key Industries Impacted:

With the growing use of plastic each day, recycling plastic waste will affect sectors like energy, packaging, apparel, water, space, medical, and chemical. These sectors are inclusive of a circular economy that heavily interlinks multiple industries.

Opportunities for Development:

Global plastic recycling and manufacturing has an economic value of RM600 billion. However, before Malaysia can be a net importer of plastic waste, we have to equip ourselves with reliable technologies and a sustainable recycling ecosystem to ensure that we do it right. Research and development that complies to the generics of advanced recycling is even more important now especially in areas like catalysis for depolymerisation and development of low-cost modular pyrolysis systems. The government has to lay out developing strong regulatory frameworks that include the products of advanced recycling as an investment. In the energy sector, Tekno-RE is actively promoting recycling municipal solid waste (MSW) into refuse derived fuel (RDF) after successfully doing it in several other countries, prompting the opportunity to promote valuable landfill land for development. We should also focus on developing the recycling industries for other valuable materials such as permanent magnets and rare earth metals, cadmium-telluride, silver, aluminium, polycrystalline, glass, composites, and batteries (lead acid and lithium ion) by having strategic partnership with technology providers, promoting the technology transfers and stimulating FDI flows into Malaysia. These industries could benefit Malaysia to be self-reliant by reducing importation of raw materials, aligned with the government's interest in circular economy.

XII. Others

Apart from the advanced materials mentioned above, there are also several other types worth mentioning that are creating small but reasonable commercial potentials. The advanced materials applications summarised below have limitations with regard to cost when it comes to expanding the commercial potential of advanced materials in Malaysia.

a. Metal Organic Frameworks (MOFs)

Metal organic frameworks are crystalline structures with many pores that consist of metal (inorganic) and organic parts that are assembled into complex structures. It is mostly used in gas storage and separation, liquid separation and purification, electrochemical energy storage, catalysis and sensing, battery, adsorbents, and release system for food preservatives. Additionally, MOFs can also be found in precursors for the construction of inorganic functional materials with unparalleled design possibilities such as carbons, metal-based compounds, and their composites.

b. Geopolymer

Geopolymers are inorganic binders that are made of aluminosilicate material and alkaline solution. They are derived from the by-products of other industries such as palm oil fuel ash, fly ash, blast furnace slag and rice husk ash, and are therefore considered as sustainable construction materials. Their applications include corrosion coatings, fire and heat resistant coatings, thermal insulator ceramic materials, removal of industrial toxic waste residue, self-cleaning concrete material, drug delivery agent, and adhesives.

c. Superconductor

A superconductor is an element or metallic alloy which, when cooled below a certain threshold temperature, dramatically loses all electrical resistance and allows electrical current to flow without energy loss — in other words, supercurrent. They are generally used in generators, particle accelerators, transportation, electric motors, computing, medical, power transmission, memory, or storage elements.

d. Super insulator

Super insulator is a material that does not conduct electricity at low temperatures. It can be destroyed by increasing its temperature, applying an external magnetic field and voltage. It is used as insulation for fire and heat retardant structures which includes fire doors and insulator manifolds.

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CHAPTER

3 OVERVIEW OF ADVANCED MATERIALS TECHNOLOGY

Advanced materials technologies put us at the forefront of functioning, long term durability, safety, and environmental compatibility of all the devices, machinery, and services around us. It focuses on advanced device design, fabrication, integration, and new technologies based on advanced materials. This field expands on all technology-related materials applications research and bridges the gap between research and development (R&D) with the commercial industry. These technologies are revolutionising the way companies do business and demand that R&D institutes are up to pace with the current trends. The industry key players depend on advanced materials technology to improve product performance, capability, and efficiency of production processes.

Benchmarking Standards

Advanced materials have been an important highlight across the globe. Companies worldwide are shifting into the high technology industry, and advanced materials are the key to revolutionising and accelerating the advancement of this market. This shift will help reduce cost, increase profitability, and enhance customer satisfaction while offering sustainable solutions and unscrambling current issues. Developed countries like the USA, Germany, Japan, and China have thoroughly paved the way for these advanced materials technologies to align with their needs, capabilities, skills, and strength. Moreover, they receive strong support from their governments, industries, and research institutes, each with institutional involvement and industry focus.

In the report '20 for 20: The Technologies With the Greatest Potential To Transform the World Over the Next Decade', Lux Research identified 20 transformational technologies most likely to change the world over the next 10 years. The report ranks and summarises the technologies that have the most significant potential to transform the world. To meet the ranking, they require additional advances to help them come to market, grow to scale, and find mainstream adoption. Materials innovations will be a crucial enabler for this success because it allows new growth opportunities and shines a light on the unmet needs in developing these materials.

According to the report, 5G, shared mobility, new ways of recycling plastic, 3D printing, new battery technology, and artificial meat will significantly impact the market. These industries are also billion-dollar industries concerning their total available market, ranging from $1 billion to $10 billion. On a global scale, both public and private organisations are willing to invest in these areas. They are dedicating resources to research and develop new materials that produce and commercialise better-finished products.

The global overview includes a comparison of different countries around the world like China, Japan, Canada, South Korea, and the UK with regard to their efforts in advanced materials technology. Table 3.1 summarises the advanced technology focal points of the countries stated, the measures taken and the observations that resulted from their action. The focus for most of these countries includes enhancing R&D technologies, enabling nanotechnology, and supporting technologies concerning renewable

Global Outlook of Advanced Materials Technology (USA, Germany, Japan, EU & China)

Country	Focus Area	Institutional Involvement	Technology/ Industry Focus	Observation
USA	Developing tools, techniques and infra technologies that support materials R&D alongside replacing rare materials in its production system.	Department of Defense, Department of Energy, National Science Foundation, etc.	Nanotechnology, enabling technologies and alternative materials.	US mission agencies and NIST drive the advanced materials technology through various programmes like the US Advanced Manufacturing Strategy Technology Innovation Program, National Nanotechnology Initiative and Materials Genome Initiative.
GERMANY	Focuses on the R&D of new materials and applications based on industrial needs. They also focus on conventional materials manufacturing that have high value.	Fraunhofer IFAM, Industrial Research Associations, The Max Plank Society, etc.	Focuses on technology that involves mobility, infrastructure, health and environment, nanomaterials and biomaterials.	There has been value capture from materials and high wage economies due to these focuses taken.
JAPAN	Uses innovation to address social, environmental, sectoral needs and applications by substituting rare earth materials and harmful elements.	National Institute of Advanced Science & Technology (AIST), National Institute of Material Science (NIMS), Japan Science & Technology Agency (JST), etc.	Focuses on nanotechnology, infra technology, biotechnology, manufacturing and information and communications technology (ICT).	Publication of roadmaps such as the Strategic Technology Roadmap (STR) assists Japan's technology focus.
EU	Supporting and enabling technologies involving applications sectors like energy and carbon capture.	European Institute of Innovation & Technology (EIT), The European Research Council, Joint Research Centre (JRC), etc.	Focuses on low carbon technologies, materials development, manufacturing, metallic alloys and nanotechnology.	Publication roadmaps involving research and low carbon technology. Several platforms have also been set up such as the Key Enabling Technologies Program and European Technology Platform for advanced materials.
CHINA	Has a vast scope of applications that include energy-related applied science and engineering, critical themes of strategic high-tech development, environmentally friendly application, etc.	Chinese Academy of Science (CAS), Institute of Metal Research, Ningbo Institute of Material Technology & Engineering, etc.	Focuses on energy-related technology, efficient or high-efficient photosynthetic species, nanomaterials, high-quality raw materials, high tech recycling technology, etc.	Rapid growth in the new materials industry, high intelligent multi-structure composite materials, materials technology, green preparation of materials and intelligent, controllable passing.

Table 3.1: Global Outlook of Advanced Materials Technology (USA, Germany, Japan, EU & China)
Source: MIGHT Analysis

energy. Each aims to address and solve a specific problem in the vast applications of advanced materials. These applications affect different government sectors. Table 3.1 highlights the government sectors of the countries involved in this global overview along with the policies and roadmaps they came up with to assist and ensure the development of these technologies in their respective sectors. Hence, the involvement of all parties will further enhance research and the commercialisation of these technologies.

The USA, Germany, Japan, the EU, and China are all active patent applicants. Figure 3.1 and Figure 3.2 summarise the ranking of these countries and the types of advanced materials in terms of the number of patents produced, respectively. China surpasses the USA as the top source of international patent applications. As for the advanced materials patented, carbon fibre had the highest number of patent registrations, followed by 2D materials and titanium nitride. Carbon fibre has a broader scope of technology application such as aerospace, mobility, construction, medical, and shipbuilding.

Malaysia can use the benchmark set by these countries to adapt and adopt the best strategies, guidelines, and parameters for its industry's advanced technology ecosystem. Identifying the number of registered patents shows the current trend of advanced materials. It creates opportunities for Malaysia to explore and develop advanced materials industries aligned to the local and global markets. The registered patents are also an important parameter to determine the growth capabilities of each advanced material.

Advanced materials are continuing to pave the way for revolutionising business processes. Companies must adapt to the innovation, research, development, and manufacturing processes to go with the pace. As a result, there will be new opportunities and avenues in advanced materials technology. In order to achieve successful development and commercialisation, those involved should assist their R&D and engineering experts by recognising and harnessing the right insights, expertise, processes, and resources.

Number of Patents Based on Global Outlook of Advanced Materials Technology

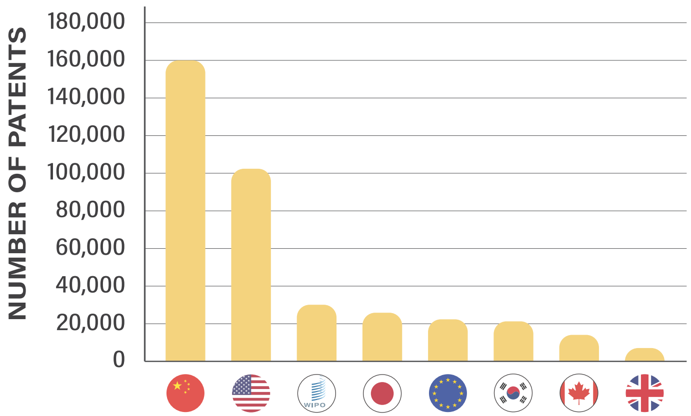


Figure 3.1: Number of Patents Based on Global Outlook of Advanced Materials Technology

Source: MIGHT Analysis, WIPO

Number of Advanced Materials Patents from 1997 to 2021 by Materials

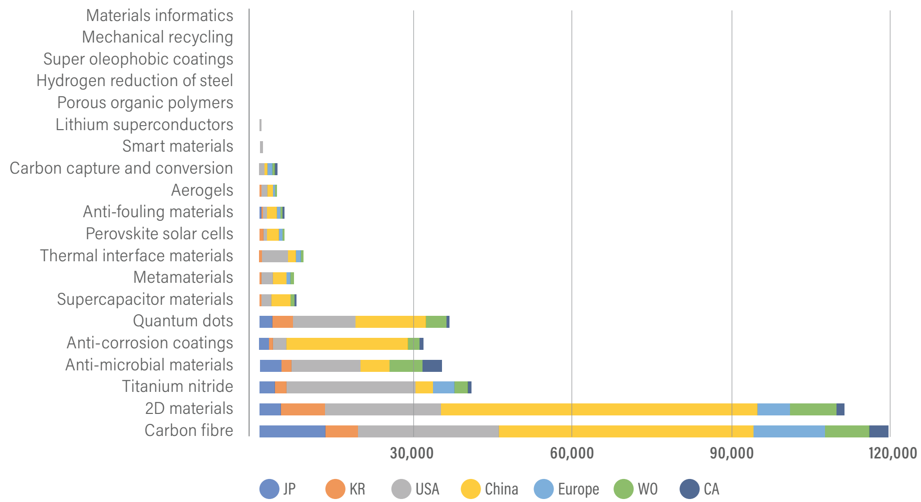


Figure 3.2: Number of Advanced Materials Patents from 1997 to 2021 by Materials
Source: MIGHT Analysis, WIPO

Malaysia Overview

Malaysia's advanced materials technology field plays a vital role in making it the emerging field of science, technology and innovation (STI). It is constantly changing the production-based economy to a knowledge-intensive economy. As a result, this provides immense opportunities for value creation to enhance productivity, efficiency, and societal wellbeing.

As a developing nation, Malaysia must have its own advanced materials technology policies and initiatives as well as strategic plans to manage and ensure this industry develops. Akademi Sains Malaysia (ASM) recognised this and embarked on the 10-10 MySTIE framework to provide a science and technology foresight on envisioning Malaysia 2050.

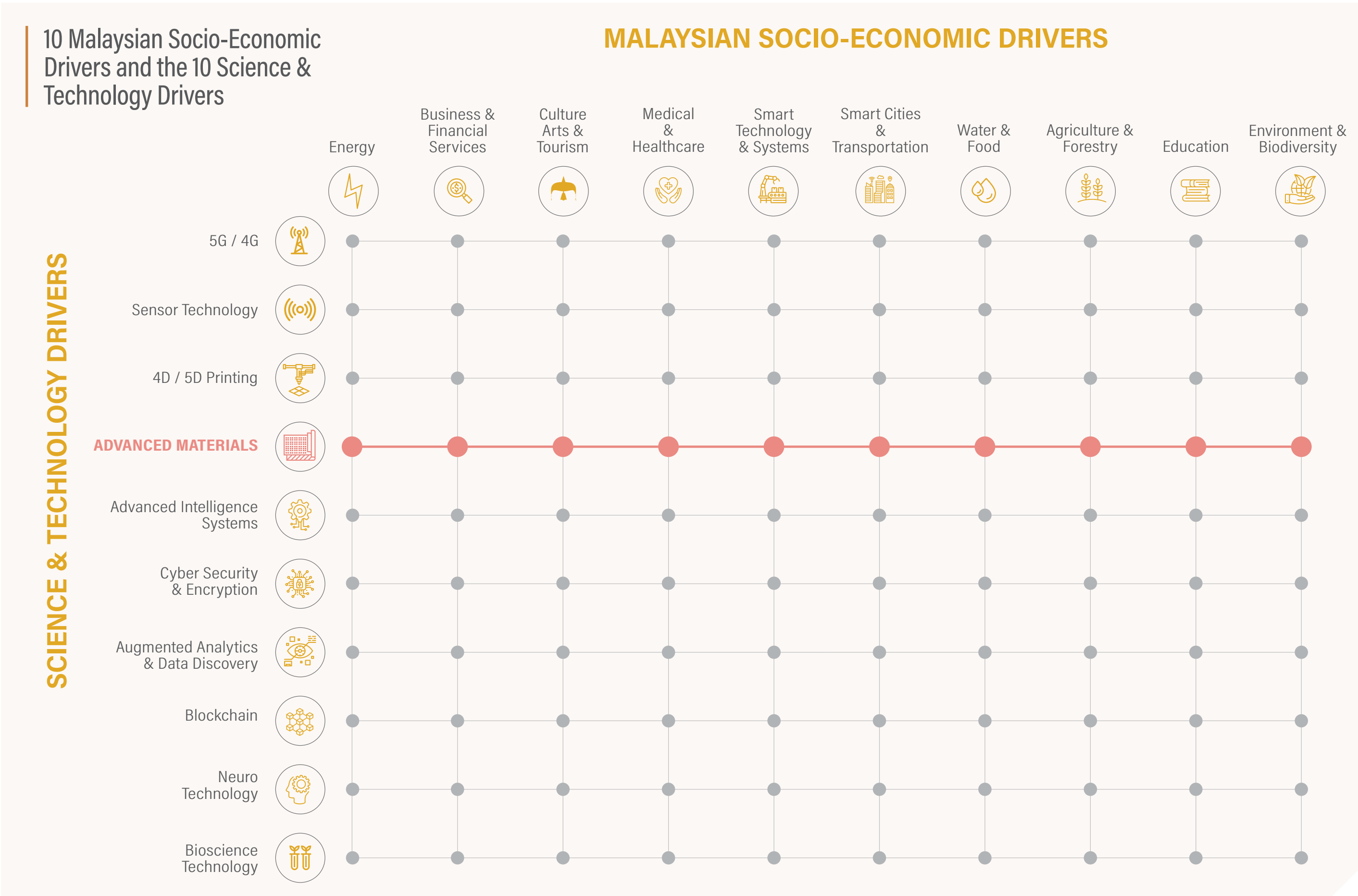


Figure 3.3: 10 Malaysian Socio-Economic Drivers and the 10 Science & Technology Drivers

Source: 10-10 MySTIE Framework

10-10 Malaysian Science, Technology, Innovation and Economy (MySTIE)

i. Energy
ii. Business & Financial Services
iii. Culture, Arts & Tourism
iv. Medical & Healthcare
v. Smart Technology & Systems
vi. Smart Cities & Transportation
vii. Agriculture & Forestry
viii. Water & Food
ix. Education
x. Environment & Biodiversity

In December 2020, MOSTI launched 10-10 MySTIE to enhance the future of advanced materials in Malaysia particularly in national priority areas, research capabilities, emerging technologies, industry analysis, and global trends. It combines the two primary drivers of the country, namely science and technology drivers and socio-economic drivers. ASM analysed and identified the top 10 Science and Technology (S&T) drivers to develop 10 of Malaysia's socio-economic sectors. The 10 S&T drivers and socio-economic drivers are highlighted in Figure 3.3.

This framework will identify fundamental, applied, and experimental R&D to transform the 10 Malaysian socio-economic drivers in moving up the global innovation value chain, enhancing economic competitiveness, reducing inequalities, and raising the quality of life. It will also transform Malaysia to become a united, prosperous, and environmentally friendly nation by 2030. There is further discussion on how each socio-economic driver is impacted by Malaysia's various emerging advanced materials technology. These advanced materials technologies have specific outcomes to the highlighted socio-economic drivers. Some of them play a more important role than others in pushing the boundaries of these technologies.

i. Energy

The energy sector seems the most promising in getting the advanced materials industry to flourish in Malaysia as it significantly contributes to the sustainability of the products and the wellbeing of citizens. Therefore, investing in the research and development efforts of the technologies that could leverage this sector would be astute — namely, the battery and hydrogen technology in sustainable energy.

Emerging Technologies and Applications

a. Solid State Batteries (SSBs)

Energy storage technology is driven by the demand for batteries for consumer electronics. Aligning with EU policy goals, there has been a growth in the strategic interest of batteries for both mobile and stationary storage applications.

Growth Drivers and Challenges:

SSBs have an excellent safety key factor because they have solid-state electrolytes making them non-flammable and less likely to short. The energy density is also increased substantially with the use of metallic lithium anodes. Due to their competitive market, whereby many companies are developing SSB technologies to be brought to the market at scale, the cost of SSBs has decreased.

Emerging Materials Solution:

The growth in the SSB market has encouraged more solid-state electrolytes such as solid polymers and solid ceramic electrolytes to replace traditional liquid electrolytes. Metallic lithium or silicon anodes, which include NMC 811, LMR NMC, LNMO, and sulphur, contribute to the high energy density of SSBs. The coating formulations of SSBs to change the surface energy or ion are also improved to prevent the formation of lithium dendrite, whereas softer ceramics like sulphides improve the brittleness of the ceramic electrolyte.

b. Hydrogen and Fuel Cells

Hydrogen and fuel cells are emerging along with energy trends, but more research is required to focus on applications that uniquely need hydrogen while also driving down system costs.

Growth Drivers and Challenges:

Hydrogen cells have a vital role in decarbonising energy used in transportation, industry, and backup power. Range extenders are needed in the backup power sector for critical facilities and telecoms but require at least 50% cost reduction. Unique materials to produce, store, and transport hydrogen remain one of the challenges for this technology. Despite this causing a decline in innovation interest since 2007, they still have a strong path for future growth.

Emerging Materials Solution:

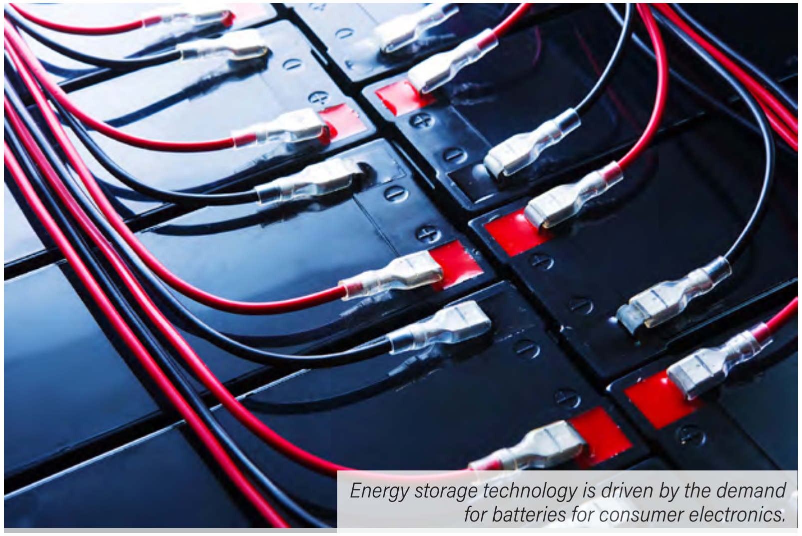
Replacing hydrogen production methods like steam reforming, water electrolysis, and fermentation with improved or non-platinum catalysts would reduce costs. As for the storage and transportation of hydrogen, there are emerging solutions like CFRP pressure vessels, solid carriers, and liquid organic hydrogen carriers (LOHCs) as opposed to steel pressure vessels in the status quo.

c. Fast Charging Battery

Fast charging batteries would create an upstage in the electric vehicle (EV) industry, but it is still reasonably underdeveloped.

Growth Drivers and Challenges:

Electric vehicles have opened avenues; however, the time it takes to charge a car is significant, and fast-charging infrastructure is still underdeveloped. Large corporations are necessary to finance expansion and new business models — solutions to reduce capital can be explored, such as the leasing of cooling systems. In addition, grid stability is challenged when there are local spikes in power demand with fast charging. Automotive OEMs and electric utilities are needed for smart grid technology to ease its electricity management.



Energy storage technology is driven by the demand for batteries for consumer electronics.

Emerging Materials Solution:

Thermal management using electrically and thermally conductive additives like graphene and a submersible cooling system are needed to enable faster charging. As for electricity management, semiconductors such as SiC, GaN, and other semiconductors can be used as power electronics compared to silicon.

d. Flow Batteries

Flow batteries are emerging alongside the renewable energy sector. Government intervention such as Net Energy Metering (NEM), Large Scale Solar PV (LSSPV), and the Smart Grid programme can help provide an extensive scale market, promote R&D, and reduce cost.

Growth Drivers and Challenges:

Flow batteries offer the scale and life cycle to support daily wind and solar fluctuations without relying on fossil fuel sources to keep additional renewable energy capacity.

Emerging Materials Solution:

Improved polymer membranes like carbon materials and fillers are emerging to enhance stack frame durability, whereas novel electrodes and membrane materials aid in reducing the parasitic and pumping loss features in flow batteries. For increased energy density, standard vanadium electrolytes are being replaced with improved vanadium and nonvanadium electrolytes for stability at higher temperatures and concentrations.

e. Others

In addition to the applications stated above, there are a few more emerging technologies in the energy field, especially in the clean energy field, such as advanced recycling of solar PV panels, affordable plastic/organic solar cells, superconducting and superinsulation materials, metal-air batteries, etc. With these emerging technologies, clean energy will become more prominent than it was before.

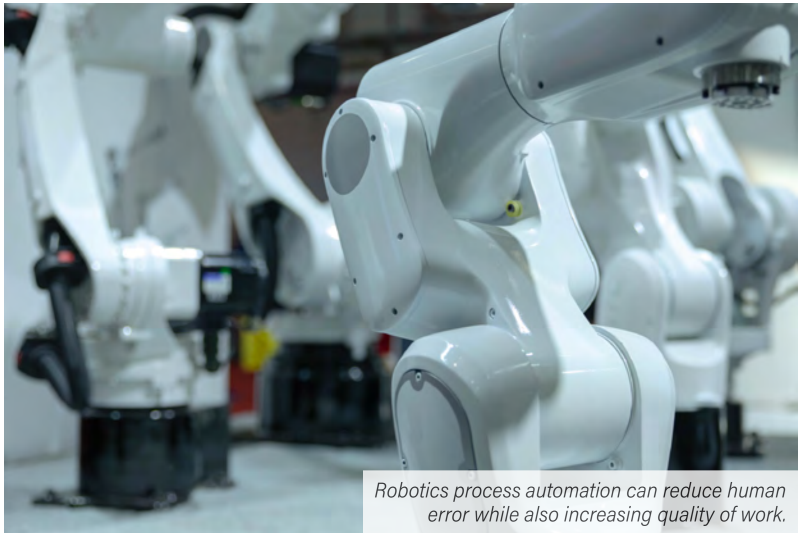
ii. Business & Financial Services

Emerging technologies with advanced materials are also reshaping business and financial services substantially as they enable increased productivity, cost reduction, and better decision making. However, several challenges come to light especially regarding lack of control over technology, cybersecurity, company-wide consistency, maintaining employee skills, and potential job loss.

Emerging Technologies and Applications

a. Blockchain & Distributed Ledger Technology (DLT)

Blockchain plays a vital role in the finance and business field because it can act as a solution to the fundamental challenges of trust, remove the need for intermediaries, and avoid human error risks. As a result, it has garnered attention and is transforming businesses, governments, and venture capitalists. There are even mentions of the possibilities for taxes to be collected using blockchain.



Robotics process automation can reduce human error while also increasing quality of work.

b. Robotics Process Automation (RPA)

Human error is inevitable in any work environment regardless of the field of work. A recent study on human errors at work concluded that even with highly experienced people, excessive failure rates and letting people work from experience and knowledge always create unwanted random variations, especially in the finance and business sector. Robotics process automation can reduce these percentages and human errors while also increasing quality of work.

c. Artificial Intelligence (AI)

Artificial intelligence (AI) is leading the front of the digital transformation strategy in finance today. It embodies computers to simulate human intelligence by amplifying cognitive abilities, providing solutions to problems where the complexity is too great, the information is incomplete, or the details are too subtle and require expert training. AI starts with data gathering and processing, evolves accordingly, and slowly becomes one of the most anticipated technologies within the fourth industrial revolution.

Growth Drivers and Challenges:

The emerging technologies mentioned above are beginning to form powerful clusters collectively reshaping financial services, such as the energy sector, by bringing new opportunities to firms and consumers alike. In the energy sector, blockchains are environmentally sustainable, cost-saving and provide increased transparency for stakeholders without compromising their privacy. RPA minimises errors in resolving customer issues and adapts quickly during disasters, crises, and the constant policy changes in the industry. The future design of the energy system in areas of application like electricity trading, smart grids, or the sector coupling of electricity, heat and transport creates great potential for emerging technologies like AI. As technologies like artificial intelligence (AI), the Internet of Things (IoT), 5G, and quantum computing gain traction, the advanced materials field involved in the making and expanding these clusters also moves towards further development.

iii. Culture, Arts & Tourism

Culture, arts, and tourism feature unique market in the involvement of advanced materials with their respective applications. Museums and the musical instruments industry are a few of the named players of this sector, however small it may be.

Emerging Technologies and Applications

a. Anti-corrosion Coating and Cleaning Chemical

With regard to culture, advanced materials are primarily involved in anti-corrosion coating and cleaning chemicals used for the preservation of artefacts. The Islamic Arts Museum Malaysia (IAMM) highlighted that most chemicals are imported, but hydrocarbon aromatics are procured locally. Anti-corrosion coating for these artefacts is currently under development by Materials Technology Group (MTEG) from Nuclear Malaysia (ANM).

Growth Drivers and Challenges:

Malaysia is rich in arts and culture, and the preservation of such historical relics is of importance. Anti-corrosion coating and cleaning chemicals play an essential role in ensuring this. Due to their status as non-profit organisations (NPOs), museums have limited funds and are incapable of purchasing equipment for material analysis and identification. In the case of IAMM the funding comes from the Albukhary Foundation. Essentially, museums like IAMM are merely the end users for advanced materials related to artefacts preservation.

b. Composite Instruments

There is a small market for composite instruments made from carbon fibre reinforced polymer (CFRP). Composite instruments are very durable, water-resistant, heat resistant, and easily repairable compared to wood instruments. Due to their automated production, composite instruments provide consistent sound quality. They are cheaper than wood instruments mainly due to the less desirable tonal quality they produce. Emerging materials in composite instruments include CFRP with araldite matrix used to make musical instruments.

Growth Drivers and Challenges:

Durability and low costs of composite instruments enable it to still reach out to the targeted market in the music industry. Furthermore, varying temperature and humidity have little to no effects on these instruments, making them suitable outdoors. The only downside that hinders this market from further expanding is the tonal quality that does not match the high quality of wooden instruments. Further research on alternative methods to fix this disadvantage will provide an even playing field between the composite and wooden instruments markets.

iv. Medical & Healthcare

There is a demand for the innovation of advanced materials in the medical and healthcare sector due to emerging trends such as the ageing population, remote healthcare services, health data tracking, preventive healthcare, regenerative medicine, flexible electronics for sensors, and wearable devices. Materials innovation and process changes are desperately needed to meet customers' demands for products with greater personalisation and better performance. In addition, manufacturers and material suppliers must adapt quickly to the fast-moving consumer trends (or pandemics) that radically shift the landscape of buying and selling.

3D-printed medical devices expands with the development of customised hearing aid shells, dental devices, prosthetics, and orthotics.

Emerging Technologies and Applications

a. Microbiome Materials

The COVID-19 pandemic has led to a rise in demand for hygiene products and personal protective equipment in the status quo. Advanced materials aid this by improving face mask performance, which includes protection against the virus and improving the aesthetics and sustainability of the mask. The use of bio-based materials reduces environmental impact, and improves manufacturing processes, hydrophobic materials, and antimicrobial coatings.

b. Wearable Devices

The growth in the wearable and mobile technology sectors raises the bar regarding material choices and designing products for long and productive lifespans. Medical manufacturing companies will have to work on novel ways to manage heat and battery life in miniaturised wearable technologies such as sensors, implants, wrist bands, and watches. More compact and durable product housings for use in rugged environments, such as distribution facilities, the military, and healthcare settings, are also needed. Manufacturing companies will also have to provide solutions for the flexible and semiflexible programmable logic boards to affix each component securely without sacrificing shock absorption or the finished product's durability.

c. Smart Coatings

Thermoplastics and coated fabrics create flexible products that offer strength and leak-proof performance even while housing sensitive electronics. This feature is called the polar molecular property and it is what gives them their weldability.

d. Advanced Metals

Nickel is a high-performing metal common in medical devices that further enhances their strength, corrosion resistance, and ductility. It is prone to localising stress and corrosion along the areas where its crystalline impinge on one another. The electrodeposition technique has implications in several industries, including micro-electro-mechanical devices such as medical implants.

e. 3D Printing

The commercial use of 3D-printed medical devices expands with customised hearing aid shells, dental appliances, prosthetics, and orthotics. However, the same customisability and potential for distributed manufacturing that makes printing medical devices attractive also make them very difficult for regulatory agencies to monitor and evaluate. As a solution, the US Food and Drug Administration (FDA) has provided guidelines for developing and producing printed devices.

Growth Drivers and Challenges:

The high demand for improved medical and healthcare products and services ensures the continuous development of advanced materials with extraordinary properties. The competition in the market has led to these products and services being more economically feasible. However, production costs to set up these advanced materials technologies are high, and most machines are imported overseas. In addition, development and production validation requires more time due to the lack of medical test equipment in universities. The advanced technology in this sector also requires qualified personnel to run the respective clinical trials.

v. Smart Technology & Systems

Smart technology is the next-generation engineering and manufacturing process that can integrate with intelligence systems. Smart manufacturing integrates several discrete technologies, such as artificial intelligence (AI), edge or cloud computing, computer vision, augmented reality, 3D printing, and robotics, within the manufacturing processes. Overall smart manufacturing would optimise production to its highest efficiency, ensure product quality control, and enable product customisation.

Emerging Technologies and Applications

a. Blockchain

Supply chain management is the critical target application for blockchain. It tracks the movement of goods and materials to reduce losses and track compliance with product and material handling regulations.

Emerging Material Solution:

Taggants and automated scanners are used in data collection, making them more trusted than human data entry. Solutions such as conventional cameras to identify products and computational modelling to improve analytics are applied to lower costs.

Growth Drivers and Challenges:

Reducing human error is one of the main advantages of blockchain. Implementation of blockchain aims to build trust in data as opposed to current implementations of the traditional database by humans. However, it also requires expensive data collection methods and more computing power than traditional database systems.

b. Quantum Computing

Quantum computing encompasses quantum mechanics to deliver a giant leap forward in computation and solving problems. However, this technology is still years away from being useful for highly scaled business applications. It is still considered very unstable, moreover with it being prone to losing information easily.

Emerging Material Solution:

Efficient cooling at ultracold temperatures depends on improved insulation. Conventional shielding can be replaced with emerging metamaterial shielding to reduce electrical and acoustic noises.

Growth Drivers and Challenges:

Quantum computing still requires significant development to be considered viable. The numerous types of quantum computing processors like superconducting, ion-trap, photonic, and silicon-based make it challenging to narrow down to the best processor that would scale while maintaining longer coherence time.

vi. Smart Cities & Transportations

A smart city predominantly comprises information and communication technologies (ICT) that develop, deploy and promote sustainable development practices to address growing urbanisation challenges. It requires innovation in chemicals and materials to identify the necessary properties, whether it needs to be the combination of malleability and durability, an anti-corrosive IoT sensor, or a robust 5G semiconductor. The Eleventh Malaysia Plan (11MP), the National Physical Plan 3 (NPP3) and the National Urbanisation Policy 2 (NUP2) are a few of the development plans geared towards turning Malaysia's cities into smart cities.

For transportation, the automotive and aerospace sectors are both making significant contributions to Malaysia's economy. The automotive market has seen an increment of CBU export value from RM1.5 billion in 2014 to RM2.08 billion in 2018. The Malaysian aerospace industry has grown significantly over the past years, and now the market has more than 230 domestic and foreign companies investing more than RM16.2 billion in total revenue in 2019. The launch of the Aerospace Industry Blueprint 2030 in 2015 boosted the industry, projected to contribute revenue of RM20.4 billion for MRO, RM21.2 billion for aero-manufacturing, and RM13.6 billion for engineering and design. The COVID-19 pandemic has significantly affected the industry, wherein revenues shrunk about 20%-30% in 2020 from 2019. However, it is expected to bounce back in 2022.

Emerging Technologies and Applications

a. 5G

5G is the latest global wireless standard that enables a futuristic network to connect virtually everyone and everything, including machines, objects, and devices.

Emerging Material Solutions:

For 5G's antennas, liquid crystal polymers (LCP), polyamide (PA), and polytetrafluoroethylene (PTFE) are leading contenders to the epoxy FR4 used in 4G devices. Metamaterial antennas provide efficient, directional signals to reduce power consumption and thermal load. 5G also needs high thermal conductivity materials like graphene, graphene oxide, boron nitride nanotubes (BNNTs), carbon nanotubes (CNTs), and nanodiamond to dissipate thermal load from multiple antennas.

Growth Drivers and Challenges:

5G is one of the fundamentals of a smart city because it delivers higher multi-Gbps peak data speeds, ultra-low latency, more reliability, massive network capacity, increased availability, and a consistent user experience to more users. In addition, 5G enables an IoT ecosystem where networks can serve many connected devices. Therefore, the materials incorporated in the new 5G hardware must accommodate the high thermal load, high signal directionality, beam shaping, and short signal range.

The materials incorporated in new 5G hardware must accommodate high thermal load, high signal directionality, beam shaping, and short signal range.

b. Commercial Vehicle Automation Materials

Emerging Material Solutions:

Vehicles can claim more energy efficiency through lightweight advanced materials such as advanced high-strength steels (AHSS), glass fibre (GFRP), and carbon fibre reinforced plastics (CFRP). Anti-corrosion and anti-wear replace conventional paint to protect the vehicles for an extended lifetime. Advanced materials like omniphobic, antimicrobial, and photocatalytic coatings enhance passengers' safety and comfort in interior cleanliness. In addition to that, the new metamaterial antennas are saving costs as opposed to the conventional radar and LiDAR system.

Growth Drivers and Challenges:

Shared mobility and last-mile delivery are promising longer-term commercial automation prospects, but despite being one of the key contributors to Malaysia's economy, the future of this industry brings unique challenges. The focus on retrofitting existing vehicles will only be in the early stages, and there are only a few material opportunities in this phase. The life cycle costs of a vehicle will be in jeopardy with high management and fleet ownership. The future of technology in autonomous vehicles will lean towards shared mobility that maintains its performance, cleanliness, and safety.

c. 3D Printing in Aerospace Industry

Emerging Material Solutions:

3D printing in the aviation sector allows more optimised alloy and polymer applications that give almost the same performance as their conventional manufacture equivalents. The open material platform nature of 3D printing business models reduces the cost of materials. Production of fuel from local products instead of high-quality biofuels from raw materials is the beginning of a cost-saving initiative in the bio-jet fuel industry. These natural-based biofuels move towards zero greenhouse gasses emission initiatives.

Growth Drivers and Challenges:

The Aerospace Malaysia Innovation Centre (AMIC) led research and technology ensure Malaysia's aerospace industry remains competitive globally. Advanced materials technology like 3D printing significantly impacts the aerospace industry because a single component designed and manufactured with 3D printing can reduce air drag by 2.1% and reduce fuel costs by 5.41%. The razor blade model, for example, remains critical for high-value markets, and 3D printing enables the best performance with the least need for end-user expertise. Aviation demands high amounts of fuel and therefore contributes to the surge of carbon dioxide emissions. Bio-jet fuels are the sustainable solution to reduce these emissions in the long run. Bio-jet fuel and next-generation technologies will play the most significant role to achieve the 2050 emissions target set forth by the aviation industry.

vii. Agriculture and Forestry

There has been a decline in the contribution of agriculture and forestry to the country's GDP compared to its early days. Therefore, applying advanced materials in this sector is essential and should be elevated to the national interest. However, a substantial amount of R&D&C&I is needed to leverage advanced materials in this sector.

Emerging Technologies and Applications

a. Bioplastic

Bioplastics are plastic materials produced from renewable biomass sources, and currently, their main constituent is corn. This technology can avoid environmental issues presently associated with it, such as the high production of corn and concerns about potential impacts on food security — switching to perennial biomass crops and agricultural co-products as feedstocks are among the proposed solutions. Perennial biomass crops create a new market for farmers, lower greenhouse gas emissions from crop production, reduce the usage of fertilisers and pesticides, and ensure better soil and water quality.

b. Biobased Feedstocks

Biobased feedstocks are made from natural-based co-products, such as poultry feathers or food scraps from food production. These products currently have little value, but they can increase their economic value by reducing waste and providing additional income streams to farmers and processors.

Growth Drivers and Challenges:

Rubber and palm oil are two of the dominant fields in this sector. Domestic manufacturing of rubber remains important, whereas palm oil has put Malaysia as one of the world's top producers — the waste products of palm oil play a significant role in bio-based materials. Bioplastics, on the other hand, is a growing market. Policies favouring bioplastics would help reduce reliance on fossil fuels, support sustainability initiatives, and allow manufacturers to diversify feedstocks. Despite all this, there is a decline in this sector. The leading causes of this decline were unfavourable weather conditions and the loss of farm labour to urban manufacturing jobs.

Bioplastics are plastic materials produced from renewable biomass sources and currently their main constituent is corn.

viii. Water and Food

A well-integrated ecosystem is needed to ensure water and food security while addressing the challenges of rising population, urbanisation, climate change, and economic disparities. Malaysia has the potential to carry out emerging technologies such as smart water management, smart farming, lab-grown meat, and 3D printed food. With milestones in every technological sector, including water resources management, the nation is close to becoming a developed and industrialised country. The food industry is among the highest GDP contributors in Malaysia, representing 10% of the manufacturing sector and contributed RM21.76 billion in GDP for 2019 with products exported to more than 200 countries.

Emerging Technologies and Applications

a. Desalination and Recycled Water

Desalination is a process that removes dissolved salts from seawater, thereby converting it into potable water, allowing people to have access to water. Desalination and water recycling are both integral components to solving the water crisis.

Emerging Material Solutions:

Graphene multilayer membranes from municipal and agricultural wastes is the way forward for the oil-water separation process. As for water treatment, haemodialysis, and gas separation, advanced polymer membranes would ease the approach to capture carbon. In addition, advanced ceramic materials can also be used for water treatment.

Growth Drivers and Challenges:

Malaysia has abundant surface water (i.e., river and lake basins) and high OPEX and CAPEX cost of using traditional membrane systems in status quo. However, with rapid urbanisation, a fast-growing population, water pollution, and water scarcity due to industrialisation and poor irrigation, Malaysia will need to depend on desalination and water recycling.

b. Protein Production

Protein production is the biotechnological process of generating a specific protein by manipulating the gene expression in an organism, expressing large amounts of a recombinant gene. It portrays to be a critical challenge and an opportunity to produce agricultural food, but the specific needs for the materials involved are limited.

Emerging Material Solutions:

Synbio strain development and 3D bioprinting are replacing conventional cell structures, making them more cost-effective. In addition, biological scaffolds like 3D bioprinting play an essential role to repair and reconstruct injured and missing tissues.

Growth Drivers and Challenges:

As the population increases, new sources are critical to the future of food supply. Conventional protein sources from livestock and fish are unsustainable and unable to keep up with growing demand. For protein production to expand, the palatability in terms of taste and texture, cost, and convenience of these products will be vital in gaining market share. It will also be an excellent opportunity to brand alternative proteins from Malaysia as Halal certified and commercialising them to other Muslim majority countries.

ix. Education

Advanced materials can impact the education sector in terms of both areas of focus — social and technology. However, this field is still not very well expressed in higher learning, especially tertiary education, in terms of social studies. To date, there are only five public universities with MQA accreditation that offer full bloom bachelor's degrees in engineering, which provide students with insights on advanced materials (IIUM, UniMAP, USM, UTM, UM); while six universities offer bachelor's degrees in science for materials that enable students to go in-depth to understand and apply principles in this field (UKM, UMK, UMP, UPM, UiTM, UTHM). In addition, other institutions offer materials as a partial programme or elective courses typically associated with mechanical or chemical engineering programmes.

Material informatics improves the understanding, use, selection, development, and discovery of materials.

R&D in advanced materials are mainly conducted by postgraduate students and researchers at various institutes at universities. Only a few research institutes in universities are equipped with state-of-the-art facilities, especially involving high technology and specific testing equipment. R&D in advanced materials fundamentally search for discoveries and applications rather than commercialisation but to complement the country's socio-economic position, developments with potential for commercialisation are still preferred.

As the advanced materials industry increasingly adopts sophisticated technologies, more advanced skilled workers must close the gap between their expertise and industry needs. Education plays a huge part in closing this gap. High skilled workers can enhance productivity, cost efficiency, innovation capabilities and spur local technological development. Now that industry, government, and academia have realised the potential of the advanced materials market, they must also work together to ensure that Malaysian workers are equipped to fulfil that promise.

Emerging Technologies and Applications

a. Material Informatics

Material informatics is an emerging field of study that applies informatics principles to materials science and engineering, improving the understanding, use, selection, development, and discovery of materials. It provides a goal to achieve high-speed and robust acquisition, management, analysis, and dissemination of diverse materials data while also reduces the time and risk required to develop, produce, and deploy a new material.

Emerging Materials Solution:

The traditional trial-and-error method is inefficient and time-consuming to study materials. Artificial intelligence, especially machine learning, can accelerate the process by learning rules from datasets and building models to produce predictions. There are proven emerging materials designed by artificial intelligence. For instance, scientists can now quickly simulate how minuscule droplets of melted metal will glob together when they cool down and solidify, conversely, showing how a mixture will separate into layers of its constituent parts when it melts. The production of advanced materials can be quickly further enhanced through this machine learning process.

Growth Drivers and Challenges:

Materials data come from many different sources — such as test data, simulation data, reference data, and supplier datasheets. Other data formats include microstructure images, processing instructions, chemical formulas, and x-ray diffraction data. The many different data sources and formats contribute to the complications of attaining and processing them. A centralised data system can ensure a systematic approach to solve this issue.

x. Environment and Biodiversity

In order to achieve the 10-10 MySTIE's objective, it is essential to have a sustainable approach in preserving and conserving Malaysia's natural environment and biodiversity. Human activities leave significant impact on the environment and biodiversity which leads to many environmental issues such as global warming, air pollution, and biodiversity loss. Advanced materials have the advantage to address and solve some of these issues.

Emerging Technologies and Applications

a. Mechanical Recycling

Mechanical recycling is the dominant waste disposal method with a relatively simple process and low overall costs; however, it cannot remove additives like dyes and flame retardants or impurities like dust or organic contaminants. As a result, several developers are improving pre-treatment to improve recycled resin quality and new feed systems to enable the recycling of new form factors like mono-material films. Mono-material is a product that is only composed of a single material, enabling effective recycling methods.

b. Pyrolysis

Pyrolysis, also called chemical recycling, is an energy-intensive process that requires economies of scale. It has the potential to address mixed plastic waste streams. Pyrolysis uses a thermochemical approach to convert carbon-based feedstocks to a mixed hydrocarbon pyrolysis oil. Pyrolysis oil can be further distilled into products like naphtha, diesel, and waxes depending on feedstock composition and process conditions.

c. Nanocellulose

Nanocellulose is nano- and micro-sized cellulose particles with high mechanical strength, high stiffness, large surface-area-to-volume ratio, biodegradable, effective renewability, and low toxicity. Nanocellulose has a wide range of applications, and that includes many emerging uses such as nanocomposite materials, biomedical products, wood adhesives, supercapacitors, templates for electronic components, batteries, catalytic supports, electroactive polymers, continuous fibre and textiles, food coatings, barrier/separation membranes, antimicrobial films, paper products, cosmetics, and cement. ZoepNano Sdn. Bhd. is the pioneer in nanocellulose commercialisation in Malaysia. They use palm-based biomass to produce their nanocellulose.

Growth Drivers and Challenges:

The rise in plastic pollution has driven key players to step up and take appropriate actions. Since 91% of plastics are not recycled and are primarily non-biodegradable, this forces startups and organisations to develop new ways to reduce plastic pollution and commercialise plastic waste using advanced materials.

One main challenge with this and many other environmental issues is poor governance. Greenhouse emission is one of the biggest environmental problems we face today. The government should introduce a carbon tax that will force the industry to innovate low carbon technology to tackle climate issues. The tax will subsequently open doors to the commercialisation of new sustainable technologies such as hydrogen fuel cells, electric vehicles, which enables the incorporation of graphene-based supercapacitors, and renewable energies such as solar energy. The government needs to support the development of green innovation to reduce the costs of low carbon technologies. It is also crucial to impose stricter policies to address offenders that cause environmental damage.

The government should introduce a carbon tax that will force the industry to innovate in low carbon technology to tackle climate issues

Case Study

MIMOS

Case Study 1

Graphene-Based Inks

by MIMOS Berhad

Overview:

Due to the rising price of silver, graphene-based inks have become an economical alternative to silver-based inks. They offer better performance and favour environmental sustainability. As a strategic agency under MOSTI, MIMOS has developed two graphene-based technologies: the MIMOS Graphene Conductive Ink and MIMOS Graphene Anti-Static Ink.

Current Strategy:

MIMOS Graphene Conductive Ink is predominantly used in the E&E industry. It is inkjet-printable, monolayer, customisable, and has high conductivity. As a result, it enables the next generation of printed technology, wearables technology, and flexible electronics applications.

MIMOS Graphene Anti-Static Ink is used primarily for the reduction of electrostatic charge. It is a low-cost topical-type anti-static coating that provides good electrostatic discharge (ESD) properties with low haze and high transmittance, and good adhesion on flexible polymer substrates. It is also water-based with no sulphuric ion contaminant formulation.

Future Potential:

Since only a few companies are currently producing conductive inks globally, Malaysia has the opportunity to develop the production capability of graphene-enabled conductive ink because the technology is still novel. The graphene inks designed by MIMOS will allow local industries to tap into emerging and huge future markets such as wearables, printed electronics, renewable energy, and electric vehicles. Additionally, it offers them a huge potential to add value to existing applications, thereby boosting investment and gross national income.

Graphene inks are expected to catalyse several new industries in Malaysia, such as Radio-Frequency Identification (RFID) and photovoltaic cells — allowing existing and upcoming local industry players to capture more of the industry value chain by moving upstream or creating competitive advantages in existing and future markets.

Case Study 2

Aerogel Insulation

by HitzeTek Sdn. Bhd.

HitzeTek "We Mitigate Your Heat"

Overview:

Environmentally friendly supply infrastructure like insulation is crucial for today's increased global energy demand. Insulation acts as a barrier to heat loss and heat gain, particularly in walls, pipeline systems, and floors. HitzeTek Sdn. Bhd. in Rawang, Selangor has manufactured a natural-based aerogel blanket using nanotechnology made of rice husks and other substrates available widely and locally in Malaysia.

Current Strategy:

Natural based aerogel is dried in a supercritical fluid of CO_2 to effectively reduce the high brittleness of aerogel and enhance the structure between the aerogel and substrates. It has a wide working temperature range (-200°C – 650°C), making it suitable for use in many fields, including piping, construction, petrochemistry, and precision equipment.

Future Potential:

Unlike traditional insulation, aerogel insulation has added advantages. It is environmentally friendly, has low thermal conductivity, is inflammable, and is 75% thinner than any other competing insulation material, making it easier to install and save cost. Currently, the local aerogel market is big and monopolised by foreign companies such as Aspen, Recaa, and Cabot. However, with the natural resources available in Malaysia, we can expand the local market effectively.

Case Study 3

Silica

by Terengganu Incorporated Sdn. Bhd.

TERENGGANU INC

Overview:

Silica is a raw material with a chemical compound consisting of silicon and oxygen, primarily found in crystalline form. The manufacturing process of the silica industry typically involves the extraction process, and refinement to standards suitable for industrial usage before being used by component manufacturers / original equipment manufacturers (OEMs) to manufacture components and end-products, respectively.

Current Strategy:

Terengganu Incorporated Sdn. Bhd., a wholly-owned subsidiary of Menteri Besar (Incorporated) Terengganu, is the master developer for Terengganu Silica Valley (TSV). TSV is an eco-industrial park covering approximately 4,000 hectares, situated in Jambu Bongkok, Marang, Terengganu. The State of Terengganu has earmarked this location to attract investment from silica-based midstream and downstream players. The main strength of TSV is the rich supply of high purity raw silica located in Setiu and Marang and natural quartz in Kemaman, Terengganu.

Future Potential:

Terengganu Incorporated Sdn. Bhd. through their development of TSV expects to attract an investment value of RM13 billion and create 7,200 job opportunities.

Case Study 4

Nickel Titanium Dental Implants

by Nitium Technology Sdn. Bhd.

NITIUM TECHNOLOGY

Overview:

Nitium Technology Sdn. Bhd. is a hard-tech medical device startup that developed the world's first porous nickel-titanium dental implant using metal injection moulding. These implants are the first to have a threaded design that enables bone-ingrowth inside the implant surface, therefore, guaranteeing both osseointegration and incorporation. In addition, the porosity allows the implant surface to provide three times more surface area to cells compared to other products in the market today.

Current Strategy:

The manufacturing technique by Nitium Technology enables them to reduce the production cost to 60% - 70% compared to the cheapest and the lowest quality implants that are currently available. They use the ideal implant materials with features superior to the latest products in the market alongside unprecedented cost reduction. As a result, this company has obtained awards and recognition from Malaysia and first world countries such as Japan, South Korea, and Germany.

Future Potential:

Nitium Technology is currently working with their manufacturing partner, an orthopaedic manufacturer, to produce their first orthopaedic implant product and will be entering the market in 2022. They are also embarking on metal 3D printing, using their material to develop cranial implants.

Case Study 5

Rice Husk Water Filters

by Maju Saintifik Sdn. Bhd.

Overview:

Rice husks are a natural resource that is of abundance during the paddy to rice process. Research has shown that these husks can be converted into pure sub-micron silica with potential in water filtration. Maju Saintifik Sdn. Bhd. has successfully manufactured the rice husk water filter and is currently analysing water quality and performing acceptance tests.

Current Strategy:

Maju Saintifik is currently running a small production due to the lack of infrastructure, but this is expected to change soon as the need for a more sustainable market scales up. Bigger rice husk water filters enable filtration of a hefty water flow, especially in commercial and large housing communities. As research continues and with the right technology, their water filters can potentially provide a more custom design to replace imported water filters.

Future Potential:

The abundance of resources for this product will encourage manufacturing in situ and provide jobs to local graduates in the agriculture sector. Furthermore, research and development by local universities can further enhance the reliability of this water filter by providing reasonable solutions to its current limitations.

Case Study 6

Biodegradable Product

by Free The Seed

Biodegradable & Compostable Paddy-Straw Packaging

Overview:

Free The Seed Sdn. Bhd. is a biotech-based and greentech-based company specialising in bio-packaging. They are involved in the R&D and manufacturing of biodegradable packaging products from biomass waste materials using Intellectual Property (IP) bio-enzymatic cellulose fibrous materials technology as invented by the company's founder, Mr. Ramaness Parasuraman, to replace Single-Use-Plastics and to reduce global carbon footprints.

In 2014, they were selected as the National Winner of the Global Cleantech Innovation Programme (GCIP) for SMEs in Malaysia. This programme invites entrepreneurs to address challenging energy, environmental, and economic problems.

Current Strategy:

There are 1,300 paddy smallholders and farmers involved in Free The Seed's initiative, implemented in the northern region of Malaysia. Free The Seed's IP-published biotechnology process utilising serine protease enzymes, delignified cellulose fibres, and enzymatic gratification methods converts existing stockpiles of rice straws to produce biodegradable packaging products that can compost organically in 180 days.

Their product complies with current sustainable packaging initiatives and is being exported to global markets. This enterprise puts an end to the current practice of open burning while the readily compostable nature of the end product ensures no further harm to the environment. As the initiative develops, the sector will see a stream of direct and indirect benefits in the form of additional income from purchasing paddy waste material and associated pre-processing activities, introducing sustainability and stewardship standards in the area.

Future Potential:

From the current two factories in Kedah, they expect to achieve zero open burnings for an estimated 47,000 hectares of paddy field, translating into an estimated reduction of 600,000kg of CO_2 per annum. With these achievements, the paddy crop sector could lead the way, showcasing what is possible through the thoughtful application of technology and paving the way to establish Malaysia as a low-carbon agriculture production country while remaining sensitive to the needs of farmers.

This initiative also expects to catalyse an entire biodegradable product packaging value chain, the emergence of knowledge workers, and significant economic activity that will positively impact the local and national economy. The global food packaging market size is forecasted to be $606.3 billion by 2026.

Free The Seed embraces the Sustainable Development Goals (SDG 1, 4 & 13) and is a leader in the Circular Economy by promoting Climate-Smart practices to replace global single-use plastics.

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CHAPTER

4 ROADMAP DEVELOPMENT

This roadmap was developed using MIGHT's methodology as described in Figure 4.1, which includes Horizon Scanning, Interviews and Expert Panels, Scenario Analysis, MIGHT's F.I.R.S.T™ Matrix, Focus Group Workshops, and Wind Tunnelling. The first three of these processes allow us to assess the current scenario and trend of the advanced materials industry and identify issues and challenges faced by the industry. Strategies and action plans were then developed based on the data and findings gathered from the various surveys, engagements, and panels discussions conducted. This entire process involved up to 262 people from 60 organisations.

Chapter four captures the findings and insights framed in five perspectives typical of policy development, **Funding and Finance, Infrastructure, Regulations and Policies, Skills and Talents, and Technology** using the MIGHT F.I.R.S.T™ Matrix tool.

MIGHT's Methodology

- Horizon Scanning
- Interviews & Expert Panels
- Scenario Analysis
- MIGHT's F.I.R.S.T™ Matrix
- Focus Group Workshops
- Wind Tunnelling

Chapter 4 captures the findings and insights which are framed in five perspectives typical of policy development, namely Funding and Finance, Infrastructure, Regulations and Policies, Skills and Talents, and Technology using the MIGHT F.I.R.S.T™ Matrix tool.

Surveys

MIGHT distributed 778 surveys to gather data and insights of the advanced materials scenario in Malaysia. The surveys were performed to complement desktop research, engagements, and workshops with industry experts and academics. With the COVID-19 outbreak in early 2020, these efforts were mostly conducted virtually due to the Movement Control Order (MCO) enforced by the government.

The surveys were carried out among industry key players (362 surveys), research universities and institutions (389), as well as financial institutions (27). The participants are well represented across sectors and industries; energy, medical and healthcare, smart technology and system (next-generation engineering and manufacturing), smart cities and transportations, water and food, agriculture and forestry, education, and the environment and biodiversity.

HORIZON SCANNING

Horizon scanning is a technique for identifying issues and trends as well as early signs of important developments. The method calls for determining what is constant and what changes - looking at what is new, shifted and discontinued. It explores novel and unexpected issues as well as persistent problems and trends, including matters at the margins of current thinking. Horizon scanning is a way to assess trends to feed into a scenario development as well as provide the background to develop strategies for anticipating future developments.

INTERVIEWS & EXPERT PANELS

Interviews are often described as 'structured conversations' and are a fundamental tool used by MIGHT. They are often used as formal consultation instruments, intended to gather knowledge that is distributed across the range of interviewees. This may be tacit knowledge, unstructured information that has not been published, or more documented knowledge that is more easily located by discussions with experts and stakeholders than by literature review.

SCENARIO ANALYSIS

Scenario analysis is a process of analysing possible futures and considering alternative possible outcomes. In contrast to typical planning methods, a scenario analysis is not purely based on extrapolation of the past or the extension of past trends. Nor does it put heavy reliance on historical data and does not expect past observations to remain valid in the future. Instead, it considers possible developments and turning points, which may only be connected to the past.

MIGHT F.I.R.S.T™ MATRIX

The MIGHT F.I.R.S.T™ Matrix is a useful analysis tool to assist the development of strategies and action plans **based on five perspectives** typical of any policy development. The perspectives are **Funding and Finance, Insfrastructure, Regulations and Policies, Skills and Talents, and Technology.** The matrix is useful as a checklist to assist framework development activity through exploration of future opportunities and vulnerabilities from diferrent perspectives. The MIGHT F.I.R.S.T™ Matrix enables discussion on how each perspective interacts with other perspectives. During the deliberation exercise, potential solutions or strategies to address current and future problems might be considered and highlighted.

FOCUS GROUP WORKSHOPS

The workshop series is an effective platform to solicit new ideas to validate findings and proposals as they will explore and anticipate issues and challenges, plausible future scenarios, and develop future proof strategies. The workshop engagements are structured and planned with guiding questions and exercises; process and facilitation; whereby participants may be assigned specific detailed tasks or work on their own.

WIND TUNNELLING

The application of wind tunnelling is to explore the visibility and robustness of strategies in light of contemporary trends and disruptive change. A wind tunnel test is a straightfoward procedure, wherein we check **how well a strategy or action plan performs when challenged by critical trends and scenarios.** Is it future-proof? Do they need minor adjustments or genuine and fundamental transformations in order to fit the future within the time-frame allocated? The wind tunnel test, which is usually a part of a strategic activity series, will ensure that relevant strategies are being produced — highlighting their strengths and weak spots as well as offering guidelines for improvements or redirections.

Figure 4.1: MIGHT's Methodology | Source: MIGHT Analysis

Industry

Industries Involvement

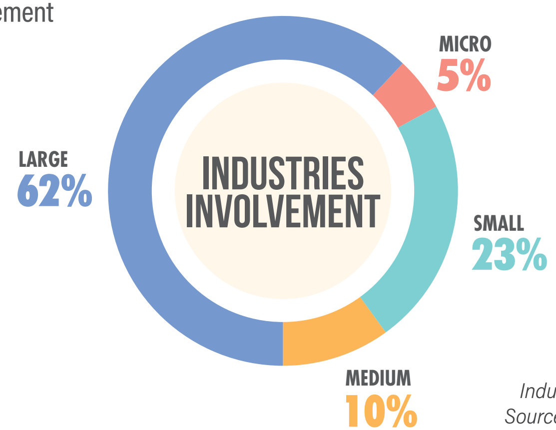


Figure 4.2: Industries Involvement Source: MIGHT Analysis

In-House R&D Facilities

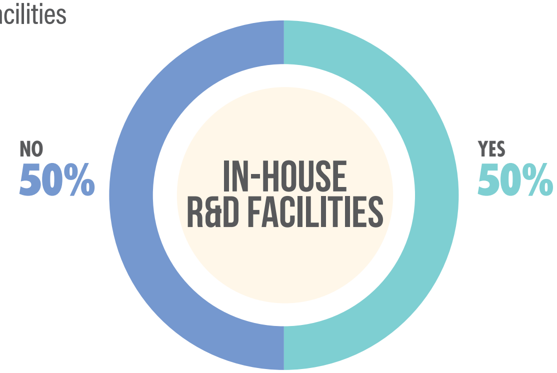


Figure 4.3: In-House R&D Facilities Source: MIGHT Analysis

A survey in the industries reveals that 62% of companies that are involved in advanced materials in Malaysia are large-sized companies — according to the SME Corporation definition — and they include Multinational Corporations (MNCs) and Government Linked Companies (GLCs) (Figure 4.2). These companies are involved in manufacturing and services in high technology sectors such as electrical and electronics (E&E), aerospace, mobility, and energy sectors. The remaining 38% are medium, small, and micro-level companies primarily consisting of startups and spin-off companies. Some of these micro companies have made breakthrough inventions and established global recognition, notably Nitium Technology Sdn. Bhd. which produced the world's first porous nickel-titanium dental implant via metal injection moulding, Lönge Medikal Sdn. Bhd. with their development of 3D printing technology of medical-grade fabrication processes, and Green Data Centre LLP, which created sustainable cooling technology for data centres using dielectric liquid properties coolant.

Half of the private companies and GLCs have in-house R&D facilities, while the remaining half do not (Figure 4.3). Those with in-house R&D facilities are usually involved in the designing and testing of industry solutions such as PETRONAS, TNB, Sarawak Energy, Proton, and UMW. In contrast, some are involved in new inventions such as Dreamedge, Nitium Technology, Lönge Medikal, HitzeTek, and Free The Seed. Out of the total survey respondents, 48% spend less than 5% of their net profit for R&D activities, while 16% spend more than a quarter of their net profit.

Based on engagements with various stakeholders, Malaysian companies are involved in manufacturing — where many are geared towards quick profit earning and are less inclined to spend on R&D due to its high CAPEX and slower return. Additionally, most of these companies are not accustomed to the innovation culture and are more contented with being a technology user rather than a technology provider. On the other hand, MNCs of other countries are more innovative and advanced in developing their technologies, such as the Australian MNC Lynas (operating in Malaysia) that has its own R&D facilities.

The survey also shows that companies in Malaysia are involved in six leading advanced materials, namely composites (27%), polymers (19%), nanomaterials (15%), alloys (14%), metal (13%) and biomaterials (12%). Composites, polymers, and nanomaterials represent more than half of the total (Figure 4.4). The composites technology/industry is considered mature

Involvement of Malaysian Companies in Top Advanced Materials

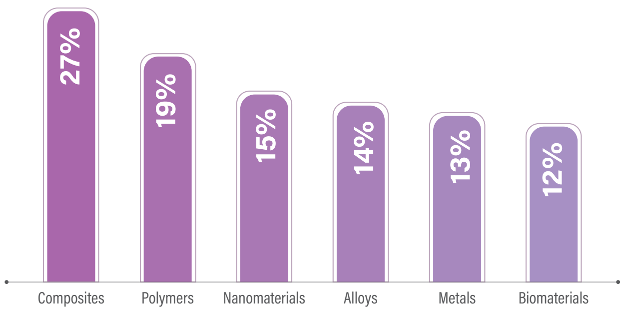


Figure 4.4: Involvement of Malaysian Companies in Top Advanced Materials Source: MIGHT Analysis

Top Five Advanced Materials Applications

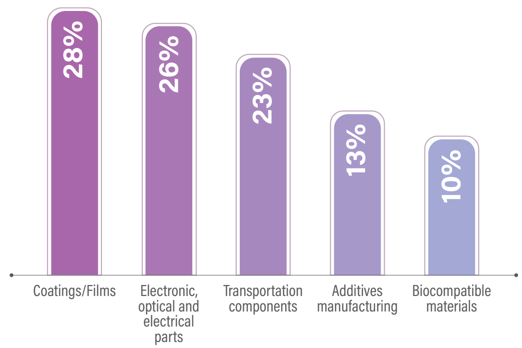


Figure 4.5: Top Five Advanced Materials Applications | Source: MIGHT Analysis

in Malaysia, accelerated by the Malaysia Aerospace Industry Blueprint 2030, launched in 2015. Furthermore, composites technologies usually require polymer matrix composites and contribute a significant portion of the polymer businesses. Thus, explaining why these two types of advanced materials contribute to the highest participation by Malaysian companies.

Several government initiatives and roadmaps have contributed to the growth of advanced materials in Malaysia. For example, the Roadmap Towards Zero Single Use Plastic 2018-2030 by the Ministry of Environment and Water (KASA) supported by the Circular Economic Roadmap 2020 encourages the industry to transform waste into valuable resources, thus spurring the production/development of advanced materials. In terms of nanomaterials, nanosilica technology has matured in Malaysia and is widely used in the energy (solar energy) and E&E industry sectors. In addition, an upsurge of graphene and carbon nanotubes production can also be observed in the past few years following the National Graphene Action Plan 2020 in 2014.

Advanced materials are widely applied in Malaysian industries. Applications for coatings/films rank highest (Figure 4.5), followed by applications for electronic, optical and electrical parts. The high volume of these two categories is due to their cross-sectoral nature and heavy usage in major industries such as automotive, E&E, aerospace, agriculture, and food industries. The materials used in these applications are significant contributors to the growth of Malaysia's manufacturing sector, one of Malaysia's main economic activities contributing to an increase of 3.0% in the fourth quarter of 2020.

Coatings/films are mainly produced from a petrochemical product, such as polymer, which has the second-highest number of companies involved, as shown in Figure 4.4. Electrical, electronic, and optical products commonly use polymer, metal, semiconductor, and nanomaterials, while transportation components use composite material, metal, alloy, and polymer. Other top industry sectors that apply advanced materials are additives manufacturing and biocompatible materials that manufacture products such as biodegradable plastics, packaging, and gloves.

Malaysia's abundant natural resources proved to be an advantage for the country's chemicals and chemical products industry. Malaysia is the second-largest palm oil producer after Indonesia and a key oil and gas producer in the Asia Pacific region. Other natural resources in Malaysia are

Strength of Advanced Materials Industry in Malaysia

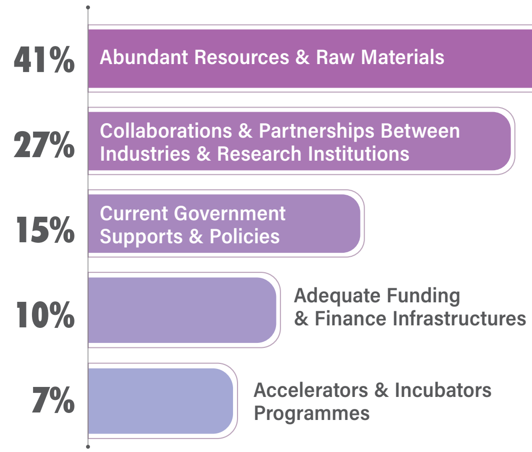


Figure 4.6: Strength of Advanced Materials Industry in Malaysia Contexts Source: MIGHT Analysis

Weaknesses of Advanced Materials Industry in Malaysia

Figure 4.7: Weaknesses of Advanced Materials Industry in Malaysia Contexts Source: MIGHT Analysis

silica (sand), tin, and minerals such as bauxite and mica. Being a leading producer of paddy also allows Malaysia to produce rice husks and rice straw during the harvesting and milling process. These materials can be used as raw materials for fast-moving consumer goods (FMCGs), bio-industrial products, and power generation.

Advanced materials is an important contributor to the manufacturing sector, with petrochemicals and oleochemicals being the primary products of this sector. Chemicals are often used as raw materials in the manufacturing of various finished goods in industries such as electrical and electronics, plastic products, agriculture, automotive, oil and gas, pharmaceuticals, and construction materials. Natural resources such as oil, gas, palm, rubber, and minerals play significant roles in contributing to the country's GDP. Other promising resources such as kenaf, rice husks, and rice straws are becoming more critical. Local companies have produced many high valued products using those materials such as aerogels, bioplastics, compostable packaging, and biocomposites. The depiction of Malaysia's strength in relation to advanced materials is shown in Figure 4.6.

As shown in Figure 4.7, the commercialisation process of technologies is the biggest challenge for companies in Malaysia. Companies have several options to mitigate this challenge through research collaboration with partners, licensing with well-established companies, or bringing the technology to the market themselves. The choice of route to commercialisation would always be dependent on several factors, mainly the nature of the technology (disruptive or complementing), time to enter the market, the amount required for development, and techno-commercial-social study, among others. Failing to analyse the cost-benefit of each route would cause the technology's failure to enter the market.

For high-end industries such as aerospace, the certification process is expensive and extensive due to the complexity of testing that needs to be outsourced to foreign countries. Additionally, as most certified high-end equipment and materials are not made in Malaysia, procuring them would involve import taxes, thus further increasing costs. Because of these reasons, funding and financial structure for these companies are observed to be major challenges as they would require considerable investments to venture into this industry. In addition to that, the lack of local suppliers/producers tied to the local demand/market size is also a weakness to this industry due to their readiness to shift processes and build local capabilities.

Issues and Challenges Faced by Companies

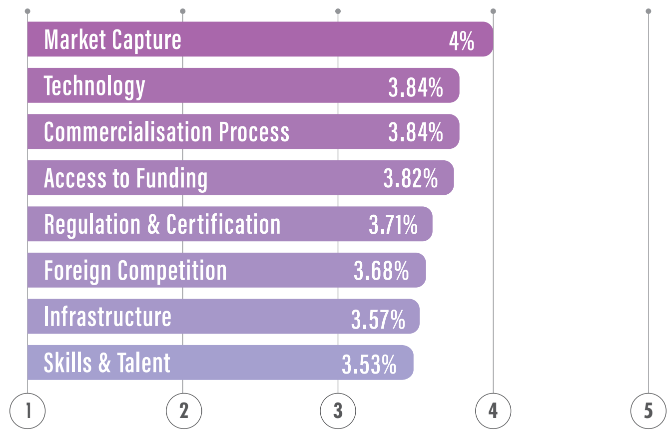


Figure 4.8: Issues and Challenges Faced by Companies | Source: MIGHT Analysis

Issues and Challenges Faced by RUIs

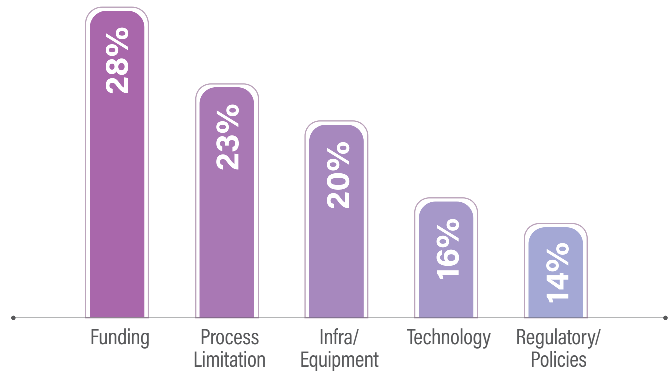


Figure 4.9: Issues and Challenges Faced by RUIs | Source: MIGHT Analysis

Figure 4.8 highlights eight key issues and challenges that are faced by this industry in Malaysia. Local companies find it most challenging to attain market readiness, especially when it comes to new materials technology. Sometimes the research produces highly niched applications, resulting in the material not being viable for widespread commercialisation. Regulation and certification of the materials are also a big hurdle for companies to introduce their local products to the market, especially in highly regulated industries such as aerospace and medical. Most of these local companies cannot compete with their foreign competitors in terms of quality and price of materials.

Government policies can play a significant role in helping new technologies to be highly and widely adopted. For example, as demonstrated by the EU, we can see a parabolic increase in electric vehicles (EV) uptake since EU lawmakers set a tighter regulation on emissions from all new cars. They also reward EV users with a 10-year tax exemption, price subsidies, and free toll passes.

Research Universities & Institutions (RUIs)

Based on the surveys and engagements conducted, funding is the most challenging issue faced by research universities and institutions (RUIs), as shown in Figure 4.9. The funding required by RUIs is for research, testing, validation, and commercialisation purposes. However, some R&D funds are usually constrained to turn research results into industry-ready prototypes. High costs for testing, certification and the need to procure imported materials are the largest contributors to the funding issue on top of process limitation and infrastructure. Furthermore, based on feedback acquired during industry engagements, RUIs' lack of collaboration with the industry in developing beneficial solutions for the industry has resulted in insufficient funding from the industry itself. MOSTI is currently offering six types of R&D funds for researchers and companies interested in producing new processes and products to address this issue. The available funds are the Applied Innovation Fund, Technology Development Fund 1 & 2, Bridging Fund, Strategic Research Fund and MOSTI Combating COVID-19 Fund for R&D ranging from TRL 2 – 9.

Publication of Material Science Documents

No	Countries / Region	Material Science Documents	Cites	Cites / Paper	Highly Cites Paper
1	China Mainland	378,904	6,670,874	17.61	5,340
2	USA	151,768	4,353,547	28.69	3,625
3	South Korea	69,068	1,234,735	17.88	708
4	India	68,356	789,903	11.56	238
5	Germany (Fed Rep Ger)	56,970	1,114,235	19.56	623
6	Japan	53,856	844,104	15.67	480
7	England	37,343	837,622	22.43	549
8	France	36,545	622,062	17.02	245
9	Iran	29,725	382,977	12.88	157
10	Australia	27,776	680,171	24.49	627
11	Russia	27,773	187,677	6.76	177
12	Italy	25,411	451,065	17.75	5340
13	Spain	25,062	446,906	17.83	205
14	Canada	23,921	457,746	19.14	296
15	Taiwan	22,187	354,349	15.97	180

No	Countries / Region	Material Science Documents	Cites	Cites / Paper	Highly Cites Paper
16	Poland	19,691	169,734	8.62	52
17	Turkey	18,376	183,920	10.01	62
18	Brazil	17,710	164,079	9.26	32
19	Singapore	14,569	555,413	38.12	630
20	Saudi Arabia	13,087	275,188	21.03	311
21	Hong Kong	12,953	385,255	29.74	405
22	Sweden	12,461	233,645	18.75	149
23	**MALAYSIA**	**11,416**	**143,984**	**12.61**	**54**
24	Switzerland	11,409	352,274	30.88	241
25	Netherlands	10,356	249,278	24.07	145
26	Czech Republic	9,075	97,064	10.7	35
27	Egypt	8,837	102,730	11.62	60
28	Romania	8,693	59,210	6.81	8
29	Portugal	8,636	150,178	17.39	51
30	Belgium	8,337	176,801	21.21	91

Table 4.1:
Publication of Material Science Documents
Source: Web of Science

In terms of publication, China records the highest number of material science documents in the world with 378,904 documents, out of which 5,340 are highly cited, as can be seen in Table 4.1. The second and third highest are the USA and South Korea with 151,768 and 69,068 documents, respectively. Malaysia ranks 23rd globally in terms of the number of material science documents and second in South East Asia behind Singapore. On the number of highly cited papers, Malaysia ranked 27th in the world with 54 papers behind Singapore (10th in the world) in South East Asia (Table 4.2). Being listed in the top 30 global rankings proves that Malaysian RUIs have high capabilities in material science research. With this advantage, both RUIs and the industry should take the opportunity to collaborate by leveraging Malaysia research capabilities for a marketable output for the industry.

Composite, graphene, silica nanoparticle, and biomaterials are the latest top trending material for Patents IP, as highlighted in Figure 4.10. It is no coincidence that the patent registered under composite is the highest over the last few years. The R&D conducted shows the maturity of the industry is reflected by the high number of patents registered. The high volume of Patents IP for graphene results from the National Graphene Action Plan, one of the government's initiatives launched in 2014. In Malaysia, graphene is used to produce conductive ink, drilling fluid, lubricant, anti-corrosion coatings, and rubber additives. With the development of graphene, Malaysia can create a potential Gross National Income (GNI) of RM20 million and 9,000 jobs. Hence, Malaysia should continue its support in encouraging the industry to develop marketable products of graphene.

Silica nanoparticles are among the highest Patent IP registered and should also be the industry focus. The abundant resources of the silica raw material in Terengganu, Perak, Johor, Sabah, and Sarawak are certainly an advantage for Malaysia to produce high value-added products. Terengganu Silica Consortium has the largest proven reserves of high purity silica in Asia and is involved in silica's upstream and downstream operations. Silica nanoparticles are widely used on coatings, water treatment and remediation, and aerogel.

Publication of Material Science Documents (South East Asia) Sorted Based on Cites/Paper

No	Countries / Regions	Material Science Documents	Cites	Cites / Paper	Highly Cited Papers
19	Singapore	14,569	555,413	38.12	630
23	**MALAYSIA**	**11,416**	**143,984**	**12.61**	**54**
36	Thailand	5,177	56,144	10.84	23
40	Vietnam	3,868	36,340	9.4	4.1
59	Indonesia	1,629	12,993	7.98	7
79	Philippines	362	3,377	9.33	0

Table 4.2: Publication of Material Science Documents (South East Asia) Sorted Based on Cites/Paper | Source: Web of Science

Malaysia IP Patents in Advanced Materials

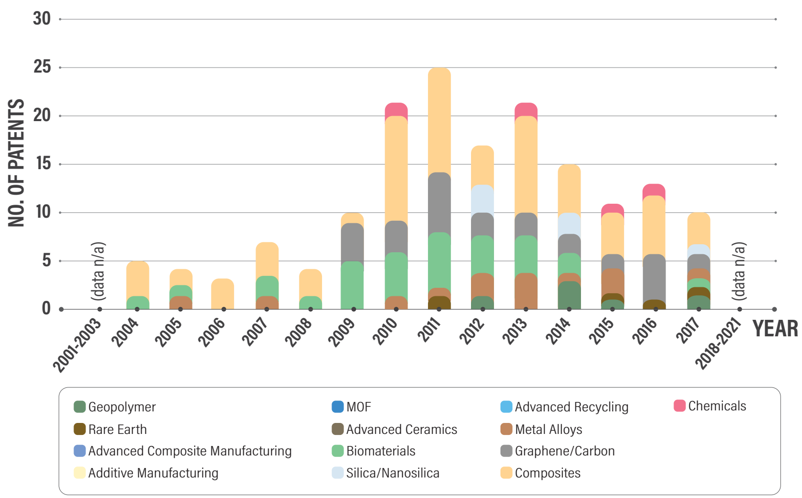


Figure 4.10: Malaysia IP Patents in Advanced Materials | Source: Lux Research

Financial Institution

There are two types of financial institutions related to the advanced materials industries, namely fund managers and Development Financial Institutions (DFIs), with a distribution of 17% and 83% respectively (Figure 4.11). However, of all the 80 fund managers in Malaysia, not all can be related to the advanced materials industries. As an example, fund managers that are linked to the development of advanced materials are Malaysia Bioeconomy Development Corporation (MBDC), Malaysia Technology Development Corporation (MTDC), Malaysia Toray Science Foundation (MTSF), Venture Tech, and Malaysian Investment Development Authority (MIDA). These fund managers provide various types of funding in a wide area of R&D and commercial. Examples of funds/grants provided by the fund managers are listed below.

- Malaysia Bioeconomy Development Corporation (MBDC) - Biotechnology Commercialisation Fund (BCF)
- Malaysia Technology Development Corporation (MTDC)- CRDF 1-3
- Malaysian Investment Development Authority (MIDA) - Domestic Investment Strategic Fund (DISF)
- MATRADE - Market Development Grants
- Malaysia Toray Science Foundation (MTSF) - Science & Technology Research Grant (STRG)
- Cradle Fund Sdn Bhd - Cradle Investment Programme (CIP Ignite & CIP Accelerate)

Six of Malaysia's DFIs are prescribed under the Development Financial Institutions Act 2002. The government established the Development Financial Institutions Act with specific functions and roles to develop and promote key development industry towards high technology. The roles of the DFIs include consultation and advisory services for the development of targeted industries. Connected to the overall socio-economic development, they both carry equal importance to the economy and people. The DFIs support SMEs in agriculture, infrastructure, maritime, export, and capital-intensive and high-technology industries. Table 4.3 and Table 4.4 list some of the Malaysian DFIs.

In addition to the surveys, engagements were also held with relevant stakeholders. The sessions were conducted virtually, and some were held physically, either at MIGHT or at the stakeholders' offices. Figure 4.12 summarises the topics of engagements held and the stakeholders involved.

Financial Institutions in Advanced Materials

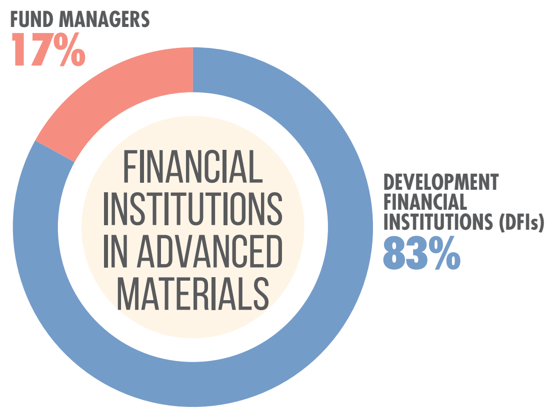


Figure 4.11:
Financial Institutions in Advanced Materials
Source: MIGHT Analysis

Some of Malaysian DFIs are listed in Table 4.3 and Table 4.4: -

List of Development Financial Institutions Under the Development Financial Institutions Act 2002

No	Name
1	Bank Pembangunan Malaysia Berhad
2	Small Medium Enterprise Development Bank Malaysia Berhad (SME Bank)
3	Export-Import Bank of Malaysia Berhad (EXIM Bank)
4	Bank Kerjasama Rakyat Malaysia Berhad (Bank Rakyat)
5	Bank Simpanan Nasional
6	Bank Pertanian Malaysia Berhad (Agrobank)

Table 4.3:
List of Development Financial Institutions Under the Development Financial Institutions Act 2002
Source: MIGHT Analysis

List of Development Financial Institutions - Not Prescribed Under the Development Financial Institutions Act 2002

No	Name
1	Sabah Development Bank Berhad (SDB)
2	Sabah Credit Corporation (SCC)
3	Credit Guarantee Corporation Malaysia Berhad (CGC)
4	Malaysia Debt Ventures Berhad
5	Tabung Haji
6	Malaysian Industrial Development Finance Berhad (MIDF)

Table 4.4:
List of Development Financial Institutions
(Not Prescribed Under the Development Financial Institutions Act 2002)
Source: MIGHT Analysis

Stakeholders' Engagement

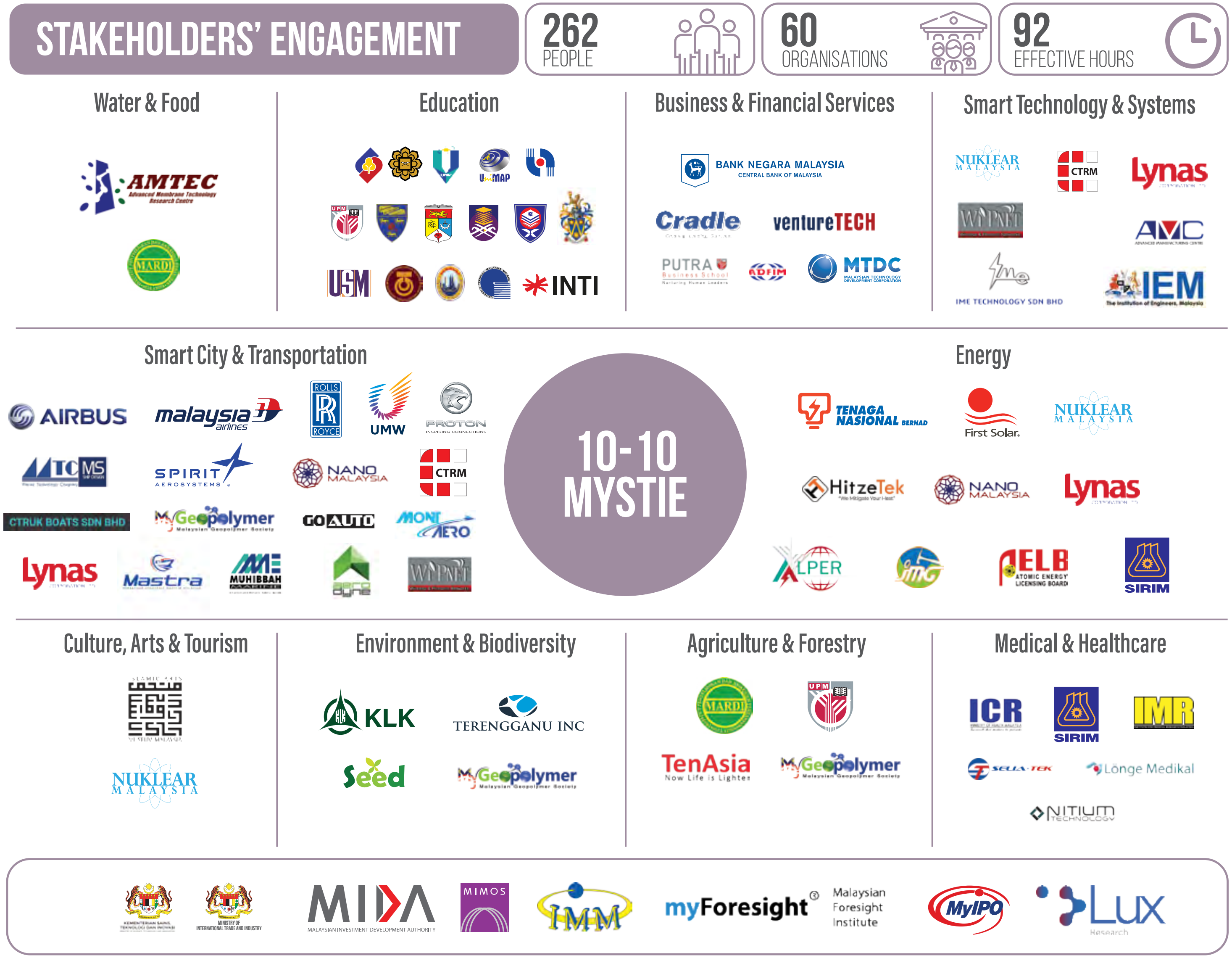


Figure 4.12: Stakeholders' Engagement
Source: MIGHT Analysis

MIGHT F.I.R.S.T™ Matrix

F.I.R.S.T™ Matrix is used to identify the enablers and gaps in the advanced materials ecosystem in Malaysia. Its findings and insights as well as future opportunities and vulnerabilities, highlight the interactions between; Funding and Incentives, Infrastructures, Regulations and Policies, Skills and Talent, Technology and Innovation, and Market as displayed below.

	Fundings & Incentives	Infrastructures	Regulations & Policies	Skills & Talent	Technology & Innovation	Market
FUNDING & INCENTIVE		• New tax incentive for the establishment of Global Trading Centre • National Development Scheme (NDS) by Bank Pembangunan	• Promotion of Investment Act 1986 • MITI • MIDA • Medical Device Authority (MDA)	• Extension of Tax Incentive for Returning Expert Programme • HRDF • MOHE Scholarships • Majlis Amanah Rakyat (MARA)	• BNM High Technology Fund • Special incentive package to support R&D investment for aerospace and electronic • MOSTI R&D Fund (Science Fund, Pre Commercialisation Fund) • Malaysia Debt Venture (MDV) • MTSF - Science and Technology Research Grant (STRG) • Soft Financing Scheme for Digital and Technology (SFDT) • Transdisciplinary Research Grant Scheme (TRGS) • Crowdfunding i.e., Kickstarter • MDEC • GTFS • Public-Private Research Network (PPRN) • Malaysia Technical University Network (MTUN) Research Grant	• Tax initiative for companies that commercialise R&D findings of public research institutions, including public higher learning institutions and private higher learning institutions • Commercialisation of Research and Development Fund (CRDF) • Cradle Investment Programme (CIP) • MATRADE - Market Development Fund (MDF) • Biotechnology Commercialisation Fund (BCF)

continued next page

	Fundings & Incentives	Infrastructures	Regulations & Policies	Skills & Talent	Technology & Innovation	Market
INFRASTRUCTURE	• Bank Pembangunan MIDA (Techno Fund, Inno Fund) • Malaysia Bioeconomy Development Corporation (MBDF) • Invest Selangor • MOHE • MOF • SME • FDIs		• MOSTI • MOT • MIDA • MITI • MDA • National Aerospace Industry Coordinating Office (NAICO) • Selangor Darul Ehsan Aerospace Industry Coordinating Office (S-DAICO)	• Laboratories and COEs under public universities • Talent Corp IMM (Institute of Materials Malaysia) • SIRIM • FMM (Federation of Malaysian Manufacturers) • TVET (Technical and Vocational Education and Training)	• SIRIM AMREC • MyLab Programme • MIMOS • NANO MALAYSIA • ASM • Domestic AdM Institutions • ANM	• Cluster Development (Technology Park)– Automotive, Petrochemical, Aerospace, Shipbuilding • UMW High-Value Manufacturing Park • Malaysia International Aerospace Centre • MATRADE • AdM Centre of Excellences
REGULATIONS & POLICIES	• Promotion of Investments Act, 1986 • National Science, Technology and Innovation Policy	• Promotion of Investments Act, 1986 • National Science, Technology and Innovation Policy		• Promotion of Investments Act, 1986 • National Science, Technology and Innovation Policy	• Promotion of Investments Act, 1986 • National Science, Technology and Innovation Policy	• Promotion of Investments Act, 1986 • National Science, Technology and Innovation Policy
SKILLS & TALENT	• MOHR	• MBOT (Engineers)	• Ministries		• IEM • AdM Researchers	• FMM
TECHNOLOGY & INNOVATION		• NanoMalaysia ANM	• National Technology Innovation Sandbox	• Online learning platforms on advanced materials		

Table 4.5 MIGHT F.I.R.S.T™ Matrix | Source: MIGHT Analysis

CHAPTER

5 STRATEGIES & ACTION PLANS

The steady growth of the niched advanced materials industry is crucial in positioning Malaysia as a competitive and robust nation globally. This chapter presents the outcomes of the country's goals on advanced materials and its prioritisation and key action plans developed for the National Advanced Materials Technology Roadmap 2021-2030. The strategies and action plans outlined here serve as guidelines and catalysts for stakeholders to accelerate the growth of the advanced materials industry — in particular, its presence and function in many applications and processes.

Results from online surveys, including direct engagements and workshops, were consolidated to provide information for this roadmap's national goals, strategies, and action plans.

Malaysia as a High-Tech Nation Thrust

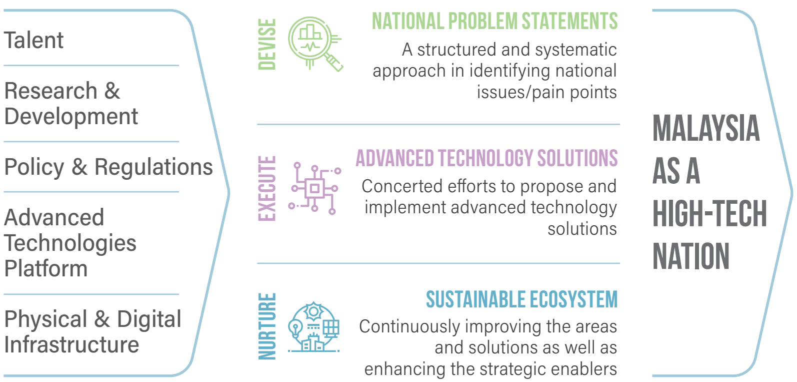
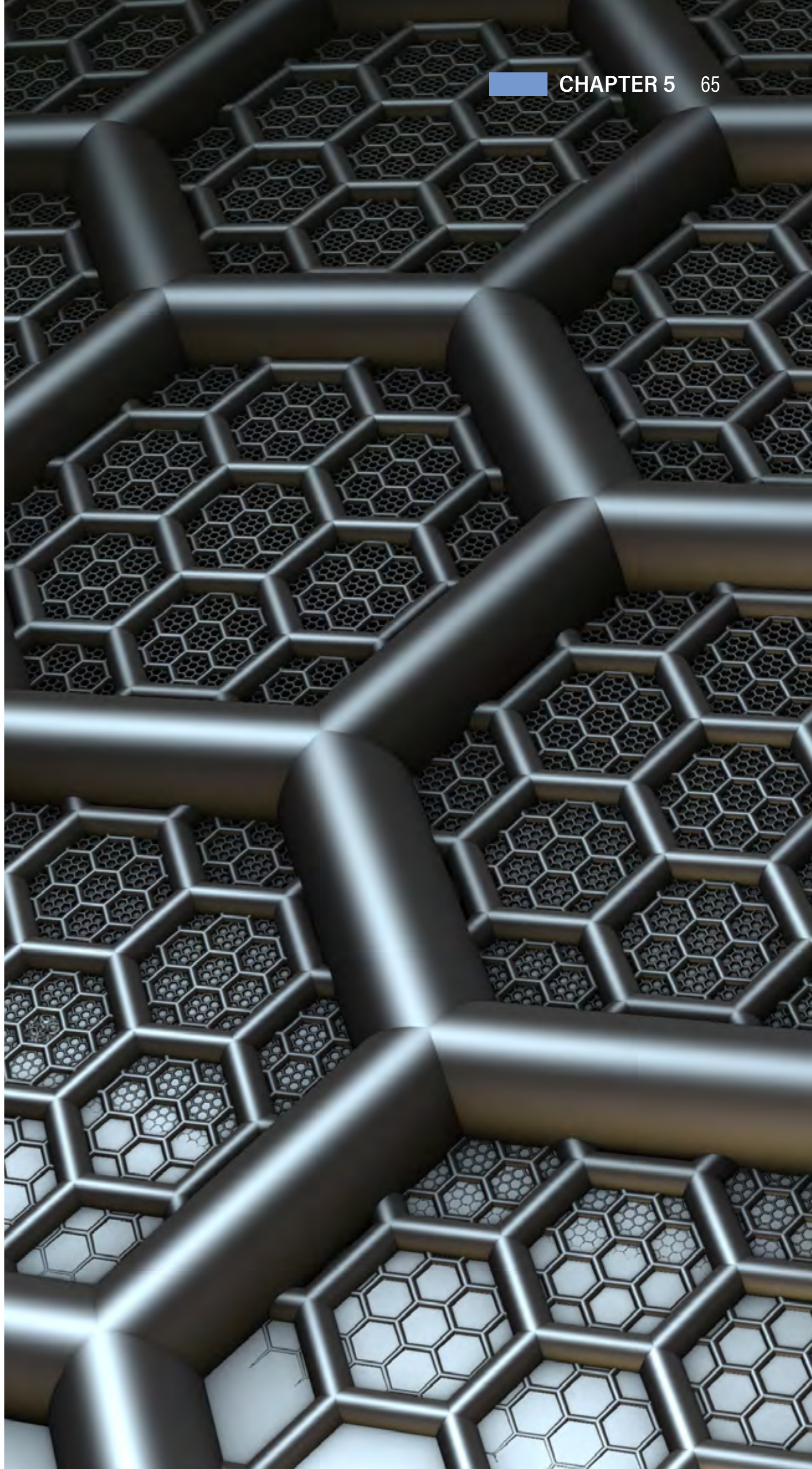


Figure 5.1: Malaysia as a High-Tech Nation Thrust | Source: NPSTI



Goals for Advanced Materials in Malaysia

The National Advanced Materials Technology Roadmap 2021-2030 is produced to guide relevant stakeholders, government, and agencies to achieve a high technology nation status by 2030 as stipulated in the **National Policy on Science, Technology & Innovation 2021-2030 (NPSTI 2021-2030)**. Figure 5.1 illustrates how Malaysia can achieve its status with the support of three essential pillars: the National Problem Statements, Advanced Technology Solutions, and Sustainable Ecosystem. The three goals outlined for the National Advanced Materials Technology Roadmap 2021-2030 to accomplish are listed in Figure 5.2.

The specific goals and targets are in support of the national vision for the transformation of the advanced materials sector. The targets listed in Figure 5.3 is a guide to measure Malaysia's progress in achieving the three goals.

Three Goals for the National Advanced Materials Technology Roadmap 2021-2030

GOAL 1	GOAL 2	GOAL 3
Nurturing world class capabilities and innovation culture in advanced materials	Strengthening Malaysia's competitiveness through balanced growth in economic and technological development in advanced materials	Intensifying global connectedness by evolving into becoming the regional centre for production and services for advanced materials.

Figure 5.2:
Three Goals for The National Advanced Materials Technology Roadmap 2021-2030
Source: MIGHT Analysis

Targets Projection

	2020	2030
Revenue (RM billion)	85	116
No. of Employment	141,727	170,401
No. of Materials Technologists & Technicians	883	1,148
Projects Commercialised	15	30
Technology Acquisition Projects	2	10

Figure 5.3:
Targets Projection
Source: MIGHT Analysis

9 GRAND CHALLENGES OF THE MALAYSIAN INDUSTRIAL DEVELOPMENT

COMPETITIVENESS

Competitiveness through Economic Complexity and Balanced Growth

1. Enhancing Malaysia's economic diversity beyond commodity and low value-added products/services.
2. Rethinking competitiveness beyond value creation solely based on growth or profitability.

CAPABILITIES

World-Class Capabilities & Innovation Culture

3. Beating the middle-income trap is challenging as the environment is tough.
4. Malaysia remains slightly behind the median country in terms of human capital performance.
5. Malaysia's productivity level is still well below advanced economies.
6. Low output of innovation and R&D to support advancement of local products.

CONNECTEDNESS

Global Connectedness via Regional Centre for Production and Services

7. Strengthening domestic supply chain for self-sufficiency and to serve the global market.
8. Relatively lower value-added in gross export *vis-a-vis* regional competitors.
9. Inefficiency of logistics related issues downplays the attractiveness of the country.

Figure 5.4:
Nine Grand Challenges of the Malaysian Industrial Development
Source: MIGHT Analysis

Figure 5.4 grouped nine grand challenges of the Malaysian Industrial Development into three categories; competitiveness, capabilities, and connectedness. Competitiveness comprises enhancing Malaysia's economic diversity and rethinking the economic complexity beyond value creation solely based on profitability. Capabilities include challenges in increasing Malaysia's productivity level as currently, it remains below the standard of countries with advanced economies and human capital performance. A regional centre for production and services will enable Malaysia to overcome its connectedness challenges by strengthening the domestic supply chain for self-sufficiency and serving the global market. Malaysia is also facing relatively lower gross export vis-a-vis regional competitors.

Advanced Materials Technology Prioritisation

Based on research and stakeholders' inputs via online surveys and direct engagements, 37 advanced materials were identified and assessed in terms of the feasibility and attractiveness criteria for each of the 10-10 MySTIE sectors by workshop participants held in April 2021.

Certain materials, such as metamaterials, were not included due to their scarcity in Malaysia's advanced materials ecosystem despite a high market value in the world. Figure 5.5 shows the prioritisation of each material, where all materials lie within the range of high priority and medium priority.

The prioritisation for each material is listed in Table 5.1. Polymers hold the highest ranking for materials' prioritisation. Most of other high priority materials are related to polymers, such as polymer 3D printing, biocomposites, plastic recycling, and adhesives, confirming the materials' market value presented in Chapter 2, where polymeric materials have the highest market, not including forecasted value.

Materials Feasibility and Attractiveness
(Averaged)

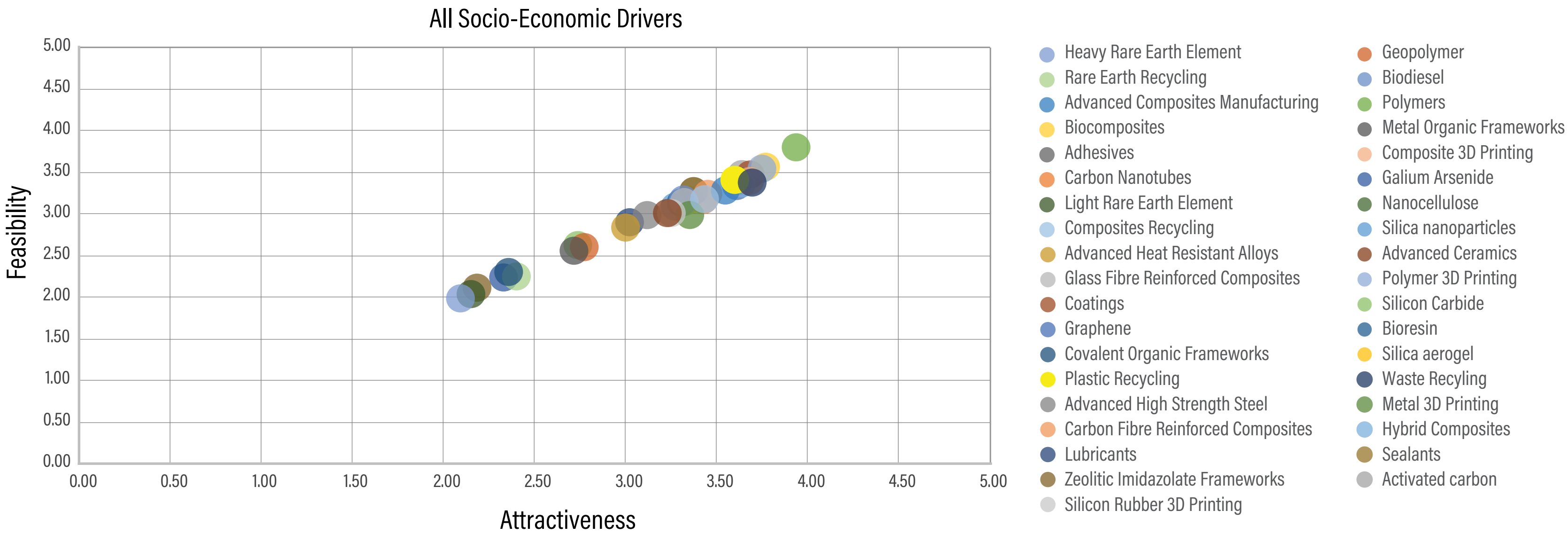


Figure 5.5: Materials Feasibility and Attractiveness (Averaged)
Source: MIGHT Analysis

Materials' Prioritisation Based on Feasibility and Attractiveness Scores in Sequence

No	Materials	Prioritisation
1	Polymers	High
2	Polymer 3D Printing	High
3	Biocomposites	High
4	Coatings	High
5	Composite 3D Printing	High
6	Waste Recycling	High
7	Hybrid Composites	High
8	Graphene	High
9	Plastic Recycling	High
10	Activated Carbon	High
11	Nanocellulose	High
12	Advanced Composite Manufacturing	High
13	Carbon Fibre Reinforced Composites	High
14	Adhesives	High
15	Biodiesel	Medium
16	Carbon Nanotubes	Medium
17	Composite Recycling	Medium
18	Glass Fibre Reinforced Composites	Medium
19	Silica Aerogel	Medium
20	Metal 3D Printing	Medium

No	Materials	Prioritisation
21	Bioresin	Medium
22	Sealants	Medium
23	Silica Nanoparticles	Medium
24	Silicon Rubber 3D Printing	Medium
25	Advanced Ceramics	Medium
26	Advanced High Strength Steel	Medium
27	Lubricants	Medium
28	Advanced Heat Resistant Alloys	Medium
29	Geopolymer	Medium
30	Silicon Carbide	Medium
31	Metal Organic Frameworks	Medium
32	Rare Earth Recycling	Medium
33	Covalent Organic Frameworks	Medium
34	Galium Arsenide	Medium
35	Zeolitic Imidazolate Frameworks	Medium
36	Light Rare Earth Element	Medium
37	Heavy Rare Earth Element	Medium

Table 5.1
Materials' Prioritisation Based on Feasibility and Attractiveness Scores in Sequence
Source: MIGHT Analysis

Grouping of Advanced Materials Technologies with High Priority

Clusters	Materials
Chemicals	Polymer Coatings Adhesives
Additive Manufacturing	Polymer 3D Printing Composite 3D Printing
Bio-based Materials	Biocomposites Nanocellulose
Advanced Recycling	Waste Recycling Plastic Recycling
Composites	Hybrid Composites Carbon Fibre Reinforced Composites
Carbon-based Materials	Graphene Activated Carbon
Advanced Composite Manufacturing	

Table 5.2
Grouping of Advanced Materials Technologies with High Priority
Source: MIGHT Analysis

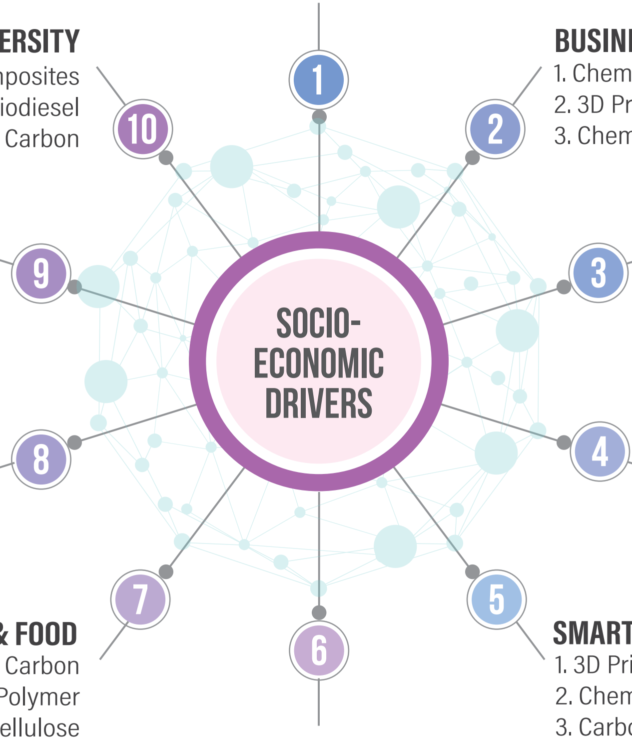
Based on Table 5.1, materials with high priority are grouped and listed in Table 5.2. Seven clusters of the 12 major advanced materials clusters listed in Chapter 2 show subgroups with high priority materials. Apart from polymer related materials and their groups, nanocellulose (bio-based materials), waste recycling (advanced recycling), graphene, and activated carbon (carbon-based materials) are high priority advanced materials technologies with high development potential in Malaysia. Technically, graphene and nanocellulose can be used as filler materials to reinforce polymer matrix composites, making them part of many polymer-related products.

Figure 5.6 presents the top three high priority materials for each socio-economic driver based on 10-10 MySTIE. For each socio-economic driver, polymer or polymer related materials such as biocomposites and polymer 3D printing are among the top three highly prioritised materials in six out of ten socio-economic drivers. 3D printing enables the fabrication of complex structures.

Graphene is highly prioritised in smart cities and transportation, as well as smart technology and systems. The material can be applied in electrical and electronic devices and electric vehicle technology to reduce carbon emissions and increase energy efficiency. In addition, advanced recycling is vital in creating a circular economy to convert waste into wealth and reduce the burden on Earth.

Generally, coatings are widely used to preserve cultural artefacts and protect various kinds of assets such as wind turbines and solar panels to function in the environment that they are placed upon in renewable energy sources. On the other hand, biocomposites and biodiesel are highly prioritised for the environment and biodiversity. Biocomposites promote the usage of sustainable materials such as kenaf as reinforcement materials, while biodiesel, made using palm oil, is an abundant material in Malaysia. Activated carbon is also ranked high in materials' prioritisation due to its application in environmental remediation.

Top 3 Materials for Each Socio-Economic Driver



ENERGY
1. Chemicals - Coatings
2. Advanced Recycling - Waste Recycling
3. 3D Printing - Polymer 3D Printing

BUSINESS & FINANCIAL
1. Chemicals - Polymer
2. 3D Printing - Polymer 3D Printing
3. Chemicals - Coatings

CULTURE, ARTS & TOURISM
1. Chemicals - Coatings
2. 3D Printing - Polymer 3D Printing
3. Advanced Recycling - Waste Recycling

MEDICAL & HEALTHCARE
1. 3D Printing - Polymer 3D Printing
2. Chemicals - Polymer
3. 3D Printing - Composites 3D Printing

SMART TECH & SYSTEMS
1. 3D Printing - Polymer 3D Printing
2. Chemicals - Polymer
3. Carbon-based - Graphene

SMART CITY & TRANSPORTATION
1. Carbon-based - Graphene
2. Chemicals - Coatings
3. Chemicals - Polymer

WATER & FOOD
1. Carbon-based - Activated Carbon
2. Chemicals - Polymer
3. Bio-based Materials - Nanocellulose

AGRICULTURE & FORESTRY
1. Bio-based Materials - Biocomposites
2. Bio-based Materials - Nanocellulose
3. Advanced Recycling - Waste Recycling

EDUCATION
1. 3D Printing - Polymer 3D Printing
2. Chemicals - Polymer
3. Advanced Recycling - Plastic Recycling

ENVIRONMENT & BIODIVERSITY
1. Bio-based Materials - Biocomposites
2. Bio-based Materials - Biodiesel
3. Carbon-based - Activated Carbon

Figure 5.6
Top 3 Materials for Each Socio-Economic Driver
Source: MIGHT Analysis

Strategies and Action Plans

The future state of the industry depends heavily on the success of action plans and approaches proposed in this roadmap's objectives. The eight strategies identified to steer the advanced materials technology in the next ten years cover the essential aspects of policy and governance, institutional and regulatory, research and technology, talent development, funding and incentives, and market enhancement.

In general, the strategies emphasise the need for Malaysia to leap forward and achieve higher revenue and higher value-added services. These can only be materialised through involvements in upstream activities, by having high-value advanced science and technology elements and employing high productivity skilled workforce. Thus, Malaysia aims to arrive at the desired 2030 destination by embarking on the technology roadmap and adopting the following strategies.

The strategies shall be implemented through key action plans and detailed out by relevant parties to develop critical programmes. The action plans act as guidelines for further deliberation via specific proposals. The number of action plans may later grow to accommodate the dynamic nature of the industry as well as to meet the needs of relevant stakeholders throughout the implementation period until 2030.

Five strategies have been identified to steer the advanced materials technology in the next 10 years

STRATEGY 1

Accelerating materials innovation ecosystem via effective **Policies and Regulations**

STRATEGY 2

Enhancing the competitiveness of local industries via integrated **Physical and Digital Infrastructure**

STRATEGY 3

Empowering business sustainability via the establishment of a **Consortium as a "One-stop Centre"**

STRATEGY 4

Enhancing Malaysia's capabilities in material development via **Conducive R&D&C&I Activities**

STRATEGY 5

Nurturing world-class talent via **Strategic Partnership**

Actions, Rationales & Stakeholders

STRATEGY 1: Accelerating materials innovation ecosystem via effective Policies & Regulations

Actions	Rationales	Measures of Success	Stakeholders
1.1 Comprehensive review on market policy through strategic government procurement in defence (warships, aircraft and military gears), mobility, utilities, medical, and healthcare.	▪ To intensify local innovation economy in securing a high-tech market. ▪ To strengthen domestic supply chain for sustainability and to serve the global market in essential sectors.	1. Revenue 2. Employment Rate 3. Project Commercialisation 4. Materials Technologists & Technicians	MOSTI, JPM, MITI, MOF, EPU, MINDEF, MOHA, MOH, KeTSA, KASA, MOT, KKR
1.2 Develop effective policies and regulations for targeted advanced materials products in rare earth metals, metals/alloys, nanomaterials, composites, and advanced chemicals.	▪ To support policies that can rebuild investors' confidence and FDI flows for economic recovery by accelerating market activities and the investment pipelines. ▪ To ensure demand and supply securities.	1. Policies & regulations	MOSTI, MITI, KASA, KeTSA, MIDA, JMG, ANM, AELB
1.3 Incentivise companies with import substitution practice and locally produced advanced materials.	▪ To boost local industries involvement in advanced materials and enhance Malaysia's economic diversity beyond commodity and low value-added products.	1. Revenue 2. Employment Rate 3. Project Commercialisation 4. Technology Acquisition	MOSTI, MOF, MOT, KASA, MITI, KeTSA, MIDA, MGTC, Energy Commission, SEDA, NanoMalaysia, Royal Customs Department

Actions, Rationales & Stakeholders

STRATEGY 2: Enhancing the competitiveness of local industries via integrated Physical & Digital Infrastructure

Actions	Rationales	Measures of Success	Stakeholders
2.1 Consolidate advanced materials COEs to spearhead the development of world-class advanced materials technology and application.	▪ To leverage existing physical infrastructure for material development, analysis, sustainable production techniques, testing, quality verification, and certification to expedite the R&D&C&I works towards stronger commercialisation.	1. Consolidation of Advanced Materials Centre of Excellences (COEs) 2. Project Commercialisation 3. Technology Acquisition	MOSTI, MOF, MOHE, MINDEF, MITI, MOHA, MAFI, KASA, KeTSA, MOT, MOH
2.2 Establish a material informatics platform to expedite advanced materials development for research universities, institutions, and local industries.	▪ To establish a material informatics platform that consists of materials property databases, combinatorial chemistry, process modeling, materials data management, AI, and deep learning. ▪ To support material informatics as an emerging technology in discovering, manufacturing, and deploying advanced materials faster and more cost-effective compared to traditional methods.	1. Consolidation of Advanced Materials Centre of Excellences (COEs) 2. Project Commercialisation 3. Technology Acquisition 4. Materials Technologists & Technicians	MOSTI, KKMM, MOHE, MCMC, MDEC
2.3 Promote development and application of advanced recycling for advanced materials industries by partnering with international players.	▪ To incorporate CE practice to ensure the sustainability of supplies through critical materials recovery. ▪ To be more cost-competitive and reduce import dependency.	1. Revenue 2. Employment Rate 3. Project Commercialisation 4. Technology Acquisition 5. Materials Technologists & Technicians	MOSTI, MITI, KASA, KPKT, MIDA, MGTC, DOE

Actions, Rationales & Stakeholders

STRATEGY 3: Empowering business sustainability via the establishment of a Consortium as a "One-stop Centre"

Actions	Rationales	Measures of Success	Stakeholders
3.1 Establish an industry-led centralised body for the advanced materials sector (National Advanced Materials Consortium (NAMC)).	▪ To govern multi-disciplinary and various stakeholder collaborations to bridge industries and RUIs for greater coordination and facilitation in achieving innovation goals and strategic investment. ▪ To synchronise and address the gaps in value chains, R&D&C&I funds and experts, industrial problems and technology updates, outreach and human capital development.	1. Establishment of National Advanced Materials Consortium (NAMC) 2. Revenue 3. Employment Rate 4. Project Commercialisation 5. Technology Acquisition	MOSTI, MITI, MOHE, MOF, MOHR, MEDAC, EPU, SIRIM, MIDA, MATRADE, MTDC, MIGHT, NanoMalaysia, TalentCorp, MRANTI
3.2 Leverage NAMC as a referral centre and coordination hub for business facilitation, creating networks and engagement of early adopters.	▪ To foster and assist in the coordination network support and initiatives through NAMC.	1. Establishment of NAMC 2. Revenue 3. Employment Rate 4. Project Commercialisation 5. Technology Acquisition	MOSTI, MITI, MOHE, MIDA, MATRADE, TCA, NanoMalaysia, MRANTI
3.3 Anchor MNCs and GLCs as collaborating partners with local companies in promoting and realising business opportunities.	▪ To secure commitment via participation from MNCs and GLCs and strengthen the local innovation economy. ▪ To market accessibility through strategic joint ventures. ▪ To ensure long-term supply and demand securities and sustainability. ▪ To bridge the supply and demand gap.	1. Establishment of NAMC 2. Revenue 3. Employment Rate 4. Project Commercialisation 5. Technology Acquisition	MOSTI, MITI, JPM, MOF, EPU, MIDA, MIGHT, SMECorp, NanoMalaysia, KeTSA, MPIC

Actions, Rationales & Stakeholders

STRATEGY 4: Enhancing Malaysia's capabilities in material development via Conducive R&D&C&I Activities

Actions	Rationales	Measures of Success	Stakeholders
4.1 Intensify industry-led collaborative research for advanced materials.	▪ To manoeuvre the R&D works towards commercialisations by increasing the funding ratio for industry-RUI at 30:70 for fundamental and applied research. ▪ To materialise and accelerate commercialisation efforts. ▪ To increase industry participation in R&D for advanced materials.	1. Project Commercialisation 2. Technology Acquisition 3. Materials Technologists & Technicians	MOSTI, MITI, MOHE, MIDA, MTDC, TCA, SIRIM, STRIDE, CREST, ANM
4.2 Develop Malaysia as the regional R&D hub and support R&D&C&I works in the country by empowering co-funding by up to 30% of qualifying costs.	▪ To attract the MNCs and local companies for R&D works in Malaysia and promote human capital development in advanced materials areas.	1. Project Commercialisation 2. Technology Acquisition 3. Materials Technologists & Technicians	MOF, MOSTI, MOHE, MITI, EPU, MIDA, MTDC
4.3 Leverage current COEs research facilities for industry use and collaboration.	▪ To reduce industries' development costs by optimising and sharing facilities and resources.	1. Project Commercialisation 2. Technology Acquisition 3. Materials Technologists & Technicians	MOSTI, MOF, MOHE, MITI, EPU

Actions, Rationales & Stakeholders

STRATEGY 5: Nurturing world-class talent via Strategic Partnership

Actions	Rationales	Measures of Success	Stakeholders
5.1 Build and enhance confidence and competencies of IHL researchers to collaborate with industry to develop advanced materials applications.	▪ To increase the numbers of skilled IHL researchers with industrial experiences from 17% to 30% and expand the industrial pools of think-tankers. ▪ To update academic courses according to industry needs. ▪ To create opportunities for experts to participate in special projects related to national interests e.g. defence.	1. Establishment of NAMC 2. Materials Technologists & Technicians	MOSTI, MOHE, MOE, IEM, MBOT
5.2 Intensify collaborations and networking with local and international organisations in advanced materials through four game changer programmes.	▪ To collaborate with international agencies and create opportunities for local regulators, policymakers and industry experts to share experiences, gain valuable knowledge and technology updates, and strengthen operational skills in advanced materials critical areas. ▪ To link up with Malaysians working abroad to share experiences and motivation for advanced materials technology development.	1. Collaborations Rate 2. Project Commercialisation 3. Technology Acquisition	MOSTI, MITI, MOHE, MOHR, MOFA, MIGHT, MIDA, MATRADE
5.3 Leverage on NAMC platform as a window to nurture 250 local talents through mentorship.	▪ To gain insight and guidance about a particular industry, explore topics related to professional preparation and networking. ▪ To reflect on the industries' experiences, challenges and interests which will translate into developing innovation economy, business development and market penetration opportunities. ▪ To fill up the shortfall of required skills by the industry.	1. Materials Technologists & Technicians 2. Employment Rate 3. Establishment of NAMC	MOSTI, MOHR, MOHE, MITI, KPLB, MIDA, MPC, TalentCorp, MARA, MATRADE

Advanced Materials Technology Roadmaps

Unique opportunities exist to develop new functional solutions from engineered materials to meet a large and growing number of unmet market demands.

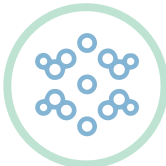
An assessment of high and medium priority advanced materials were performed during workshops with stakeholders to outline the opportunities in the industry within the next ten years. The outcomes indicated that innovating companies involved in these advanced materials group have a potential advantage over their competitors. Unique opportunities exist to develop new functional solutions from engineered materials to meet a large and growing number of unmet market demands.

Graphene applications, silica nanothechnology applications, advanced composite manufacturing, advanced recycling, metal 3D printing, advanced bioplastics, ceramic composites and rare earth elements are the advanced materials applications that may accelerate commercial utilisation in the next decade.

GRAPHENE APPLICATIONS

Graphene excites researchers the most due to its remarkable performance — it is not only the thinnest and lightest material known, but also incredibly strong and flexible. It can be an electrical superconductor and insulator as well as an excellent material for membranes, making it a centre of attention for cross-sector applications — E&E, water treatment, pharmaceuticals, agriculture, mobility, defence, etc. However, graphene is relatively hard to produce, thus making it expensive. Research has to be focused on the technology to mass produce greener and cheaper graphene derivatives, i.e., using plasma guns instead of graphite mining and CVD.

Leveraging on abundant raw materials in Malaysia, works have been done in producing graphene or graphite (raw materials for graphene) produced from municipal waste i.e., food waste and agricultural waste, such as palm kernel and POME, as done by Zhonghe Graphene and AMTEC UTM. Agencies such as MIMOS continue to produce innovative products from graphene, and NanoMalaysia acts as the central agency to facilitate the industries involved in graphene and nanomaterials.



SILICA NANOTECHNOLOGY APPLICATIONS

Entrepreneurs and researchers in Malaysia have developed skills in producing silica nanotechnology from available materials in Malaysia, i.e., rice husks, rice straws and kenaf. As a result, they have made high-value products such as aerogels, hydrophobic coatings, thermal insulators, slow-release nutrients, and water treatment membranes.

However, more potential applications can be developed locally, such as release-on-demand drugs and coatings, that can be useful in many sectors, i.e., construction, agriculture, medical/ pharmaceutical, and mobility. In addition, partnerships with advanced technology companies, such as Synmatter LLC in Orlando, can fast-track the local skills and expertise in silica nanotechnology.

ADVANCED COMPOSITE MANUFACTURING

Malaysia could be the regional powerhouse in advanced composite technology. With an abundance of materials, we have developed a complete ecosystem that includes skills and talent, competencies, and infrastructures. However, highly regulated sectors such as aerospace could hinder local materials and technology development, while government intervention and policy may just be the solution for such sectors to ensure sustainability.

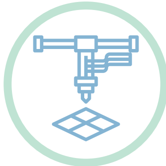
In terms of manufacturing aerospace components, Malaysia plays big with the presence of Tier 1 and Tier 2 companies such as UMW Aerospace, Spirit Aerosystems, Safran, and Honeywell, which manufacture components for OEMs. Then there is AMIC as one of the agencies carrying R&T works in aerospace advanced composite manufacturing technologies that falls under its "Factory of the Future" research initiatives.

ADVANCED RECYCLING

The implementation of circular economy in Malaysia has shifted waste into valuable resources that can be recycled and used as raw materials for different products. In line with this aspiration, recycling plastics is crucial to reduce environmental impact and represents one of the most dynamic areas in the plastics industry today.

Through practice, from the seven types of plastic, it is only practical to recycle three, namely PET, HDPE, and PP, which are 99% recyclable in Malaysia. The remaining types are more challenging to recycle due to the lack of supporting facilities in the country. The current technology of plastic recycling in Malaysia is using mechanical recycling, depolymerisation, and pyrolysis.

Recycling provides opportunities to reduce oil reliance, carbon dioxide emissions, and the quantities of waste requiring disposal. Moving forward, Malaysia needs to move gradually towards recycling high value, high demand and locally unavailable materials such as solar PV panels, rare-earth metals, composites, and end-of-life metals.



METAL 3D PRINTING

3D printing/additive manufacturing is one of the essential components in the Industry 4.0 framework, which also comprises big data, model simulation, cloud technology, augmented reality, Industrial Internet of Things (IIoT), artificial intelligence (AI), autonomous robots, and cybersecurity. This technology will disrupt the conventional centralised parts and equipment supply into distributed and in-situ replacement, which overcomes the supply shortage due to many reasons, whether production, raw material, or logistic limitations.

Automotive and large manufacturing companies will reap the most tangible benefits due to the significant cost savings of digitalising their inventory. Apart from that, the adoption of this technology will provide a shorter time to market as metal 3D printing will be able to reduce the time taken in manufacturing complex parts.

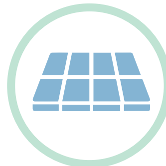
Other sectors that will benefit from this technology include consumer manufacturing, aerospace, and healthcare companies, especially dental healthcare and prosthetics. Local companies such as Dreamedge, Robopreneurs, Dassault Systemes, and IME Technologies offer a 3D printing as-a-service (aaS) business model for companies who do not wish to invest in 3D printing machinery.

ADVANCED BIOPLASTICS

Future projections of a circular economy emphasise that a combination of recycled and bio-based resources will serve as a feedstock for plastic needs. In addition, the development of bioplastic is encouraged by public environmental awareness, government policies (e.g., Malaysia's Roadmap Towards Zero Single-Use Plastics 2018-2030), and global initiatives (e.g., Sustainable Development Goals (SDG)) that gear towards friendly environmental solutions.

However, for that idealistic future to be realised, there must be significant investments in new technologies, including advanced recycling technology and bio-based plastic capacity. The forecast by Lux Research showed that the adoption of conventional and advanced recycling, bio-based plastics, and alternative materials such as metal quantifies the impact of bans and other regulations to predict the future of sustainable plastics.

At the current stage, many local companies are still using non biodegradable plastics for packaging applications. However, in line with the National Policy on Industry 4.0 (Industry 4WRD) initiative towards advanced plastics and sustainability, companies that produce plastics and those that use them in their products need to understand the outlook for sustainable plastics and find alternatives in their strategy.



CERAMIC COMPOSITES

The high resistance of ceramics matrix composites can be tailored for customised purposes and offer energy-efficient, eco-friendly, and lightweight applications to several sectors, including aerospace, ground transportation, and power generation systems. Companies such as Safran, CeramTec, Isolite Ceramic Fibres, and others manufacture parts like engine shrouds, brake pads, building fire insulations, water treatments filters, etc., used by these sectors. Researchers are studying polymer-ceramic composite electrolytes, which can offer ionic conductivity, high mechanical strength, and favourable interfacial contact with electrodes, significantly improving the electrochemical performance of solid-state batteries (SSBs).

RARE EARTH ELEMENTS

Recent studies showed that Malaysia is endowed with large reserves of non-radioactive rare earth elements (REE). Developing the local upstream and expanding the downstream industries will attract FDIs and DDIs, especially in E&E, medical appliances, green technology, energy, automotive, and manufacturing sectors. Major economies like the USA, Europe, and Japan seek to diversify their sources of supply apart from China.

Nuclear Malaysia (ANM) and the Mineral and Geoscience Department (JMG) continuously perform R&D works to improve the industrial processes, particularly in reducing the impact to the environment — smart digital mining, optimal integration, and productivity are recommended as part of Smart Mining or Green Mining. Regulatory bodies such as the Atomic Energy Licensing Board (AELB) should continue to monitor the players in this industry.

Initiating the REE recycling technology and local industry can also be beneficial in the long term in ensuring the sustainability of supplies and countering price manipulation, as done in Canada. But, most importantly, to ensure the safety of the people and the environment in the REE industry, a clear communication plan should be set in place. There will be a loss of great opportunities for Malaysia to excel if this issue is heavily politicised. Currently, Malaysia operates the second largest REE processing plant in the world after China.

ADVANCED MATERIALS TECHNOLOGY ROADMAP

	Graphene Applications	Silica Nanotechnology Applications	Advanced Composite Manufacturing
COMMERCIALLY-READY PROJECTS 2021–2023	• ESD/EMI Compounds • Rubber Compounds and Additives • Anti-corrosion Coatings • Inks for Printed Electronics • Thermal Management Sheets • Lubricants	• Aerogels • Hydrophobic Coatings • Water Treatment and Remediation	• Out of Autoclave (OOA) • Thermoplastic Composite (TPC)
MEDIUM-TERM BUSINESS OPPORTUNITIES 2024–2026	• Anti-bacterial Coatings • Graphene-based Battery • Smart Textiles	• Product Tracking • Advanced Encapsulation for Agriculture	• Resin Transfer Moulding (RTM) and Infusion • 3D Printing
LONG-TERM BUSINESS OPPORTUNITIES 2027–2030	• Computing Solutions • Membranes for Water Treatment • Mechanical Reinforcement Additives for Composites • Polymer Additives • Construction Applications • Heavy Industry Applications • Medical Implants • Superconducting Power Grid	• Drug Delivery • Smart Coatings and Active Delivery of Agrichemicals	• Automated Fibre Placement (AFP) • Automated Tape Laying (ATL)

Advanced Recyling	Metal 3D Printing	Advanced Bioplastics	Ceramic Composites	Rare Earth Elements
• Enhanced Mechanical Recycling of PET and HDPE • Alloys and Metals Recycling • Lead Acid Rejuvenation • Lithium Batteries Recycling	• Aerospace Components • Medical Implants • Moulds and Tooling	• Films and Bags • Food Packaging • 3D Printing • Construction Structures • Hospital Single-use Plastics • Electronic Packaging • Automotive Parts and Panels	• Engine Shrouds, Brake Pads, Thermal Components, Industrial Wear Parts • Ceramic Implants	• Mixed REE Product, Standard Operating Procedure (SOP) for Producing Mixed REE, IP Registration, Techno-feasibility Report • Waste-to-wealth (Fertilisers) • Expanding ODM and OEM for REE Applications
• Pyrolysis of Mixed Plastic Waste • PET Depolymerisation • Solar PV Recycling	• Oil and Gas Components • Wear Parts • Marine and Offshore Components	• Bottles and Rigid Packaging • Medical Appliances • Bio-scaffolds for Protein Productions	• Automotive Wear Parts for Engines • SSB Electrolytes	• REE Product at Demo Lab Scale • SOP for Producing REE at Demo Lab Scale, Mixed REE Products at Lab and Demo Scale, SOP for Modeling and Simulations Registration • Medical, Mobility and Green Energy Related Industries
• Solvent-based Recycling of Mixed Plastic Waste and Multilayer Films • Composites Recycling • Rare Earth Metals Recycling • Permanent Magnets Recycling	• Automotive Components • Home Appliances • Heavy Industry	• Home Appliances • Heavy Industry • Waste-based Plastics • Rolling Stocks • Aerostructures	• Rotating Components for Turbines • Large Sized Automotive Components	• SOP for REE Production at Pilot Scale, REE Products Ready for Commercialisation, MPPP Ready for Commercialisation, Potential Customers/Collaborators/Partners, Establishment of National Rare Earth Extraction Research Centre • Recycling of Products for REE

Figure 5.7: Advanced Materials Technology Roadmap | Source: MIGHT Analysis

CHAPTER

6

MOVING FORWARD

Affordable, reliable and high-performance materials are key enablers for countless transformational technology advancements. However, many material discoveries made in the laboratory today never reach the widespread market deployment stage due to costly development cycles and prolonged timeframe for advanced materials to make it from lab to market. As a result, the progress of advanced materials development is hindered and unable to keep pace with Malaysia's goals towards becoming a high-tech nation.

Availability of capital and incentives for startup companies as the key players in the ecosystem will ensure the sustainability of advanced materials in the country. Funding and incentives should be directed towards R&D, commercialisation, and adoption of these technologies in the manufacturing process, specifically for medical, pharmaceutical, ICT, water, mobility, energy, and food and beverage sectors. Long-term research is vital in addressing current challenges for withstanding or emerging technologies involving water security, health, energy, and food security.

This roadmap addresses the current and emerging challenges faced by the advanced materials industry in order to nurture and promote future innovation. The establishment of centralised bodies such as the National Advanced Materials Consortium (NAMC) and National Advanced Materials Centre of Excellence (NCOE) are proposed as two main priorities outlined for Malaysia to achieve and maintain a sustainable advanced materials ecosystem. NAMC is tasked to govern a multi-disciplinary stakeholder collaboration, industrial issues, and technology updates along with human capital development while vital dissemination of R&D&C&I works and funds for local advanced materials industries will be implemented by NCOE.

The roadmap also presents types of materials that could accelerate the advanced materials industry in Malaysia. The abundant natural resources available in the country can be developed into significant trends with a positive impact on the growth of the Malaysian economy. A game changer programme has been proposed to develop local industries capabilities in producing advanced materials. New approaches enabled by the identified game changer materials are set to partake in pursuing larger market growth for the country. With close monitoring, the implementation of strategies through the game-changers programme in this roadmap will ensure continued investments in the industry, create new technology opportunities and increase values to achieve the nation's goals.

Figure 6.1 highlights the priorities and game-changers that have been identified as crucial for Malaysia to reach its true potential as a high-tech nation through Advanced Materials.

Global technological breakthroughs in the advanced materials industry are stimulating demand for infrastructure, human capital, and technology development. New technology initiatives often require government support, particularly in the early years thus, RM 1.09 billion of co-funding from the Government for 10 years will serve as an impetus to spur the advancement of the advanced materials sector in the country. Under the National Advanced Materials programme, three major government co-funding programmes are indicated in Table 6.1.

NAMC is proposed as the fund's manager to ensure synchronisation of advanced materials R&D&C&I works and to enhance public-private partnerships as well as to oversee the acquisition of strategic technologies. Technology convergence and collaborative platforms for innovation in advanced materials in terms of funding, access, and IP policies can align and power value chains, foster standards, catalyse innovation ecosystems as well as build education, skills, and social capital in Malaysia.

Transformation of Malaysia Towards High-Tech Nation

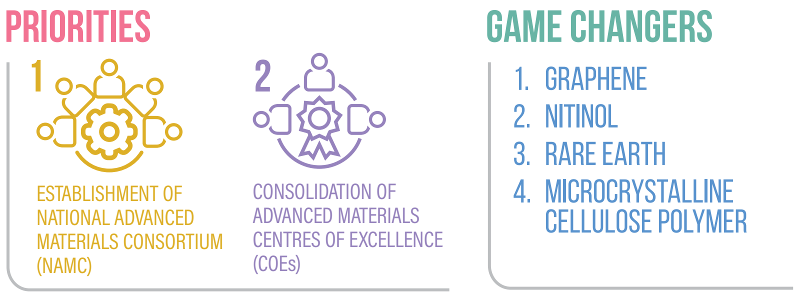


Figure 6.1:
Transformation of Malaysia Towards High-Tech Nation
Source: MIGHT Analysis

National Advanced Materials Programmes

National Advanced Materials Programmes (RM1.09 BILLIONS)

	Government Co-Funding (RM million)	
Expenses	**12MP**	**13MP**
Technology Acquisition Fund	15	15
Advanced Materials Commercialisation Fund	30	30
Game Changer Programmes*	500	500
TOTAL	**545**	**545**

Table 6.1:
National Advanced Materials Programmes
Source: MIGHT Analysis

National Advanced Materials Consortium (NAMC)

NAMC is a consortium co-chaired by the ministry and industry, proposed to monitor the implementation of the National Advanced Materials Technology Roadmap from 2021 until 2030. Reporting directly to the High-Tech Council and chaired by the Minister of MOSTI, it would act as an advisor to the government through policy and regulation, manufacturing industry and technology development, supply chain and market development, finance and business models as well as human capital development. Figure 6.2 illustrates the proposed advanced materials consortium structure.

Structure of the Proposed Advanced Materials Consortium

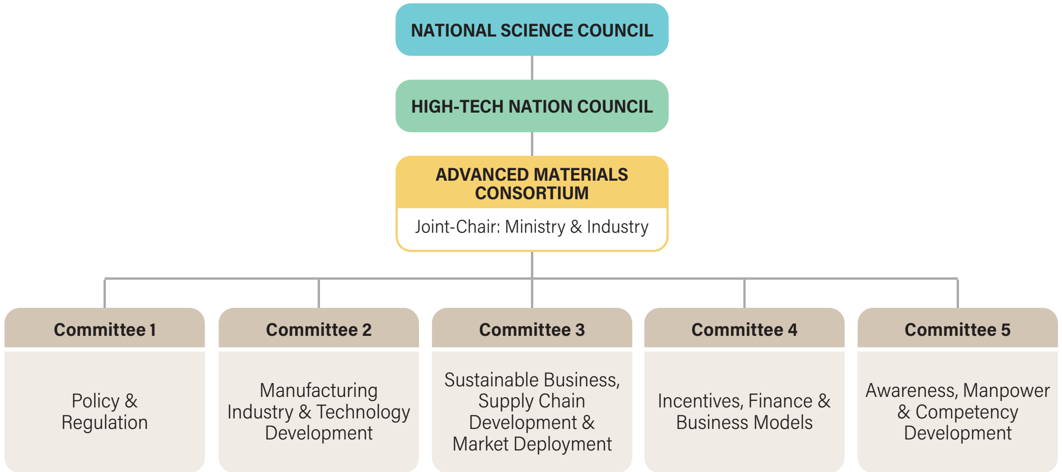


Figure 6.2:
Structure of the Proposed Advanced Materials Consortium
Source: MIGHT Analysis

This consortium will be tasked to provide industry guidance, business facilitation and recommendations on strategic approaches to enhance the growth of the country's advanced materials industry. NAMC will also coordinate the implementation of the strategies, monitor their progress and synchronise R&D&C&I works covering various institutions, including Government ministries and agencies along with educational and research institutions. Follow-up studies on the effectiveness or any arising issues under the implementation of the Roadmap will be carried out by NAMC which will, if necessary, recommend actions to improve existing strategies. Figure 6.3 describes the objectives, functions, and governance scope of the proposed National Advanced Materials Consortium.

NAMC will be materialised through an industry-wide four-step approach known as the Plan-Do-Check-Act (PDCA) approach or the Deming cycle. This industry-wide four-step approach is simple and effective for continuous improvement and is part of the quality control and operation process. (Figure 6.4)

Additionally, NAMC will serve as a hub of contact for business facilitation, creating networks and engagement of early adopters and new players through an online digital platform, referred to as the industrial databank. This easy-to-access industrial databank will incorporate industry directories and product information that is essential for industry players.

This roadmap proposes the Government allocate a RM1.5 million budget per annum for NAMC to spearhead these initiatives. This allocation will be utilised to organise business facilitation, impart industry intelligence and produce Roadmap progress and operating expenditure (OPEX) reports.

Objectives, Functions and Governance of the Proposed Advanced Materials Consortium

1 OBJECTIVES

i. To monitor the implementation of the National Advanced Materials Technology Roadmap from 2021 until 2030; and
ii. To act as an advisor to the government on policy and governance, industrial frameworks, regulations, R&D&C&I, investment and financing, human capital development, technology, and market and supply chain under the National Advanced Materials Technology Roadmap to ensure sustainable development of the industry.

2 FUNCTIONS

i. This consortium will report directly to the High-Tech Nation Council which is chaired by the Minister of MOSTI.
ii. Provide guidance, advisory services, business facilitation, and recommendations on strategic approaches to further enhance the growth of the country's advanced materials industry;
iii. Coordinate implementation of initiatives under the Roadmap and synchronise R&D&C&I works covering various institutions including Government ministries and agencies, educational and research institutions as well as the industry;
iv. Monitor the implementation of the Roadmap, including the status of industry progress;
v. Conduct follow-up studies on the effectiveness of initiatives and strategies including arising issues under the implementation of the Roadmap; and
vi. Take follow-up actions to improve existing strategies, if necessary.

3 GOVERNANCE

The consortium should be joint-chaired by MOSTI and relevant industries. This is to foster industry-driven efforts working hand-in-hand with the government in achieving food security, water security, energy security, health security, and sovereignty security.

Figure 6.3: Objective, Function and Governance of the Proposed Advanced Materials Consortium
Source: MIGHT Analysis

Plan-Do-Check-Act (PDCA)

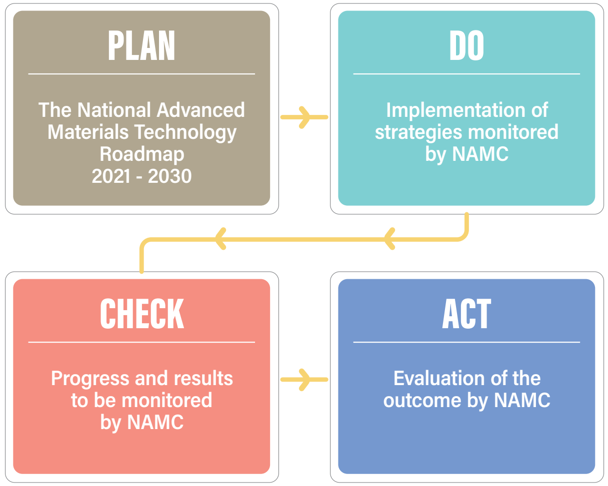


Figure 6.4: Plan-Do-Check-Act (PDCA)
Source: MIGHT Analysis

National Advanced Materials Centres of Excellence (NCOE)

Identifying new scientific innovations, opportunities, effective utilisation of new materials, and a platform to discuss new challenges in achieving accelerated materials research is vital for the industry. The consolidation of the Advanced Materials Centres of Excellence under one umbrella known as the National COE (NCOE) will be the cornerstone in providing valuable resources to support local industries through governance and directory, list of experts, workforces, R&D&C&I, shared facilities as well as market assistance. NAMC's Committee 2, the Manufacturing Industry and Technology Development, is proposed to oversee this consolidation which will enable Malaysia to focus on advanced materials solutions towards issues in 10-10 MySTIE socio-economic drivers.

At present, there are 46 COEs involved in advanced materials or advanced materials related technology in the country — from public and private higher learning and research institutions. Under the NCOE framework, all physical and digital infrastructures related to advanced materials will be fully integrated. By leveraging on the existing physical centres, infrastructure for material development, analysis, sustainable production techniques, testing, quality verification and certification, NCOE aids the local industry in discovering and producing reliable and economically viable materials.

Additionally, NCOE will host a digital material informatics platform that utilises cloud data, AI and machine learning technology to enable rapid predictions purely based on past data. These technologies allow researchers and industry players to assess useful information in determining material properties that are hard to measure or compute using traditional methods. The time taken for R&D processes are reduced greatly, benefiting stakeholders by allowing them to develop new materials faster. Local industry innovation capabilities and competitiveness can be amplified by this digital platform as it provides a cost-effective solution to explore, manufacture and deploy advanced materials more promptly and at a lesser cost. This integration of both physical and digital infrastructure in NCOE will encourage Malaysia to swiftly adopt these technologies through technology acquisitions or by expanding local capabilities with strategic partnerships (Figure 6.5).

Championed by countries such as the US, China and Japan, this emerging concept of material informatics is beginning to take shape within materials science. International companies and start-ups such as Nutonian, Citrine Informatics, Lumiant, Uncountable, and IBM's Accelerated Materials Discovery are already offering material informatics platforms to clients such as 3M, Showa Denko, BASF, and Michelin.

Having big data as one of the base technologies, unyielding commitment from public and private research organisations is a must to ensure the platform works at its best, adopting 4IR technologies and transforming the country into a high technology nation. This roadmap proposes the Government allocates **RM6 million per annum** for technology acquisition, research facilities, resources, and maintenance. Funds are to be given to NAMC as the grant distributor.

The Proposed Physical & Digital Infrastructure in NCOE

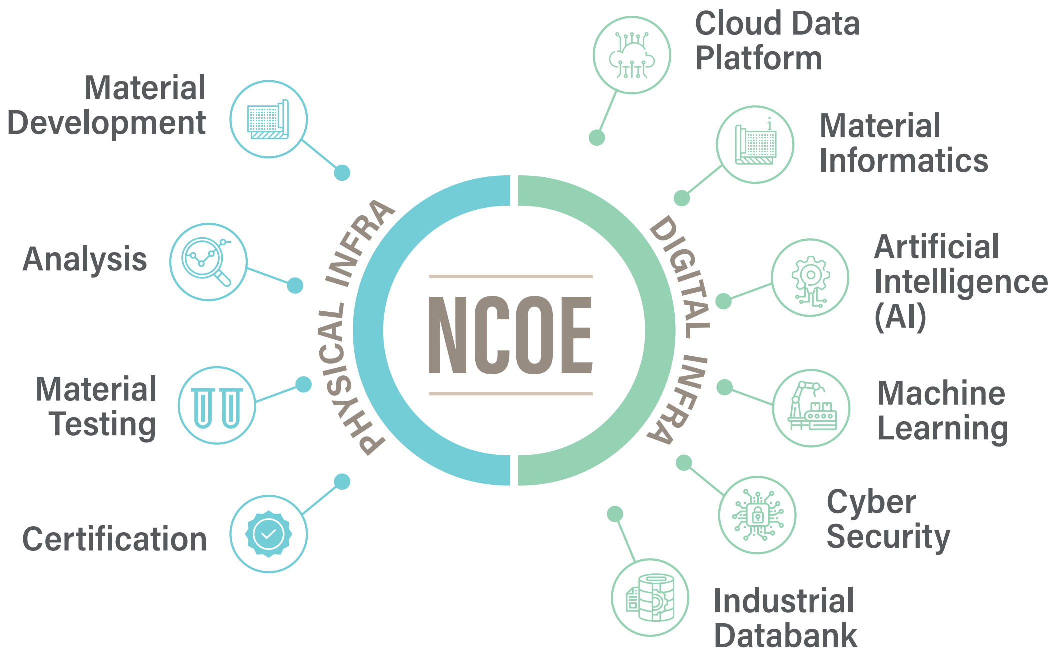


Figure 6.5:
The Proposed Physical and Digital Infrastructure in NCOE
Source: MIGHT Analysis

National Advanced Materials Programmes

The National Advanced Materials Programmes is proposed specifically to upsurge the local industry's capabilities in producing advanced materials, open new avenues for economic growth and create innovative new paths to support the sustainability and innovation capabilities of local industries. Ownership of IPs, manufacturing capability, raw materials availability, market readiness and cross-cutting applications of these advanced materials are among the determining factors considered for the four game-changing materials selection. In this roadmap, this programme will be initiated with four types of advanced materials with the highest potential future uses, which are graphene, nitinol, rare earth, and microcrystalline cellulose (MCC) polymers.

While more uses of advanced materials are found in the laboratory, the industry is faced with the challenge of translating them into viable products for market consumption. The two key challenges are scaling up the manufacturing process and improving the efficiency of production. Synergy in multi-stakeholders participation will reduce the import dependency of advanced materials in crucial economic sectors.

As technological advances are made and shared in the future, this programme expands the potential market for relevant industry players as well as for other types of advanced materials stated in this roadmap, such as advanced ceramics, lightweight alloys, nano-silica, and others.

Game Changer 1:
Graphene

Graphene is widely known as the world's thinnest, strongest, most conductive material and is able to revolutionise countless areas in construction, manufacturing, consumer products, and more. Incredibly strong, thermally conductive, and almost fully inelastic, the properties of graphene are such that numerous industries can benefit from it.

Natural graphite, a mineral composed of many layers of graphene, is not available in Malaysia but local companies could utilise materials that can be found in the country, such as biomass from oil palm kernel shells, to produce graphene. Through NCOE and material informatics, innovators will be able to share their expertise and solutions to transform locally-sourced materials into high-quality artificial graphite prior to producing graphene. A strong partnership between RUIs and industries is a must to enhance the success rate of this technology commercialisation.

The economies of scale for graphene price depends on which market the industry players wish to penetrate. For example, replacement of carbon black in the manufacturing industry requires 25 weight% loading of the carbon black material, in comparison to graphene which only requires 1.5 weight% loading for the same or superior performance.

Although the price of the lowest quality carbon black is only $1.50/kg compared to the higher price of graphene at around $25/kg, manufacturers will need higher quantities of carbon black compared to graphene. However, there is more to the comparison than just pricing, where graphene possesses sustainability advantages over other materials. As a product, graphene produces a substantially lower carbon footprint compared to carbon black. Table 6.2 lists the economies of scale for each market segment in graphene industrial applications.

In this programme, Malaysia is projected to produce 200,000 metric tonnes of artificial graphite and 500 metric tonnes of graphene nanoplatelets (GNP) per annum by 2030. Malaysia should focus on developing capabilities to produce single-layer graphene (SLG) which is higher in value compared to other types of graphene. This initiative requires an investment of RM2 billion, with forecasted revenues to reach RM10 billion per annum while creating 1,500 employment opportunities. (Figure 6.6)

Economies of Scale for Graphene Market Segments

No	Market Segment	Industrial Applications	Economies of Scale Price (USD)
1	Carbon black	Tyres, rubbers, plastics, inks, coatings, and construction.	$10-25/kg
2	Activated carbon	Methane and hydrogen storage, air and gas purification, water treatment, odour treatment, medical and pharmaceutical, catalyst, solvent recovery, and food processing.	$10-15/kg
3	Graphite	Steel, foundries and refractories, lubricants, brushes for electrical motors, electrodes, automotive parts, and pencils.	$15-20/kg
4	MWNT (low quality)	Additives for plastics, rubbers, composites, and textiles.	$30-40/kg
5	MWNT (highly purified)	Electrodes, transistors and wirings, sensors, drug delivery, biomedical imaging, tissue engineering, transparent conductive films, and conductive polymers.	$100-1,000/kg
6	SWNT	Energy storage, elastomer applications, electronic thermal coatings, aerospace coatings, semiconductors, and sensors.	$100,000/kg

Table 6.2: Economies of scale for graphene market segments

Investment, Revenue and New Employment Positions Target for Graphene by Year 2030

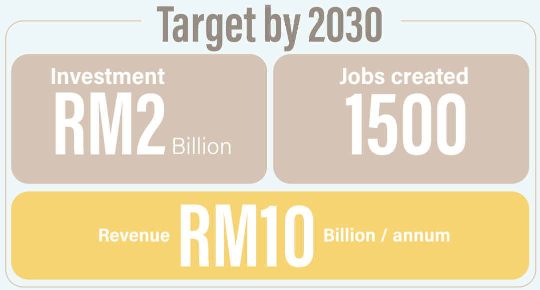


Figure 6.6: Investment, Revenue and New Employment Positions Target for Graphene by Year 2030 Source: MIGHT Analysis

Graphene batteries. Graphene can improve battery attributes to achieve morphological optimisation and performance.

Game Changer 2:
Nitinol-based Alloys

Nickel-titanium alloy (Nitinol) is one of the most promising metal materials to be found in the field of shape memory alloys (SMAs) and functional materials. The composition of both the Nickel and Titanium can be manufactured to exhibit two unique properties such as the shape memory effect (SME), and super-elasticity (SE), or pseudo-elasticity (PE) depending on the application. Nitinol is particularly useful and offers many advantages for medical device manufacturers because of its thermal memory which provides flexibility, and the necessary strength for many applications.

Many recent metal-processing technologies seek the most cost-effective and reliable techniques in manufacturing Nitinol. Metal injection moulding (MIM) is among the popular techniques that can enhance Nitinol properties as it reduces more than 60% of the average production cost without compromising the quality of the products. This process allows the production of near-net-shape components without the occurrence of rapid tool wear as found in the case of conventional machining operations. With optimised manufacturing conditions — including feedstock preparation, injection parameters, and sintering conditions — it could become a waste-free process. Metal injection moulding (MIM) is applied for the production of shape memory parts using premix Nitinol powders with different nickel contents as starting materials according to applications/products properties requirements.

Nitinol will continue to be an important material in various industries, particularly due to its excellent properties in wear resistance, corrosion resistance, high damping capacity, and biocompatibility. High-potential features of Nitinol have caught the interest of several international corporations such as Johnson & Johnson, NASA, Roll-Royce, Stryker, JAXA, and Lockheed Martin.

By 2030, Malaysia aims to become one of the major global producers of Nitinol by incentivising local manufacturers to develop devices such as medical and dental implants with world-class quality. This initiative requires an investment of RM77 million, with forecasted revenues of RM192 million per annum and an expected 500 employment opportunities created. (Figure 6.7)

Investment, Revenue and New Employment Positions Target for Nitinol by Year 2030

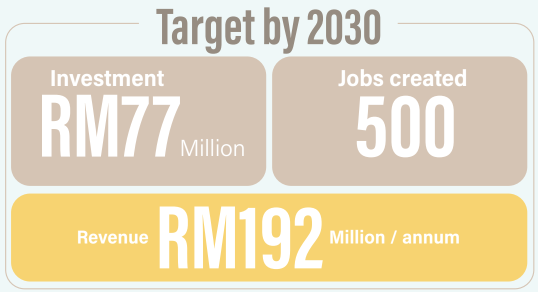


Figure 6.7:
Investment, Revenue and New Employment Positions Target for Nitinol by Year 2030
Source: MIGHT Analysis

Experts are currently looking into developing nickel-titanium alloy nanoparticles for electrical and thermal sensors in devices for aerospace industry.

Game Changer 3:
Rare Earth

A significant amount of niche rare earth elements is gaining ground in several Malaysian states, especially in Kelantan, Kedah, and Perak providing opportunity for the local advanced materials industry to expand upstream and downstream in Malaysia, through the experience and expertise acquired from LYNAS.

The global rare earth metals market size was estimated at $5 billion in 2020 and is expected to reach $5.6 billion in 2021. Global rare earth elements production amounted to around 210,000 metric tons of rare earth oxides (REO) in 2019 and China alone produced roughly 60% of that total amount. China, Australia, and Malaysia are the key countries involved in rare earth mining and processing activities.

Demand for electric vehicles and praseodymium/neodymium (NdPr) based permanent magnets across the globe have been fuelling the rare earth materials market considerably — indicating a preference for high-purity customised products that yield high application efficiency. Electric and hybrid motor vehicle development, as well as wind turbine manufacturing growth, is contributing to the surge of rare earth materials used in the manufacturing processes.

The rise in permanent magnet, catalysts, and metallurgical industry applications is expected to contribute to substantial market growth. Environmental regulations in developed countries have been pressing the need for zero-emission vehicles which call for the use of rare earth materials. In specific cases, the annual growth of prices has been very high; for instance, neodymium prices have risen substantially in 2018 (over 2017 prices) due to significant demand for magnet applications.

As the rare earth materials market is heavily monopolised by China, which causes uncertainties in supply and price, end users around the world have been seeking rare earth alternatives. Substitutes (e.g., cobalt) are being researched for permanent magnet applications in the field of microelectronics. Over the last decade, massive infrastructural development activities have taken place in developing economies, such as China, India, Brazil, and South East Asia.

Lynas Malaysia is one of the largest and most modern rare earth separation plants in the world. It is designed to treat Mount Weld's concentrate, and produce separated REO products for sale to customers in locations including Japan, Europe, China, and North America. Commissioned in late 2012, Lynas Malaysia is capable of producing 22,000 tonnes per annum of separated REO products, and is the largest producer outside China, which offers Malaysia a competitive advantage in the region. The most valuable product produced at the plant presently is praseodymium/neodymium (NdPr). The plant has 1,016 employees, where 97% of them are locals and 90% of them are highly skilled employees.

According to the report from the National Mineral Industry Transformation Plan 2021-2030 (TIM 2021-2030), Malaysia has an untapped 18.18 million tonnes of non-radioactive rare earth elements (NR-REE) reserves, with a value of RM747.2 billion. KeTSA is also expecting to launch the standard operating procedures for non-radioactive rare earth elements (NR-REE) to ensure sustainable mining activities. Investors' confidence and investment flow needed to support economic recovery can be rebuilt with supportive policies and guidelines by the Government through accelerating market activities and investment pipelines. The rare earth industries in Malaysia are expected to attract RM100 billion of investment and provide 4,000 jobs by 2030. (Figure 6.8)

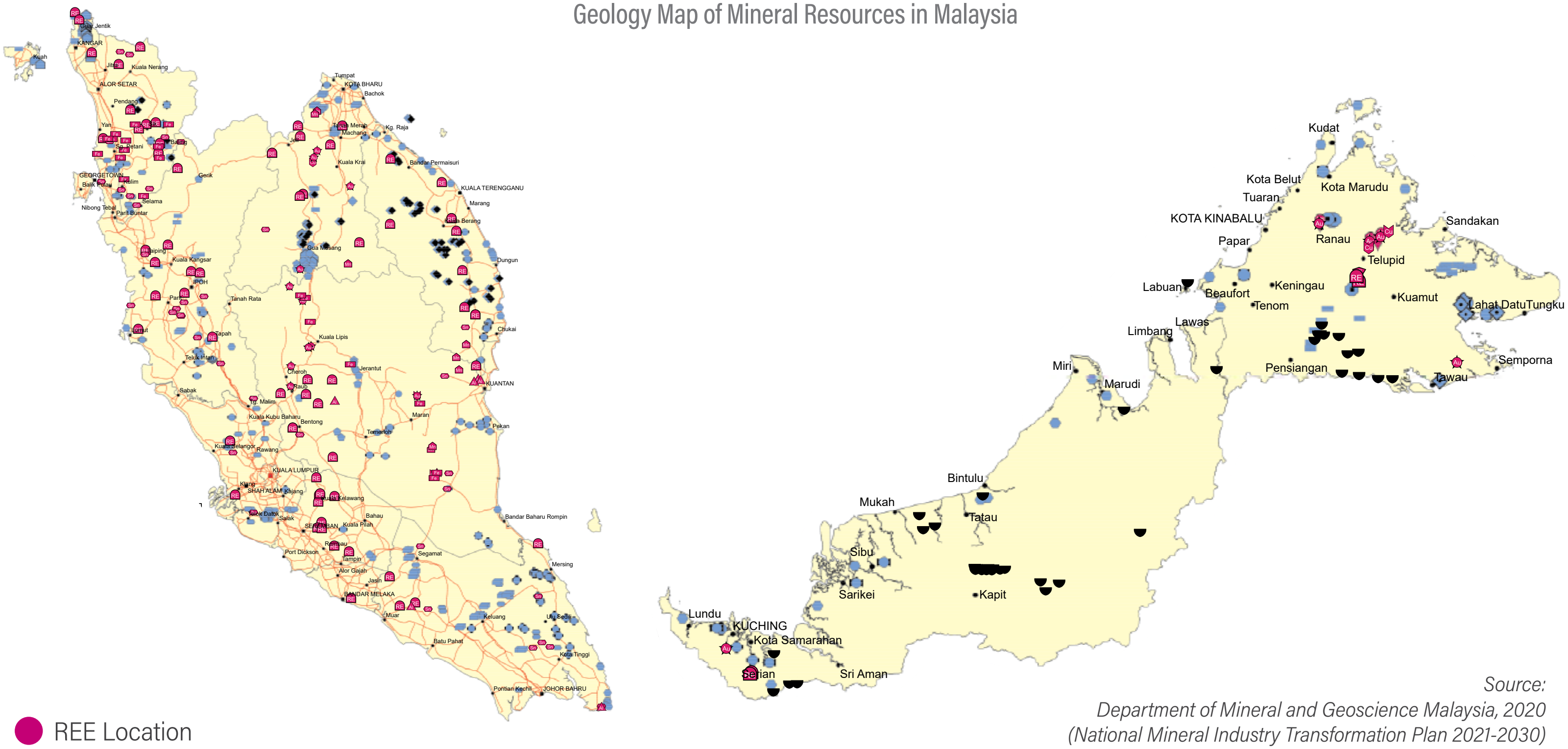
Investment, Revenue and New Employment Positions Target for Rare Earth by Year 2030

Target by 2030

Investment RM100 Billion	**Jobs created** 4,000
Revenue RM747.2 Billion	**REE Reserve** 18.18 Mil Metric tons

Figure 6.8: Investment, Revenue and New Employment Positions Target for Rare Earth by Year 2030 Source: MIGHT Analysis

Geology Map of Mineral Resources in Malaysia



Source: Department of Mineral and Geoscience Malaysia, 2020 (National Mineral Industry Transformation Plan 2021-2030)

Game Changer 4:
Microcrystalline Cellulose (MCC) Polymer

Microcrystalline cellulose (MCC) is a pure partially depolymerized cellulose synthesized from an alpha-cellulose precursor with hydrolysis by mineral acids, usually in form of pulp from a fibrous plant. It is an important additional ingredient in pharmaceutical, food, cosmetics, and structural composites. According to Expert Market Research, the Global Biodegradable Medical Packaging Market value is estimated to increase to $197.4 Million, at a compound annual growth rate (CAGR) of 11% during the forecast period of 2018 to 2026.

The increasing demand from the healthcare industry for environmentally friendly and sustainable products fosters market growth and drives industry players to produce biodegradable medical plastics using raw materials obtained from plants. Additionally, the market is also being driven by the enforcement of strict laws and prohibitions against the use of plastic bags and other plastic products.

In Malaysia, local biomass resources such as kenaf, oil palm waste, agriculture waste, and others are bounteous. Surplus production of around 2.5 million tonnes of paddy straw will need to be set afire each year if the biomass waste is not utilised into other forms of products or materials by the local industry. This game changer programme aims to assist industry players in taking advantage of local resources which will also put a halt to the open burning practice carried out by farmers after the harvesting season.

A by-product of MCC is widely used in various sectors such as electronic packaging, hospital single-use products, bioplastics as well as, food and beverage packaging. Malaysia needs to further stimulate this programme as it will help in decreasing dependency on fuel-based plastics, improve recyclability and reduce landfill waste. This initiative is expected to attract RM75 million of investment and will generate RM45 million in revenue per annum with 500 employment opportunities by 2030. (Figure 6.9)

Investment, Revenue and New Employment Positions Target for MCC Polymer by Year 2030

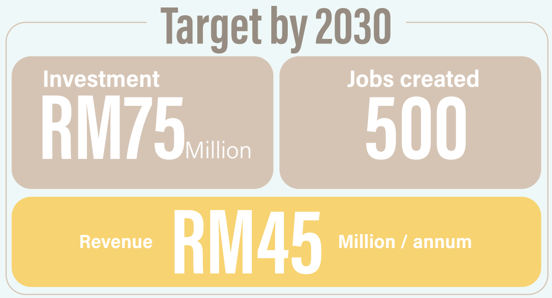


Figure 6.9:
Investment, Revenue and New Employment Positions Target for MCC Polymer by Year 2030
Source: MIGHT Analysis

Degradable polymers are increasingly being used in tissue engineering. They can be used as an implant and do not require a second surgery for removal.

Conclusion

Advanced materials technology is often considered the crux for several technology innovations that turn improbable concepts into reality across the chemical and materials industry. The National Advanced Materials Technology Roadmap 2021-2030 outlines a distinct direction in manoeuvring future innovations. It is a guide on how to utilise and market innovative combinations of materials, process technologies, partnerships, and collaborations across a variety of industries, leveraging points along the value chain to create and capture value in an evolving landscape.

The National Advanced Materials Technology Roadmap 2021-2030 has laid out key initiatives based on the strategies adopted to be implemented over the next ten years. This roadmap aligns with existing policies such as the National Policy on Science, Technology and Innovation (NPSTI) 2021-2030, National Policy on Industry 4.0 (Industry 4WRD), and National Fourth Industrial Revolution (4IR) Policy. These frameworks position advanced materials among the main drivers for industrial transformation.

The commitment of all stakeholders relevant to the roadmap is critical to the success of this roadmap's implementation. With the right attitude, entrepreneurial instinct and political will, the advanced materials technology industry will be a robust high-technology sector delivering vital economic contributions to Malaysia by 2030.

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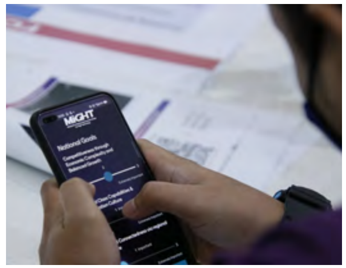
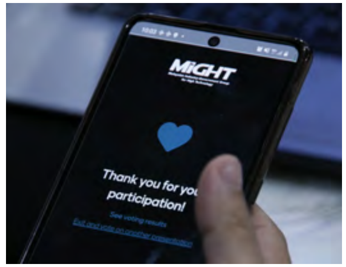
STAKEHOLDERS ENGAGEMENT




Competitiveness through Economic Complexity and Balanced Growth
World Class Capabilities & Innovation Culture
Global Connectedness via regional Centre
Important
Extremely Important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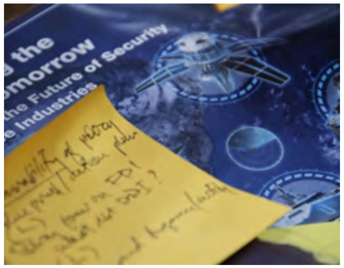
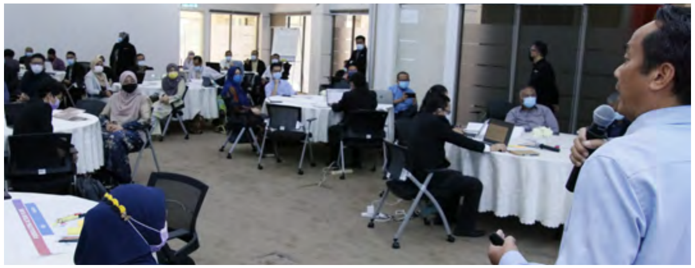
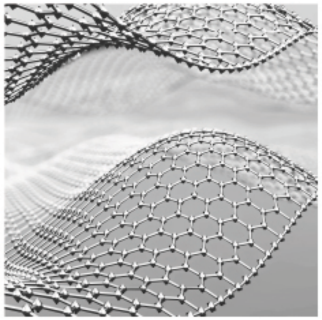
participation!





INSIDE
BACK COVER



National Advanced Materials Technology Roadmap
2021-2030

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