Technology Strategy Board
Driving Innovation



Advanced Materials

Key Technology Area

2008-2011

The vision of the Technology Strategy Board is for the UK to be a global leader in innovation and a magnet for innovative businesses, where technology is applied rapidly, effectively and sustainably to create wealth and enhance quality of life.

Our three-year strategy for 2008-2011 is to drive innovation by **connecting** and **catalysing**. To achieve this we are focusing on three themes: challenge-led innovation, technology-inspired innovation and the innovation climate. For more information on the overall strategy see **www.innovateuk.org.**

We have identified a number of key application areas and key technology areas on which to focus, and for which we are developing specific area strategies.

This document presents the strategy for the key technology area of **Advanced Materials.**

The Technology Strategy Board would like to thank the materials community for their help in preparing this strategy document.

Foreword

The Technology Strategy Board is a new organisation with a new vision and ambition to make the UK a global leader in innovation. Our job is to ensure that the UK is in the forefront of innovation enabled by technology.

Our task at the Technology Strategy Board is to "Connect and Catalyse". As part of our challenge-led approach to innovation we treat societal and economic challenges of the future not just as threats but as opportunities for innovative solutions that enhance the quality of life and increase wealth.

The world is changing. Globalisation, digital communications and the growth of emerging economies present profound challenges to UK business sectors. Yet where there are challenges there are also opportunities. Open access to global supply networks and emerging markets is easier than ever before; the highly skilled UK workforce, world class science base and open-market philosophy also put us in a strong position.

UK materials businesses span a broad value chain from primary production and processing, through product design and fabrication, to end-of-life recycling. The UK is world class in many of these activities and we must exploit this fact through the manufacture of high value products and processes that focus on current and future global opportunities. For instance, the UK is now at the forefront of developing low carbon technologies that address climate change; this is reflected in activities already underway at the Technology Strategy Board such as our Innovation Platforms in Low Carbon Vehicles and Low Impact Buildings, both of which have a strong materials strand.

The Advanced Materials strategy presented in this document identifies those technology themes which will help UK materials businesses to collaborate and make the transition towards high value activities. I welcome its technology-inspired approach focused through key challenge areas and emphasis on the development of high value-added products and processes. This will create wealth through exploitation in multiple market sectors where the UK has recognised strengths.

This Advanced Materials strategy complements our High Value Manufacturing strategy and will provide the foundations for our work in this area in the 2008-2011 period. We are looking forward to working in partnership with key players in innovative materials businesses and contributing to wealth creation in the UK.

Iain Gray
Chief Executive, Technology Strategy Board

Innovative advanced materials technologies make a direct and positive impact on economic growth, the environment and quality of life, via improved processes and products, throughout their life cycle.

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Executive summary

Businesses in the UK that produce, process, fabricate and recycle materials have an annual turnover of around £170 billion. They contribute about 15% of UK GDP, with a gross value-added (GVA) of around £60 billion, and form an important element in the supply chain of many high value manufacturing businesses. This strategy outlines ways in which the materials sector can continue to innovate and grow, further enhancing its contribution to solving key societal problems and enhancing national wealth creation.

The strategy presents a holistic approach for innovative advanced materials development and application, which aims to provide continuity and commitment in key areas and to support the UK as a provider of high value-added products, processes and services. It aligns with the higher level strategy and investment criteria of the Technology Strategy Board and complements other individual Technology Strategy Board Key Technology and Application Area strategies.

Its scope encompasses materials, and their associated process technologies, with the potential to be exploited in high value-added products. These are considered within four broad major categories: structural, functional, multifunctional and bio-materials, together with important cross-cutting areas; including nanomaterials, modelling, design, metrology and standards, process technologies and manufacturing.

Three priority areas, based on an analysis of common market sector drivers, are identified as channels for technology-inspired activities leading to high added-value products and processes with exploitation potential via multiple strong UK market sectors, (Figure 1).

- **Energy**
  - secure, clean and affordable energy supply, distribution and usage
- **Sustainability**
  - focused on transport, construction and the 'reduce, reuse and recycle' agenda, including packaging
- **High Value Markets**
  - including technologies for Healthcare, the Creative Industries, and Defence and Security.

The need is recognised for continued investment in underpinning and emerging generic materials technology development, and exciting thrust areas are identified which are anticipated to have a major impact in the key challenge areas. These are listed in Figure 2, together with a broad mapping of their likely major impact potential. The UK has recognised capability strengths within each of these areas, in both the Science and Technology (S&T) base and industry.

Figure 1 – A technology-inspired strategy focused through key challenge areas

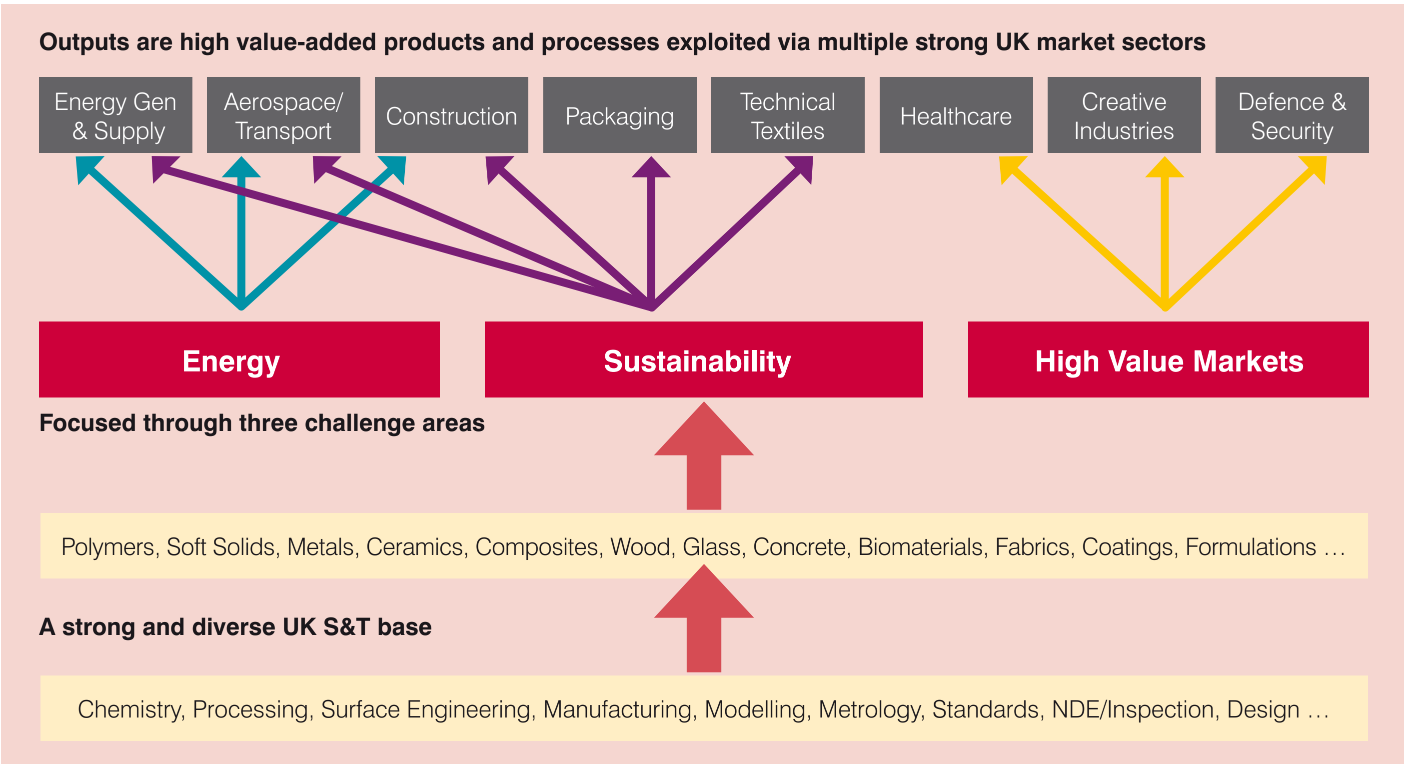


Figure 2 – Technology thrusts in each of the key challenge areas

	Energy	Sustainability	High Value Markets
Lightweight materials and structures, including composites and hybrids	x	x	x
Materials to withstand more aggressive environments (e.g. high temperature, corrosive, erosive)	x	x	x
Electronic and optical functional materials	x		x
Smart and multifunctional materials, devices and structures	x	x	x
Surface engineering and coating technologies	x	x	x
Particulate engineering; near-net shape manufacturing	x	x	
Fibre and textile-based technologies	x		x
Bioresorbable, bioactive and biocompatible materials			x
Natural and bio-based materials		x	x
Joining technologies	x	x	x
Materials for portable power sources (batteries/fuel cells)	x		x
Nanomaterials	x	x	x
Materials with reduced environmental impact through life		x	
Materials designed for reuse/recycle/remanufacture		x	
NDE/SHM/condition monitoring	x	x	x
Predictive modelling through the full life cycle, including lifetime prediction	x	x	x

Strong stakeholder co-ordination and multidisciplinary collaboration is proposed, in order to facilitate the effective delivery of the strategy.

In the period 2008-2011, the Technology Strategy Board will:

- invest in materials technologies which address the key challenges of energy and the environment;
- invest in materials technologies focused on the 'reduce, reuse and recycle' sustainability agenda;
- continue to invest in materials for high value markets, including healthcare, the creative industries and defence and security;
- work with other government and industry stakeholders to identify opportunities for joint or aligned activities; including generic underpinning R&D and proof-of-concept studies;
- work with other stakeholders in respect of metrology and standards development;
- support an innovation culture via, for example, the use of Knowledge Transfer Partnerships (KTP) and Knowledge Transfer Networks (KTN); and
- seek, with other stakeholders, to identify European and other international strategic alignment and financial gearing opportunities in support of improved UK competitiveness and inward investment.

1. Background

1.1 Strategic context

This document sets out a strategy for Advanced Materials, which continues to build upon the strong foundations of the UK 'Strategy for Materials', published by the Materials Innovation and Growth Team (IGT), in March 2006 [1]. It incorporates developments in the strategy and priorities of the Technology Strategy Board since that time and, in particular, takes account of the recommendations of the recent Sainsbury [2] and Council for Science and Technology Reports [3].

Key issues to be addressed in order to realise the vision set out in the 2006 IGT report, of "...Britain continuing to be one of the foremost advanced technological societies in which world-class materials expertise underpins sustainable growth...", were identified as:

- **Resources**
  uncertainties in the availability of energy and raw materials.
- **Globalisation**
  threat from low-cost manufacturing in emerging countries; opportunities in emerging markets.
- **Sustainability**
  energy efficiency, the low carbon economy, recycling, reuse and ecodesign.
- **Innovation**
  making best use of the R&D base, bringing more value-added products to market, faster than the competition; enhancing existing materials through design.

Specific actions to meet these challenges were identified as the acceleration of innovation; the transfer of knowledge; awareness raising; improvement of skills and knowledge; and building a better environment.

Each of these challenges and associated areas of action are strongly aligned with the overall strategic intent of the Technology Strategy Board and are embodied within its current activities in the Advanced Materials and related areas. This includes the Materials Knowledge Transfer Network (KTN) [4], working in conjunction with MatUK [5]; the representative body for the UK materials community, established following a key recommendation of the 2006 IGT report.

1.2 Materials context

Advanced Materials, defined here as materials, and their associated process technologies, with the potential to be exploited in high value-added products, is both a multidisciplinary area within itself (including, for example, physics, chemistry, applied mathematics) and cross-cutting over both technology areas (e.g. electronics and photonics, biosciences) and market sectors (e.g. energy, transport, healthcare, packaging). Consequently, defining a core strategy for advanced materials technology is complex: it must take into account, and be consistent with, the major drivers and strategies of these related areas. It must also take into account a range of Technology Readiness Levels (TRL) [6] and identify appropriate mechanisms to deal with these.

The UK materials sector is both large and diverse, with a large number of major stakeholders, including:

- Industry, including SMEs
- Academia and RTOs
- Technology Strategy Board
- Government Departments e.g. DIUS, BERR, MOD
- Regional Development Agencies (RDA) and Devolved Administrations (DA)
- Research Councils (RCs), primarily EPSRC
- National Measurement Institutes (NMI)
- Professional Bodies, primarily IOM[3].

It encompasses the full life cycle; from materials extraction, primary production, process development and materials characterisation, through product fabrication, testing and use, to end-of-life waste management and recycling. Supporting activities include research, design and development, together with skills and standards development.

There are also strong crossovers with the chemistry sector in respect of, for example, soft solids and formulations, and the role of upstream chemistry in the design and manufacture of materials.

Given their breadth of technology content and market channels, materials businesses in the UK have the potential to be highly fragmented. In practice, the work of KTNs and others in this area have helped to stimulate a cohesive business sector.

The following sections address these issues, leading to a holistic strategy for innovative advanced materials development and application which aims to provide continuity and commitment in key areas and to support UK business as a provider of high value-added products, processes and services.

2. Technology overview

Advanced Materials can be subdivided conveniently into four broad major categories [7]:

- Structural
- Functional
- Multifunctional
- Biomaterials.

together with important cross-cutting and underpinning themes:

- Nanomaterials [8]
- Modelling
- Design
- Metrology and Standards
- Process Technologies
- Manufacturing [9].

In particular, a number of individual technology areas can be identified which have broad material, product and market applicability and represent specific technological thrust areas. These include:

- lightweight materials and structures, including composites and hybrids;
- materials to withstand more aggressive environments (e.g. high temperature, corrosive, erosive);
- electronic and optical functional materials;
- smart and multifunctional materials, devices and structures;
- surface engineering and coating technologies;
- particulate engineering; near-net shape manufacturing;
- fibre and textile-based technologies;
- bioresorbable, bioactive and biocompatible materials;
- natural and bio-based materials;
- joining technologies;
- materials for portable power sources (batteries/fuel cells);
- materials with reduced environmental impact through life;
- materials designed for reuse/recycle/remanufacture;
- NDE/SHM/condition monitoring; and
- predictive modelling through the full life cycle, including lifetime prediction.

The UK has capability and recognised strengths across all of these categories, themes and technology areas, in both academia and industry. More-detailed descriptions are included at Appendix 1.

The Advanced Materials area also encompasses technologies over the entire Technology Readiness Level (TRL) spectrum, from the conceptual development stage of, for example, nature-inspired (biomimetic) materials, to the everyday use of metal, plastic, ceramic and bio-based products. It represents an underpinning technology platform, with many crossovers into other technical areas and with the potential to address challenges across a broad applications landscape.

Figure 3 shows a mapping of each of the primary materials classes against current Technology Strategy Board Key Technology Areas (KTA), Key Application Areas (KAA) and Innovation Platforms (IP), demonstrating the strong and pervasive impact of Advanced Materials technologies.

Figure 3 – Advanced materials is a pervasive technology

	Structural	Functional	Multifunctional	Biomaterials
High Value Manufacturing	Machine tools, advanced materials processing	Sensors, NDE	Surface engineering	Surface engineering
Biosciences and Medicines and Healthcare	Implants (hip, knee, dental)	Sensors, electrodes, power sources	See Biomaterials	Bioactive/biocompatible materials, drug delivery, wound dressings, tissue scaffolds, anti-microbial materials and surfaces
Electronics, Photonics and Electrical Systems	Electrical machine components	Sensors, actuators, super-conductors, displays, magnetic materials, optical materials, organic (plastic) electronics, nano-structures, quantum structures, quantum computing	Structural magnets, smart devices, flexible devices, pervasive computing, integrated systems	DNA computing, biomimetics, bio-interfaces
Energy Generation and Supply	Materials for generation, transmission and storage – boilers, turbines, pipelines, pressure vessels, composite wind turbine blades, high temperature materials	Photovoltaics, superconductors, fuel cell and battery materials, nanostructured carbons, membranes, filters	Biomimetic materials, sensors and structural health monitoring, catalysts, self-repair and smart materials, power harvesting, insulation, packaging	Anti-corrosion biofilms
Environmental Sustainability	Bio-based materials and composites	Sensors	Biodegradable materials, recyclable materials, smart packaging	See Multifunctional
Creative Industries	Textiles	Sensors, actuators, power sources, displays, printing	Smart textiles, power harvesting, biomimetic materials	
Transport – including Aerospace	Lightweight materials, HT materials, corrosion-resistant materials, surface engineering	Sensors, actuators, power sources, NDE	Smart systems, SHM, active control	
Emerging Technologies	Nanostructured materials	Nanomaterials, meta-materials	Biomimetic materials, nanomaterials, meta-materials,	Bioactive, biocompatible materials and coatings
Intelligent Transport Systems	Signage	Sensors, displays	Energy absorbing materials, smart materials, lightweight materials	
Low C Vehicles	Lightweight materials	Sensors, low friction coatings, battery and fuel cell materials	Smart materials (drag reduction), battery and fuel cell materials	Plant-based materials
Low Impact Buildings	(Virtual) thermal mass for off-site manufacture of components	Coatings, thermal mass, solid-state lighting	Insulation, coatings, smart materials, reconfiguration and reuse, water- resistant materials.	Green roofs
Assisted Living		Sensors	Smart textiles, sensors	

3. Industry overview

Businesses in the UK that produce, process, fabricate and recycle materials (Figure 4) have an annual turnover of around £170 billion. They contribute about 15% of UK GDP, with a gross value-added (GVA) of around £60 billion, and form an important element in the supply chain of many high value manufacturing businesses. Raw materials supply, primary production and processing represent a combined GVA of around £25 billion, with fabrication around £35 billion [10]. Recycling represents an important opportunity for high value-added growth.

The definition of the materials sector in this way, acknowledges the ongoing shift from the UK being a supplier-centred industry to a customer-centred industry. Instead of being viewed as just commodities, materials are being engineered to enhance performance and to reduce life cycle costs. The competitive position of materials suppliers is increasingly dependent on their ability to supply materials with pre-engineered functionalities, tailored to end-user applications.

Examples of specific UK industrial materials capability against value-added activity type are shown in Figure 5.

Key market sectors which rely on, or are strongly underpinned by, advanced materials technology include:

- Energy Generation and Supply
- Aerospace
- Transport
- Healthcare
- Packaging
- Technical Textiles
- Construction
- Defence and Security.

Further details of each of these sectors, including market size and segmentation, together with key drivers and examples of value-added products, are included at Appendix 2 and summarised in Section 4.2.1. Each represents a high value market, with additional growth potential, in which the UK already has a strong presence.

For example, an anticipated £10 trillion investment in global energy infrastructure up to 2030; a £20 billion UK aerospace industry with 5% growth over the next 20 years; and a £18 billion global market for biomaterials, with up to 10% growth. Opportunities also exist to exploit materials technologies into multiple sectors.

Other market sectors, including electronic and photonic products, chemicals and fast moving consumer goods (FMCG), which have a strong materials aspect but are not addressed individually here, are considered either within other sectors e.g. packaging, or form part of other Technology Strategy Board KTA and KAA strategies.

Figure 4 – The advanced materials value chain

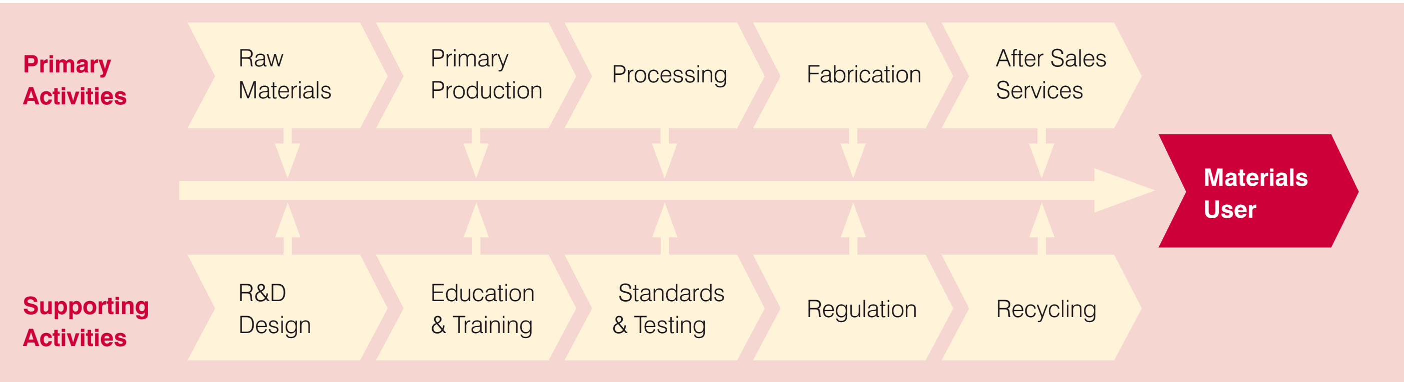


Figure 5 – Examples of UK industrial capability along the materials value chain

Activity type	UK industrial capability
Raw materials – energy producing	Oil and oil derivatives
Raw materials – non-energy producing	Quarrying stone; clay; sand
Primary production	Ferrous; plastics; coatings; pulp and paper; concrete
Processing	Ferrous; aluminium; titanium; glass; plastics; paper and paper board; polymer matrix composites; masonry; ceramics; fibres
Fabrication	Basic: metals; plastics; rubber; glass; paper board; concrete and masonry; ceramics; composites; textiles Components: formed parts and electronic and electrical embedments On/offsite modules of large structures
Recycling	Metallics; glass and ceramics – improving for plastics

4. Technology strategy

4.1 Approach

In formulating a strategy for Advanced Materials, it is necessary to recognise that it is an area which is highly pervasive across a wide range of market sectors, and which encompasses whole product life cycle issues across many material classes, processing methods and supporting technology areas. It is important, however, to provide a focus for the strategy, in order to contribute towards the delivery of significant economic and societal impacts.

Specific materials types have properties which make them more or less attractive for applications in different market sectors. It is not particularly useful, therefore, to analyse the overall usage of advanced materials by market sector in order to identify which of those markets offer the potential for the highest impact for innovative materials technology development. This can be achieved, to some extent, in respect of individual material types and Appendix 3 provides some examples of data which might be useful in helping to identify specific market-driven directions for future investment.

An approach which offers greater impact is to take a more holistic view, from the perspective of higher level challenges derived from an analysis of current key drivers across multiple market sectors and the identification of common themes.

Previous strategy documents and recent consultation and feedback exercises, involving key materials sector stakeholders, have identified the themes of 'energy' and 'sustainability' as common drivers of materials innovation. This reflects the wider continuing societal concerns about the environment, natural resources, security of energy supply and fuel poverty and, thus, provides a strong underpinning framework for the future strategy for advanced materials innovation.

The materials sector is well placed to address these challenges and, in doing so, to help to sustain high value manufacturing and methods of construction in the UK and to foster the development of a range of innovative, sustainable and competitive high performance materials, products and processes.

The sustainability agenda is of particular cross-sector relevance and importance, incorporating the full spectrum of the reduce, reuse and recycle agenda; from the availability of raw materials from difficult or dwindling sources, through to the management of waste at end of life, including both recycling and disposal. A more detailed description and consideration of the broader Sustainability agenda can be found in the Technology Strategy Board's Environmental Sustainability strategy [11].

The Technology Strategy Board will also invest selectively in materials-related aspects of specific market sectors; focusing either on established areas such as Healthcare, where strong materials impact has already been identified, or new areas such as the Creative Industries, where there is strong growth potential.

Specific priorities for 2008-2011 will be:

- **Energy**
  - secure, clean and affordable energy supply, distribution and usage
- **Sustainability**
  - focused on transport, construction and the 'reduce, reuse and recycle' agenda, including packaging
- **High Value Markets**
  - including technologies for Healthcare, the Creative Industries and Defence and Security

and these will be delivered jointly with relevant Technology Strategy Board KTAs, KAAs and IPs.

Underpinning technologies, such as materials characterisation, non-destructive evaluation and the predictive modelling of materials performance, degradation and through-life environmental impact will continue to be supported. Multifunctionality will also be a key driver in many sectors; for example, self-sensing and self-repairing composite structures in aerospace and defence, smart packaging, and the use of smart textiles within the healthcare and creative industries sectors.

Overall, this strategy outlines ways in which the materials sector can continue to innovate and grow, further enhancing its contribution to solving key societal problems and enhancing national wealth creation. It aims to promote innovation that addresses both evolutionary and revolutionary technology development and exploitation into both strong existing and high growth potential emerging markets and businesses.

It is consistent with the recent Council for Science and Technology Report on Technology Policy [3] which also prioritises some specific energy and healthcare-related topics as ones where a larger-scale focus by Government could accelerate the real returns for the UK within a five-year timeframe.

4.2 Technology Strategy Board investment criteria

The value of investment in advanced materials technologies generically and, in particular, in each of the three priority areas identified in Section 4.1 has been assessed against the set of Technology Strategy Board investment criteria:

- the UK capacity to develop and exploit the technology;
- the size of the global market opportunity;
- the right potential for impact in the right timeframe; and
- a clear role for the Technology Strategy Board to add value.

4.2.1 Overview

The underpinning and pervasive nature of advanced materials technology, across a number of large, growing and emerging market sectors, provides multiple opportunities for exploitation by UK business, in various parts of the product supply chain and life cycle. Advanced Materials has been identified [9] as a priority area for added-value within the UK High Value Manufacturing area and opportunities exist both in strong established markets such as aerospace, where multinational end-user companies and their supply chain partners within the UK have a major global market reach and share, and in high value markets such as Healthcare and the Creative Industries, where the UK also has a strong business base. Opportunities also exist within the overall materials value chain for UK business, in the production and supply of materials to non-UK companies, as part of the global economy. The UK has a particular strength in product design, again across a range of market sectors, from automotive to FMCG. This represents another value-adding opportunity within the product life cycle, which is enhanced by access to novel materials and processing technologies aimed at high value-added products.

This industrial capability is supported by a world-class science base (Appendix 5), which encompasses all of the major materials classes, and an underpinning national measurements infrastructure (Appendix 1). These are linked to industry via strategic partnerships and individual collaborations within Technology Strategy Board programmes (Appendix 6) and those of others. Together with industrial PV funding and a thriving knowledge transfer community, this places the UK in a strong position to continue as a global leader in the development and innovative use of advanced materials technology, leading to economic growth and enhanced quality of life. From an international perspective, the UK has, since 2003, participated in 80% of the core materials-related projects funded under the EU Framework 6 Programme for Nanosciences, Nanotechnologies, Materials and New Production Technologies (NMP). This again demonstrates the strength of both its industrial and academic S&T bases, but there is a need to increase the future engagement of UK business.

There are concerns regarding the future maintenance of a sustainable skills base and appropriately trained workforce in the advanced materials area. This is an issue which is common to other key technology and application areas and needs to be addressed seriously within the UK, building on initiatives already underway e.g. via the IOM3 and MatUK. Strong inter-agency co-operation will be required and the Technology Strategy Board will seek to contribute to this activity via appropriate mechanisms; e.g. KTNs and KTPs, together with support for RC-led schemes, e.g. iCASE and EngD.

Figure 6 shows a mapping of the key market sectors described in Section 3 against each of the priority areas. It includes summary top level market data (see Appendix 2 for further detail), together with examples of potential high value-added products, where the UK has identifiable strengths and a capability to both develop and exploit.

Defence and Security markets are not included explicitly in the table. Specific advanced materials applications in these sectors, e.g. protective materials, can be considered within other commercial market areas, e.g. technical textiles.

Figure 6 – Potential value-added products across many market sectors

Sector	Market Size*	Energy	Sustainability	High Value Markets
Energy Generation and Supply	■ £10 trillion* investment in global energy infrastructure from 2005 to 2030	■ Corrosion resistant high temperature materials for energy generation ■ Fuel cells and batteries ■ Super-conductors ■ Hydrogen storage materials	■ Wind turbine blades ■ Photovoltaic devices ■ Corrosion- resistant materials ■ Materials for carbon capture and sequestration	
Aerospace	■ £100bn* global market ■ £20bn turnover UK industry ■ 5% pa growth over next 20yr	■ Lightweight structures ■ High temperature materials for engines	■ Near-net shape processing ■ More-electric systems	
Automotive	■ £1 trillion global market ■ 3% UK share of vehicle build	■ Lightweight structures ■ Fuel cells and batteries	■ Bio-based materials and composites ■ Near-net shape processing	
Marine	■ £5-7bn UK industry turnover	■ Lightweight, corrosion-resistant structures ■ More efficient propulsion systems (incl. nuclear)	■ Bio-based materials and composites	
Rail	■ £20bn* global market for rail products ■ Growth of 1 to 4% pa ■ £15bn* global market for rail infrastructure	■ Lightweight structures	■ Bio-based materials and composites	
Healthcare	■ £18bn* global market for biomaterials ■ Up to 10% growth			■ Implants ■ Stents ■ Drug delivery ■ Tissue regeneration ■ Anti-microbial materials
Packaging	■ £210bn* global turnover ■ £10bn pa UK sales ■ 3.5% pa growth		■ Biodegradable materials ■ Recyclable materials ■ Smart packaging	■ Anti-microbial materials and surfaces ■ Packaging design and product form
Technical Textiles	■ £260bn* global market for textiles and clothing ■ £63bn* global technical textiles market ■ Growth four times that of conventional textiles ■ £3.5bn UK technical textiles market			■ Tissue scaffolds ■ Wound dressings ■ Smart textiles
Construction	■ £100bn UK construction industry output	■ Insulation materials ■ Smart coatings	■ Bio-based materials	

* Note: The financial figures in this table have been taken from a number of sources (see Appendix 2) and converted, where necessary, for comparative purposes, using a factor of £1=$2.

The Technology Strategy Board can add value within the Advanced Materials area via a variety of means, depending on the relative maturity (TRL) of specific technologies and the nature of the proposed interventions. It will support the successful exploitation of technologies into the marketplace, via activities including:

- co-ordination and prioritisation of investment across multidisciplinary technology themes: structural, functional, multifunctional and biomaterials;
- bringing together the various Advanced Materials and relevant market sector communities;
- stimulation and facilitation of collaborative R&D, encompassing multidisciplinary projects with both focused and spillover market exploitation potential;
- encouragement of the formation of strong supply-based CR&D partnerships, including end-users and the industrial SME base, in order to provide exploitation pathways and subsequent product development; and
- support, with other stakeholders, for:
  - technical feasibility studies and pre-product demonstrators, to help the de-risking of technology exploitation for industry,
  - the development of emerging and low TRL technology solutions,
  - measurements and standards development, and
  - skills development.

4.2.2 Energy

The energy-related application of materials encompasses both fixed and mobile energy sources and usage, primarily within the energy industry, transport and construction sectors. It includes energy generation, transmission and storage, together with energy saving and conservation. Figure 6 shows examples of potential added-value products in this area, including lightweight, high temperature and corrosion-resistant materials and structures and materials for fuel cells and batteries.

The UK has strong industrial and academic capabilities in relevant materials and energy-related technologies. For example, BERR's UK Renewable Energy Trade Promotion Service lists more than 100 businesses. The Autumn '07 Technology Strategy Board CR&D Call on Materials for Energy identified many strong supply chain-based consortia and underpinning materials technologies will provide advances that can be exploited via energy technologies in which the Technology Strategy Board, ETI and the newly announced Environmental Transformation Fund will invest.

From a market perspective, there will be a £10 trillion investment in global energy infrastructure from 2005 to 2030. Opportunities also exist within the £100bn global aerospace market, the wider transport sectors and construction.

Materials technology has the potential to provide solutions to the immediate and ongoing economic and environmental issues related to energy generation, conservation and storage. 30-35GW of new electricity generation capacity is expected to be needed over the next two decades and around two thirds of this by 2020. In addition, a 60% reduction in CO_2 emissions is required by 2050, and a 26-32% reduction by 2020. To meet the 2016 zero carbon homes target, the thermal performance of the existing housing stock, as well as future build, must be dramatically improved. In the aerospace sector, there are also ambitious energy and environmental-related targets to be achieved; for example, the European ACARE 2020 vision [13], which will require the development of innovative materials technologies. In the UK, advanced and

Powering ahead

London-based TidalStream Ltd has designed a novel tidal power generation system. Government policy to reduce CO_2 emissions, diminishing supplies of energy and rising demand for electricity are creating an urgent need for renewable energy. A semi-submersible floating tidal power generator, based on wind energy technology, could allow the UK to meet a significant part of its electricity needs from deep coastal waters. Already tested in the Thames, the TidalStream system could harness power from fast flowing waters found at depths of 40 metres or more, where an estimated 63% of the UK's tidal energy resources are thought to be. Technical support, provided by the National Composites Network, involved a design study of the turbine's composite material supporting structure. Hydrostatic pressures for normal operating and runaway load cases were investigated using first principles and finite element analysis. This demonstrated the viability of the concept under normal operating conditions using composite materials. Critical areas of the main structure requiring further attention were indentified, and modifications to cope with a runaway situation were highlighted. Manufacturing cost estimates were also provided within the design study.

smart materials and structures are a key element of the National Aerospace Technology Strategy (NATS) [14], underpinning the development of future systems. In the wider transport sector, lightweight materials and structures are a key element of more energy efficient vehicles within the current low carbon vehicles agenda. Further details of these market opportunities are included at Appendix 2.

There is a role for the Technology Strategy Board to add value in this area by co-ordinating and prioritising across multidisciplinary materials technology themes, energy generation sources and market sectorisation. It can also encourage the formation of supply chain-based CR&D programmes and stimulate knowledge transfer between the various materials and energy communities. Technology Strategy Board investment in relevant materials technologies will underpin and complement the Technology Strategy Board Energy Generation and Supply KAA and ETI objectives and programmes.

Fit against criteria for investment	
UK Capability	High
Market opportunities	High
Timeliness & impact	High
Added value	High

Waste not, want not

Axion Polymers, based in Manchester, specialises in developing and operating novel processing solutions for recycling waste materials. At its new recycling factory in Salford, the company reprocesses waste electrical and electronic equipment plastic waste into high grade polymer compounds for re-use under the Axpoly and Axplas brand names. Many of the plastic components of electronic goods are made from ABS, but foaming or voiding can appear in the reprocessed material. Axion Polymers contacted the Polymer Innovation Network (PIN) about this issue and was put in touch with Dr Chris Arnold at Swansea University, who has experience in this area. A work programme was set up and it quickly qualified for a proof of concept SPARK Award from PIN. Axion was able to supply Swansea with ABS mouldings from a range of applications – from lawnmowers to mobile phones – which the researchers reprocessed on small scale laboratory equipment. Using a torque rheometer, they showed that different product streams give different levels of foaming or voiding. Analytical techniques identified the gases given off during extrusion; in order to identify health risks, propose links with the source of the materials concerned and offer solutions to overcome voids in the recycled products. Solutions have been demonstrated on full-scale process equipment. Mechanical testing of the recycled samples has helped Axion to identify possible second use applications for its products.

4.2.3 Sustainability

The sustainability agenda has strong linkages to energy-related issues, such as carbon dioxide emissions and climate change, but also extends into other important aspects of materials production, usage and disposal – the reduce, reuse and recycle agenda.

Sustainable materials technologies have exploitation potential in a number of high value market sectors; e.g. energy, aerospace, transport, construction and packaging. Figure 6 illustrates potential high value-added products across these markets; from photovoltaic devices to bio-based materials and composites, for each of which the UK has both the science base and industrial strengths to develop and exploit. Particular strengths include process development, design, through-life assessment and smart materials.

The use of innovative materials solutions in the development of more sustainable products and processes is timely in the context of continuing societal concerns; e.g the packaging debate, and represents an increasingly difficult challenge as primary resources become less available and expensive. The assessment of environmental impact through life is also becoming of increasing importance in the product design process, with, for example, the need to balance improved performance against more difficult reuse or recycle characteristics. Positive economic impact will accrue across the materials supply chain and into multiple market sectors. Further market information is included at Appendix 2.

There is a dual role for the Technology Strategy Board in this area, in the context of both improved quality of life and wealth creation. It can add value via investment in the development of multidisciplinary sustainable materials technologies and their exploitation in a range of market sectors, via the facilitation of industry-led collaborations. It can also stimulate knowledge transfer through, for example, the encouragement of increased interaction between relevant KTNs; e.g. Materials, Resource Efficiency and Chemistry Innovation, and support for KTPs. Technology Strategy Board investment in relevant materials technologies will underpin and complement its investment within the Environmental Sustainability KAA and High Value Manufacturing KTA, as well as the Low Carbon Vehicles and Low Impact Buildings Innovation Platforms.

The Technology Strategy Board can also work with other stakeholders in regard to metrology and standards issues, particularly in the context of re-used or recycled materials and waste management.

Fit against criteria for investment	
UK Capability	High
Market opportunities	High
Timeliness & impact	High
Added value	High

Lighter glass packs

'ContainerLite' was an industrial collaborative project that aimed to reduce glass waste by exploring the most effective ways of light-weighting bottles and jars in conjunction with the supply chain. Consumer perception research by the Institute of Psychological Sciences at the University of Leeds aimed to understand perceptions of glass as a packaging material and to gauge sensitivity to weight changes. This enabled Coors, Burton on Trent, to lightweight their Grolsch bottle. The primary target to deliver weight savings of 7,400t (to which Grolsch alone contributed 4,500t, without affecting overall shape or style change) was achieved by the project's completion.

The secondary target, to work with glass manufacturers to gain an additional 30,000t of savings per annum within 12 months of the project's completion, has also made significant progress. 'ContainerLite' was a WRAP-funded project managed by the Packaging Materials Link

4.2.4 High Value Markets

This strand of activity will include specific high value market opportunities and challenges, which fall outside of the mainstream focus on energy and sustainability. This will include both areas where there is already significant materials development and initial market penetration (e.g. healthcare), and areas where materials development could have the potential to lead to market growth (e.g. creative industries). Defence and Security represents another sector which will offer opportunities, often drawing upon mainstream civil markets and products.

In the case of healthcare, for example, the UK has strong academic and industrial bases in both relevant materials and healthcare-related technologies. Potential added-value products, from anti-microbial materials to tissue regeneration scaffolds, are shown in Figure 6. Previous Technology Strategy Board CR&D Calls have led to investment in strong materials-related proposals and collaborative science and industry-based consortia.

There is an estimated £18bn global market for biomaterials, with up to 10% growth. However, markets for specific materials and products are less well defined.

There are significant opportunities for the exploitation of materials technologies in a range of future healthcare products and investment is timely against the background of an ageing society. Development timescales can be long and will vary due to the nature of specific products and associated issues of product safety and acceptance.

There is a role for the Technology Strategy Board to stimulate further interaction between the materials and healthcare sectors and to facilitate the formation of multidisciplinary CR&D programmes and knowledge transfer activities aimed at the development and exploitation of innovative products.

Within the creative industries, there are a number of potential, but less well defined, value-added product opportunities. For example, smart textiles, which have the potential to be exploited in clothing and for embedded electronic interface systems, has a strong UK science base and can be exploited through a strong technical textile industry. Technical textiles represent a £63bn global and £3.5bn UK market, with growth four times that of conventional textiles. This area is also supported by a growing interaction between the materials and design communities; design being a key aspect within this sector. Further design-related opportunities, with regards to product form, also exist within the strong UK packaging sector, which has annual sales of £10bn.

It is timely, within the Technology Strategy Board's wider activities in the creative industries, to investigate the opportunity for the exploitation of materials technologies in that sector and related areas. However, it is premature to define and quantify specific economic impacts.

There is a role for the Technology Strategy Board to add value by facilitating the bringing together of the relevant materials, design and creative industries sectors, in order to better define and quantify the market potential and to explore opportunities for collaborative working and technology exploitation.

Fit against criteria for investment	
UK Capability	High
Market opportunities	Medium
Timeliness & impact	Medium
Added value	High

4.2.5 Recommendations

Based on the above assessments, the Technology Strategy Board will:

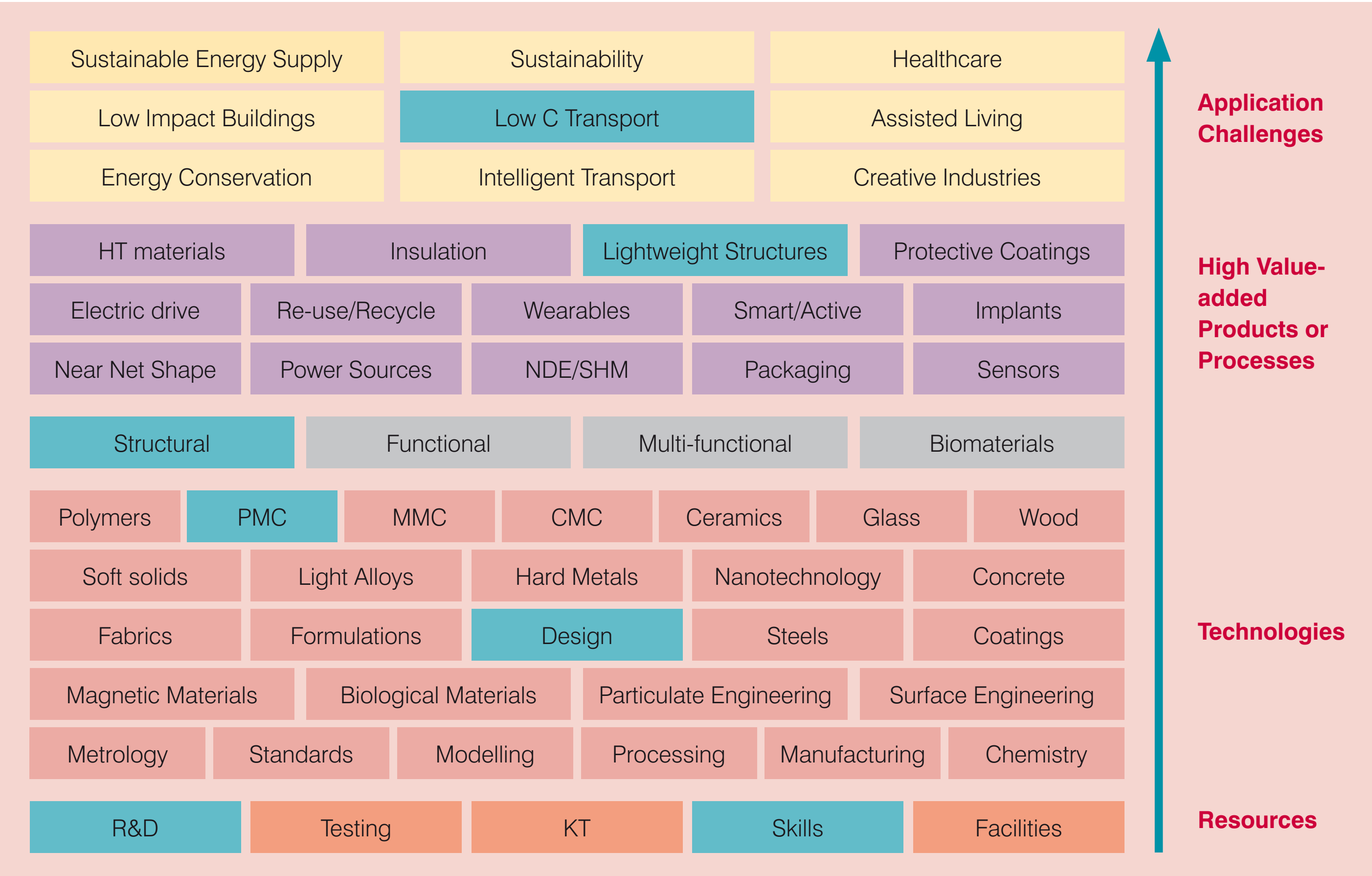
- continue to focus investment in materials for energy applications, building, with other stakeholders, a coherent programme of underpinning R&D and knowledge transfer, leading to exploitable technologies for added-value products and processes;
- focus investment in the development, with other stakeholders, of a coherent programme of underpinning R&D and knowledge transfer activities, aimed at the sustainable, through-life, use of materials; and
- continue to invest selectively in other high value market areas. This will include healthcare, the creative industries and defence and security.

4.3 Implementation

Figure 7 represents the top-level Advanced Materials landscape, showing the desired flow of the individual technology-based elements into high value-added products and processes which will provide commercial and societal benefits in one or more of the prioritised challenge areas or end-use sectors. The individual topics shown are representative only. The example highlighted in blue demonstrates the approach: in this case, the application of people-based skills, channelled through an R&D project combining polymer matrix composite technology and design, to develop lightweight structures, aimed at the low carbon vehicles agenda. Details of individual road-maps addressing specific, materials-relevant, technology or market sector areas are provided at Appendix 4.

In order to facilitate the effective delivery of the strategy, business activity by relevant stakeholders is highly desirable. To this end, strong inter-agency co-ordination and collaboration will be required, particularly between the Technology Strategy Board and the RCs, RDAs/DAs, Government Departments and industry. Where there are common civil and defence-related technology drivers, e.g. lightweight or protective materials, joint or aligned programmes with the MOD will be sought. This co-ordinated approach will help to facilitate the faster exploitation of more innovative technologies by the phasing and gearing of investment across the entire TRL range of the product development lifecycle – see Figure 8. Joint funding may be appropriate within existing programme frameworks e.g. Technology Strategy Board CR&D, EPSRC Grand Challenges, MOD Competition of Ideas and, potentially, via large key 'lighthouse' projects, aimed at addressing particularly important and complex problems.
The benefits offered by international

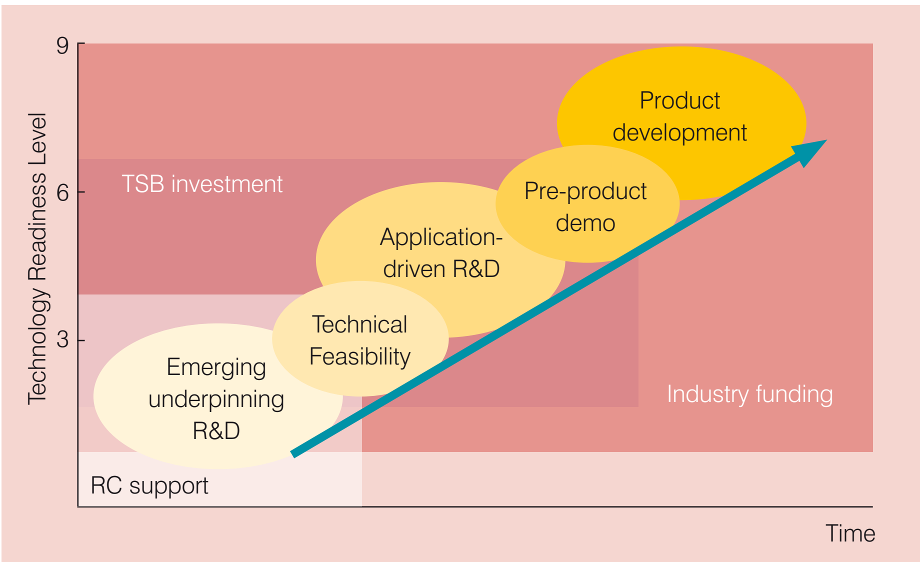
Figure 7 – The advanced materials landscape



collaboration; e.g. via EU programmes, both in terms of financial gearing and access to non-UK research and industrial supply chain capability in support of UK business, will also be explored.

A major concern within the materials sector is the need for further 'proof-of-concept' projects, which are often required to help to facilitate and de-risk the transfer of technology between either the academic laboratory and more applied research, or prior to specific product development by industry (Figure 8). Further consideration is required, with other stakeholders, regarding the inclusion of such activities as part of the overall product development investment cycle.

Figure 8 – Continuity of investment across the product development cycle.



5. The way forward

This document aligns the Advanced Materials strategy with the higher level strategy and priorities of the Technology Strategy Board, including incorporation of issues raised by the recent Sainsbury [2] and CST Reports [3]. It also addresses issues that have emerged from discussions with key materials sector stakeholders.

Overall, the trend towards investment in more market and challenge-led programmes will continue; for example, the Materials for Energy theme within the CR&D Autumn 2007 Call. Opportunities to promote materials technologies which exist within most of the current Technology Strategy Board's Innovation Platforms will be developed further, together with joint activities across existing KTAs and KAAs. This approach will also be supported by the encouragement of further joint activity between KTNs.

There is a recognised need to develop support mechanisms which provide longer notice of intent, are more flexible, and are joined-up with other stakeholder communities, to provide a continuity of funding over the entire product development lifecycle, as well as filling existing gaps, such as 'technical feasibility' and 'pre-product demonstrator' support. Opportunities will be explored with other stakeholders in relation to co-funding within current programmes, as well as the establishment of new collaborative initiatives. The development of common roadmaps will facilitate this process.

Interaction with key industrial players in major market sectors will continue to ensure that the strategy remains business-focused and increased communication with the SME community will be sought, including via the RDA/DAs.

Investment in underpinning generic R&D will continue, in collaboration with the Research Councils, with a focus on topics with the potential for exploitation in future high value-added products across a range of market sectors. This will include smart, multifunctional and polymer composite materials, together with high value metallics. Issues related to metrology and standards development will be addressed in consultation with the National Measurement System, BSI and relevant National Measurement Institutes.

Opportunities for complementary or synergistic activities via international collaborations will also be explored, including with UKTI and the EU.

To achieve the desired outcomes from the Advanced Materials strategy in the period 2008-2011, the Technology Strategy Board will:

- invest in materials technologies which address the key challenges of energy and the environment;
- invest in materials technologies focused on the 'reduce, reuse and recycle' sustainability agenda;
- continue to invest in materials for high value markets, including healthcare, the creative industries and defence and security;
- work with other government and industry stakeholders to identify opportunities for joint or aligned activities; including generic underpinning R&D and proof-of-concept studies;
- work with other stakeholders in respect of metrology and standards development;
- support an innovation culture via, for example, the use of Knowledge Transfer Partnerships (KTP) and Knowledge Transfer Networks (KTN); and
- seek, with other stakeholders, to identify European and other international strategic alignment and financial gearing opportunities in support of improved UK competitiveness and inward investment.

Appendix 1 – Technology overview

A1.1 Structural materials

Structural materials represent a highly diverse area, with links to, for example, the transportation (including aerospace), energy, construction, healthcare, leisure, and defence and security sectors.

The major classes of structural materials include metals, metallic alloys and metal matrix composites (MMC); polymers and polymer matrix composites (PMC); ceramics and ceramic matrix composites (CMC); together with concretes, glasses and natural materials, e.g. wood.

Common technical challenges are:

- materials to withstand more aggressive environments (e.g. high temperature, corrosive, erosive);
- the requirement to reduce environmental impact through life;
- the need to understand complete materials systems (e.g. coated components, sandwich structures, composites, joints and hybrids);
- improved modelling through the full life cycle, including lifetime prediction;
- better condition monitoring and NDE (materials and manufacturing processes); and
- reduced costs through innovative production and processing, including increased automation.

A1.2 Functional materials

Functional materials are materials which generally exhibit some non-structural properties; for example electronic, magnetic or optical, and are incorporated into associated functional devices and systems; for example, microelectronics, photonics and electrical machines.

This area has strong crossovers into the Technology Strategy Board's Electronics, Photonics and Electrical Systems (EPES) KTA [15], which is strongly underpinned by functional materials technology and where many of the innovation barriers are linked to materials properties and processing. This includes, for example, plastic electronics, superconductors, magnetic materials, electronic materials for use in extreme environments (e.g. SiC), compound semiconductors, microelectromechanical systems (MEMS) and optical materials. Some emerging technologies, also considered within the EPES area, include carbon-based materials (e.g. carbon nanotubes, graphene and conducting polymers), quantum structures (dots and wires) and spintronic device materials.

Some classes of functional materials; for example, piezoelectrics and magnetostrictives, are also often discussed in the context of multifunctional materials and, particularly, 'smart' materials and systems. One important use of such materials is in the development of Sensors and Diagnostic Systems, which was identified as a priority area in the 2006 MatIGT report [1].

A1.3 Multifunctional materials

Multifunctional materials represent a highly diverse and strongly multidisciplinary area, with links to functional, structural and biomaterials. Strong market drivers exist to develop high added-value products across numerous sectors, including aerospace and transportation; healthcare; packaging; energy; construction; security; consumer products and defence. In addition, there are strong environmental, energy-related and sustainability drivers, increasingly being underpinned by legislation.

Two examples of applications to illustrate this field are:

- damage tolerant, self-diagnostic and self-healing materials; and
- fully-integrated structural/power generating materials.

As the next big step in product development, multifunctional materials offer great opportunities for the UK to exploit the strengths which the UK science base can provide. Technically, interfacial and surface properties, often embodied within composite materials, will be key and more interdisciplinary work, including multifunctional modelling, is required. Issues concerning the practical integration of functionality into structures, e.g. connectivity, reliability and end-of-life management are also critical to exploitation, especially in high value and safety-critical products.

The concept of biomimetics, which aims to draw inspiration from nature, represents an interesting sub-set of multifunctional materials technology.

A1.4 Biomaterials

Biomaterials can be defined either as materials applied to a biological system or materials derived from a biological source. In some cases, these may be combined.

Within the first definition, biomaterials can also be considered as a subset of structural, functional or multifunctional materials, operating in a specific, biological, environment. Applications include, for example, implants, tissue scaffolds and sensors. The study of such biomaterials is very interdisciplinary and areas identified for future development include:

- bioresorbables and bioactive materials, together with novel manufacturing routes to achieve new properties in existing materials;
- new interfacial structures for the control of biomaterial-tissue interactions; and
- the integration of sensing systems into biomaterials for in-situ implant monitoring.

In the context of biologically-derived materials, biopolymers offer the prospect of a renewable source of new materials within a low carbon society. Biomass-generated polymers include celluloses, starches, chitosan and proteins. Other materials include polylactic and polyglyconic acids produced from naturally occurring monomers, as well as polyethylene produced from ethene, generated by the dehydration of bio-ethanol, and polypropylene produced from glycerol-derived propene. Biopolymer chemistry can create a number of intermediates and final compounds, e.g. plastics that fit into existing processes and product lines. However, with the exception of cellulose, most of this technology is currently not cost competitive with petroleum-based plastics. Applications include catalysis, and biodegradable containers and packaging, as well as biomedical engineering.

Biomaterials are also discussed within the Biosciences and Medicines and Healthcare KTA and KAA strategies [16].

A1.5 Cross-cutting themes

Nanomaterials represent a subset of advanced materials technology, and are considered here as a subset of each of the above categories, within each of which operation at the nanoscale (less than 100nm dimension) brings with it specific opportunities and challenges. An improved understanding of materials at the nanoscale, and the ability to control their structure, will provide the potential to develop a range of products with novel characteristics, functions and applications. Classes of nanomaterials include thin films and surface coatings (1-D); nanotubes, wires and fibres (2-D); and nanoparticles, quantum dots and nanocrystalline materials (3-D). Understanding surface and interfacial characteristics is a key challenge in this area, where non-bulk properties dominate and lead to novel properties.

Developments in metrology and standards will be an important underpinning element in the wider exploitation of nanomaterials technologies, particularly in the context of health and safety issues. Nanomaterials are also considered separately, as part of an overarching Technology Strategy Board Nanotechnology Strategy [8].

A further important cross-cutting theme is Materials Modelling, which is the subject of an ongoing MatUK strategic study [17], and offers a reduction of risks and costs, together with improvements in efficiency and effectiveness. Key areas to support the materials industry include: multi-scale modelling for property and lifecycle performance prediction and the modelling of multifunctional behaviour and operation under extreme conditions; supporting new process development via the adaptation of existing software tools, together with the development of novel multi-physics software technologies; through process and lifecycle modelling, using coupled models of each stage; for example, from forming, through heat treatment and machining, to in-service operation; and modelling to enable quicker novel material formulation.

For the UK to remain internationally competitive, leading edge materials and process developments will need to be supported by computational models which both capture each stage of the manufacturing and in-service processes, and enable the prediction of structure and condition at every stage of product formation and life; that is, both fully-coupled multi-physics and multi-scale processes. This will require the integration of various modelling efforts, supported by the use of state-of-the-art computational and visualisation facilities.

The exploitation of Advanced Materials, including processing technologies, is also a priority theme within the High Value Manufacturing strategic agenda [9]. This includes a growing awareness of the importance of design in successful exploitation into high value products; particularly, in the area of structural composites and functional or multifunctional materials. Designers need to work at the front-end of the advanced materials and manufacturing innovation strategies, participating more fully in the initial stages of bringing new products and services to market and in ensuring that through-life and end-of-life issues are considered from the outset. A recent study undertaken by MaDE, the design node of the Materials KTN, has identified the following priority application areas:

- health, ageing society and disability;
- crime prevention; and
- waste, repair, recycle, reuse and packaging

The ability to apply measurements and standardisation tools and techniques to support innovation in Advanced Materials, including modelling, is also important. Work by the Materials IGT and MatUK has highlighted a need, across all key market sectors, to address standardisation in a systematic fashion to create coherence and optimum value across the materials supply chain. Integrated standards solutions are required that accommodate innovations and technology convergence, meet the needs of industry across market sectors, and support Technology Strategy Board strategies and interventions; e.g. Innovation Platforms. Standardisation is also required to support the sustainable use of materials and products throughout their lifecycle. An EU Community Innovation Survey in 2005 showed that 64% of innovation-active companies in the UK use standards and technical definitions as a source of information for innovation [2] and over one quarter of annual technological growth can be attributed to BSI standards [18, 19].

Adoption of new materials, or their use in new applications, depends on an ability to understand, characterise and measure these materials throughout their working life. This includes their processing properties, performance and durability. Under the auspices of the DIUS-led National Measurement System (NMS), the UK has a world-class reputation for metrology and measurement standards, with the National Physical Laboratory (NPL) [20] recognised as one of the top three National Measurement Institutes. The development of new standards, and research into measurement techniques, helps to boost UK productivity and NPL has identified Advanced Materials as one of its key target technology areas; based around structural materials, surface engineering, materials chemistry, and multifunctional materials.

Appendix 2 – Industry overview

A2.1 Energy generation and supply

Key strategic energy challenges were identified in the 2006 Energy Review and Energy White Paper [12] as

- tackling climate change, by reducing carbon dioxide emissions both within the UK and abroad; and
- ensuring secure, clean and affordable energy, as we become increasingly dependent on imported fuel.

Building on the IGT recommendations in 2006, MatUK has recently published a Strategic Research Agenda (SRA) for Energy Materials. [21]. This industry-led initiative has recognised that the key to many of the required technological advances in the energy sector, which will impact on the Government's energy policy, is the availability and deployment of appropriate materials solutions. This will extend across a balanced future central and distributed energy generation portfolio; potentially including a mix of clean fossil, nuclear and renewable sources. Energy generation in each of these areas, together with transmission, distribution and storage systems, will continue to need advancement in the development and application of materials technologies, both to achieve incremental product improvement and also to contribute to innovative new technologies. Materials will also have an important part to play in the more efficient use of energy, including within the Construction Sector.

The key drivers for Energy Materials R&D are identified as how materials technology can contribute to: reducing environmental impact; improving security of supply; and reducing cost.

In addition, there is an opportunity of wealth creation for the UK, including a massive potential export market for low carbon energy materials technologies; 98% of global CO_2 emissions are created outside of the UK. The cumulative projected world-wide investment in energy infrastructure from 2005 to 2030 is $20.2 trillion [22], of which UK industry can position itself to gain a significant share.

The SRA R&D priorities focus on materials solutions which map onto the above drivers by contributing to:

- higher performance in harsher environments
- improved life management and reliability
- reducing time to market and life cycle costs.

A key UK strength is identified as a world-class industry and academic capability and reputation in the energy materials sector e.g. high temperature materials and coatings, modelling, composites, nano and functional materials; with emerging energy technologies leading to innovative opportunities for materials development.

The Energy Technologies Institute (ETI) [23], recently launched as a public/private partnership, sees materials as one of a number of key underpinning technologies which will help it to achieve its objectives.

A more detailed description and consideration of the broader Energy Sector can be found in the Technology Strategy Board's Energy Generation and Supply Key Application Area strategy document. [24]

A2.2 Aerospace

The global aerospace market is worth $200 billion per annum, of which the UK holds a 13% share. The UK aerospace industry is the second largest in the world, with a turnover of £19.8 billion in 2006. Comprising more than 3,000 companies and supporting, directly and indirectly, some 400,000 UK jobs [25], it adds, on average, £2.5 billion per annum to the UK's balance of trade [14]. Around 25% of the sector is associated with aero-engines. The global aerospace market is set to grow by around 5% per annum over the next 20 years, with aircraft sales of around $2.6 trillion, including some 15,000 single-aisle aircraft worth $1 trillion [26].

Under the sponsorship of the Aerospace Innovation and Growth Team (AeIGT), the UK National Aerospace Technology Strategy (NATS) [14] identifies Advanced and Smart Materials and Structures as a key research theme, underpinning the development of future systems via technology validation (demonstrator) programmes such as Powered Wing, Environmentally Friendly Engine, and More Electric Aircraft; with key drivers being safety, environment, life cycle cost, performance and availability.

Advanced Materials technology, particularly polymer matrix composites and advanced metallics, including high temperature and magnetic materials, already forms a critical part of the strategic plans of the global aerospace industry, in support of its current and future environmental and cost targets; for example, the European ACARE 2020 vision [13], covering improved safety, reduced fuel burn, reduced time to market, lower maintenance and acquisition costs, and the demanding environmental requirements of reduced pollution and noise. New generation aircraft, e.g. Airbus A380, A400M, A350XWB and Boeing 787, are increasingly using advanced composite materials in both their airframes and engines. Overall, 50% of the A380 and 35% of the 787 (where Rolls-Royce engines are used) systems will be provided from the UK. This technology trend is set to continue with a growing requirement for improved structural components and associated manufacturing processes, together with the use of smart and multifunctional materials technology in future systems; e.g. single-aisle, A320 and Boeing 737 replacements.

In combination, the customer, business and environmental requirements in this sector drive the aircraft and engine manufacturers to produce aircraft that are:

- easier, quicker and cheaper to build and maintain;
- more lightweight;
- more energy efficient; and
- easier to dispose of.

New materials and manufacturing processes will also underpin the development within the UK of rotorcraft and unmanned air vehicle technologies, the latter being a rapidly growing area for both civil and military applications.

A2.3 Transport

In 2005, the automotive sector was worth £1 trillion globally, producing 63 million vehicles, of which 1.8 million came from the UK [27]. Materials technologies, including some adopted from the aerospace sector, play an important role in this sector, particularly in the context of vehicle lightweighting in support of the low carbon vehicles agenda. In this context, materials technologies also have a critical role to play in the development of affordable, lightweight and durable electrochemical power sources and drive systems for electric and hybrid vehicles. The intelligent transport agenda will also lead to an increasing use of functional and multifunctional materials for both discrete devices and structurally-integrated functionalities. Design and processing issues for cost-effective and reliable volume manufacturing are important in the adoption of new materials for automotive applications and through-life concerns include crashworthiness and repairability. Motorsport plays an important early adopter role in this sector; for example, in the use of polymer composite materials in safety-critical components.

Within an overall £37 billion turnover UK marine sector [28], segments which are directly relevant to materials and manufacturing activities represent around £5 to 7 billion (circa £3 billion GVA) [27, 29, 30]. This area has three sub-divisions; shipbuilding and repair, leisure boating, and marine equipment, including nuclear and other propulsion technologies, and directly employs around 60,000 people. With increasing oil prices there is growing demand on ship owners to cut operating costs through the lightweighting of hulls and better through-life planned maintenance. Other specific drivers in the civil sector include corrosion resistance and protection, joining and safety. In the nuclear propulsion area, safety, radiation damage, corrosion and through-life cost dominate. The UK has significant academic and industrial innovative strengths in all of these areas and is well placed to exploit these.

Offshore renewable energy too is becoming an increasingly attractive option for the UK. With many installations being operated with minimal human intervention, it is necessary to provide intelligent feedback on performance and, where appropriate, provide remote input to rectify faults. This operational aspect will pose challenges in the use of multi-functional materials. The UK also has strengths in the innovative design of high quality specialist products for the leisure market, where the key drivers include safety, weight saving, durability and structural optimisation, via improved design. The biggest challenge will be to bring together what is a highly fragmented industrial base, so that UK strengths can be exploited as widely as possible.

The global market for rail products is around $40bn per annum, with annual growth of 1-4%. The UK has one primary manufacturer of rolling stock, together with a supporting supply chain and rolling stock maintenance industry. The market for railway infrastructure is around $30bn per annum [31]. Materials technologies have an important role in this sector, including both materials for lightweight, crashworthy rolling stock and materials for the construction and maintenance of fixed, often ageing, infrastructure, both over- and underground. Specific drivers include safety and reduced through-life costs.

A2.4 Healthcare

Within the healthcare market, biomaterials have seen exceptional growth and development over the past decade, creating a worldwide market (2005) of over $36 billion; which is projected to grow by up to 10% per annum, for some clinical applications [1]. The key driver is increased life expectancies creating an ageing population, and developments in biomaterials and smart materials have led to innovative medical devices, implants and drug delivery vehicles; opening up the possibilities for new and improved therapeutic treatments. Biocompatibility between the body and implanted devices is seen as key to the successful implementation of these newer devices and advances in surface compatibility with the 'hostile' biological environment has resulted in improvements in acceptability, both ethically and medically, for long term implantation e.g. stents, orthopaedic implants and in-situ diagnostic and control devices such as pacemakers, heart valves and electrodes for cochlear implants. Regenerative medicine offers the potential for new biocompatible materials with enhanced functionalities which will regenerate rather than repair cell and tissue damage.

Opportunities also exist for enhanced materials for dressings which augment healing through antimicrobial, moisture or cell movement properties; inform clinicians, passively or actively, of the state of the disease; or respond to the changing environmental conditions of an injury. Specific areas of interest include biocompatible materials and coatings; piezo-active fibres; auxetic materials; adhesives; coated, drug eluting and fully-biodegradable stents; hydrophilic neuro-catheters; hydrogels and microgels; and micro/nano-scale 3-dimensional scaffolds.

A2.5 Packaging

Packaging plays a vital role in the preservation, transport and presentation of consumer and industry goods across the developed world, with the highest intensity of operations in SE Asia, North America and Europe. Globally, the packaging industry is considered to be worth some $424 billion annual turnover, of which food packaging represents around 38% [32]. Materials technology is fundamental to the sector: polymer and paper form the largest two sectors, each around 35% of the total market, with metal and glass-based packaging at 17% and 10% respectively [32]

With the strong design community and extensive branded goods market in the UK, the UK packaging industry is held in high esteem. It has traditionally had a strong track record of innovation to support on-going improvements in core functions to contain, protect, preserve and promote. UK sales amount to £10 billion annual turnover – representing some 3% of the national manufacturing base – and the industry employs 85,000 people [33].

However, the UK packaging industry is only part of a wider supplier chain which includes a variety of materials and equipment, such as inks, adhesives and coatings, together with packaging equipment and services. Packaging should also be considered in the context of the goods and services which it supports and enables to market. Just about any element of 21st century life is dependent on packaging; be it food, drinks, healthcare or personal goods.

The intricate network of the 'packaging world' has traditionally been driven by consumer demand and cost reduction. It is also increasingly clear that packaging has played, and will continue to play, a key role within the environmental agenda, enabling and supporting the sustainability of its contained products.

Looking to the future, the 'packaging world' faces key issues across social, technological, environmental, economic and political contexts. In particular, meeting the needs of an ageing population; for example, ease of opening and reclosing, intelligent and powered dispensing or enhanced drug compliance; providing tangible benefits that enhance quality of life, such as extended shelf life, enhanced hygiene and validatable brand security; harnessing communication technologies to create time temperature and other tracking indicators to enhance efficiency of product distribution and logistics; recycling, lightweighting, low energy manufacture, waste minimisation and other sustainability enhancements to maximise net environmental benefits of packaging; reducing time to market and increasing prototyping flexibility to maintain competitiveness to an increasingly dynamic consumer world; and meeting the legislative or consumer-driven needs of 21st century retailing, such as sensory engagement, pack legibility or, simply, increased ease of shopping.

The key technology enablers to meet the application drivers in this sector are both challenging and diverse: understanding material properties sufficiently to be able to drive predictive modelling to enhance speed and effectiveness of design and manufacture; new functional properties by manipulating novel surfaces and additives along with new formulations of intelligent inks and adhesives; printable information and communication devices, along with electric power and sensing, to deliver intelligent and smart packaging; environmental enhancing technologies such as design for recycling, waste as a resource, and enhanced materials from renewable sources; and novel approaches to design and innovation, such as biomimetics and inclusive design along with reliable and systematic consumer modelling and forecasting.

Encouragingly, these challenges represent areas which align well with areas of strength in UK academic capability. Thus, whilst the issues present substantial scientific challenge, and the nature and depth of the issues will pose new demands on those active in packaged goods, collaboration and interaction between industry – both producers and users – and the science base, will allow the UK to continue to play a leading role in worldwide packaging and packaged goods.

A2.6 Textiles [34]

The global textiles and clothing sector trade has grown rapidly in recent years to reach $530 billion in 2007. This trend will continue, as population levels increase and living standards rise. The EU has 230,000 textiles and clothing companies employing 2.7m people and representing an annual turnover of some 200 billion euros. EU textile firms control 31% of the global high-end market and 11% of the mid-market. The EU production of non-wovens rose by 6.5% in 2006, producing a positive trade balance of some 928m euros; a 14.4% increase.

The UK textiles and clothing sector was worth £10.2 billion in 2006, with £3.5 billion coming from technical textiles. Global technical textiles reached $126 billion in 2007, but are growing four times faster than conventional textiles, with the EU as a net exporter. The global automotive interiors market is due to reach $210 billion, resulting in an average consumption of 35kg of textiles per car.

Recent years have seen the rapid growth of China (21.9% increase in textile production in 2007) and India (with projected growth to $987m by 2010). Global demand for carbon fibre continues with production capacity increasing to 45,000 tonnes by 2010. Newly introduced nano-fibre production has increased from $40.2m (2005) to $48m (2007), with new production facilities coming on stream.

The UK has significant global influence in terms of fashion, design, the creative arts and retailing. The UK science base has internationally leading expertise in 3D textile manufacture, electro-spinning, fibre surface modification, nanotechnology, simulation and modelling, smart and intelligent textiles, natural fibres, auxetic fibres, medical textiles, protective clothing and non-wovens. Major drivers will be sustainability, the impact of the cost of oil on synthetic fibre production, the demand for multi-functional smart textiles, increasing demand for medical textiles for an ageing population and diversification of China and India into high added-value technical textiles.

A2.7 Construction

The UK construction industry has an output worth £100 billion per annum, accounting for 8% of GDP and employing 2.1 million people [21].

Currently, the key driver for this sector is energy usage through:

- the energy embodied in construction materials and products;
- the energy used during the construction process; and
- the energy used by the users of buildings.

More widely, the sector has to respond to the challenge of sustainable development. Buildings are responsible for almost half the UK's carbon emissions, half the water consumption, about one third of all landfill waste and 13% of all the materials used in the UK economy.

Aligning with the three key priority areas defined within the Energy Materials SRA [21], specific priorities for applied R&D in this sector include:

- coatings for improved performance and protection;
- new joining technologies;
- condition monitoring of buildings – affordable 'smart' structures;
- development and use of recyclable materials; and
- lower temperature manufacturing processes.

'Materials for Energy Conservation in the Built Environment' is the subject of a review by the Construction Materials Working Group of MatUK and will be published in 2008.

A2.8 Defence and Security

The Defence Technology Strategy 2007 [35] identifies Advanced Materials as a key cross-cutting technology, which underpins many aspects of the design, development and manufacture of military platforms and equipment. Key drivers and areas of interest are:

- low observable materials
  - EO,IR,RF and acoustic materials
- platform structural materials
  - polymeric materials, composites, metallics, high temperature materials
- smart materials and active structures
- multifunctional materials and structures
- structural modelling, design and through-life support
  - NDE and health monitoring, corrosion and environmental protection, environmental issues.

Materials, especially ceramics and steels, for protection (armour) and the modelling of structural and dynamic issues of composite materials are highlighted as being of particular national strategic importance.

There are also a number of materials-related topics included in a list of 'Emerging Technologies Relevant to Defence':

- biomimetics
- nano-materials
- smart/interactive textiles.

Although defence-related markets are typically small compared to equivalent civil markets, they often require the development of innovative technologies in order to meet the stringent requirements of military operations. This can benefit civil applications and, hence, justify the co-support of dual-use technology R&D. UK industry can also benefit from the sale of defence equipment, both as an adjunct to civil products and from overseas sales.

Security in the civil environment is an area of growing concern and commercial opportunity in the post '9/11' world. Closely related to the defence agenda, its drivers and potential materials-related solutions include:

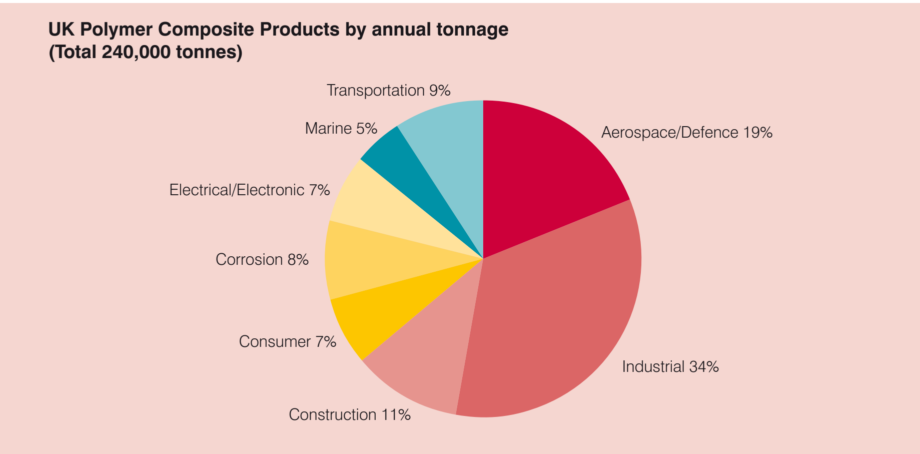
- physical protection
  - armour materials, including 'smart' materials, and
- anti-counterfeiting/identification and identity protection
  - smart functional materials.

Appendix 3 – Market data

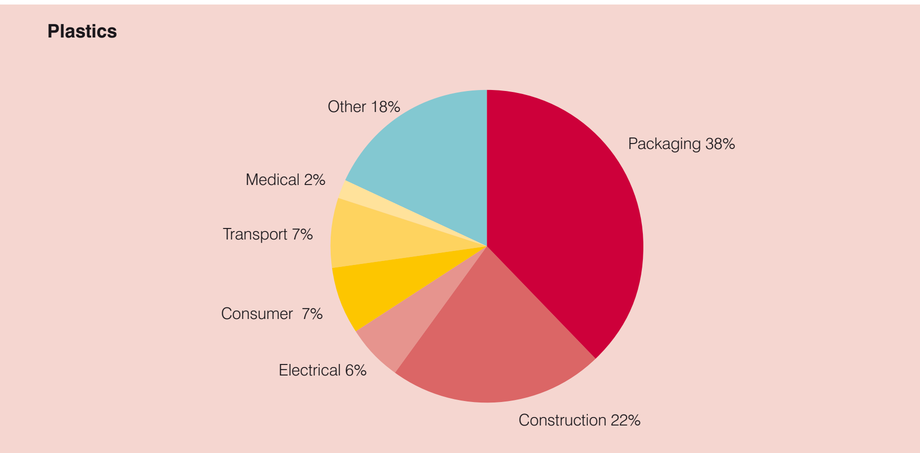
The following charts (Figure 9) represent examples of materials usage against market sector. They illustrate generally the widespread usage of several different classes of material across major market sectors; but with relative usage being specific to individual material/application combinations.

Figure 9 – Examples of specific materials usage against market sector

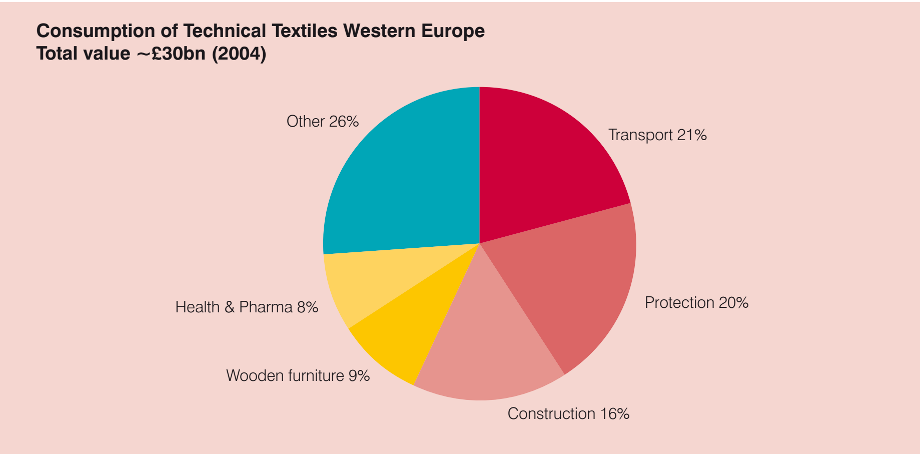
(a) Polymer composites [36]



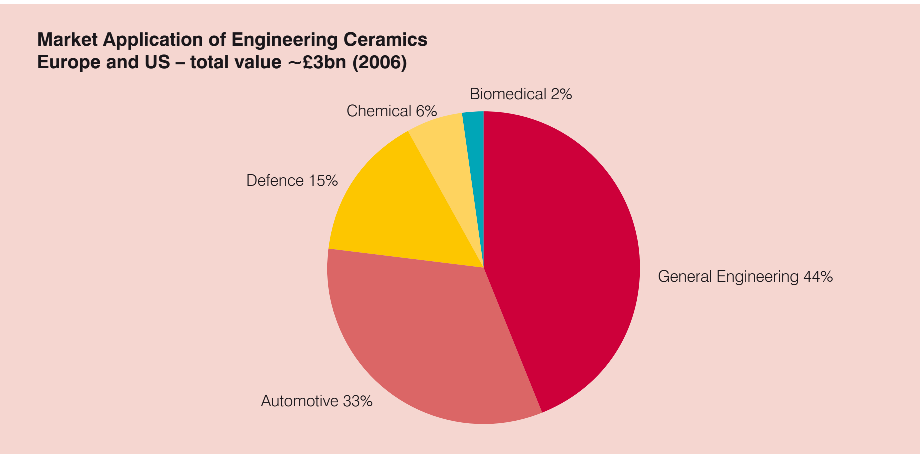
(b) Plastics [37]



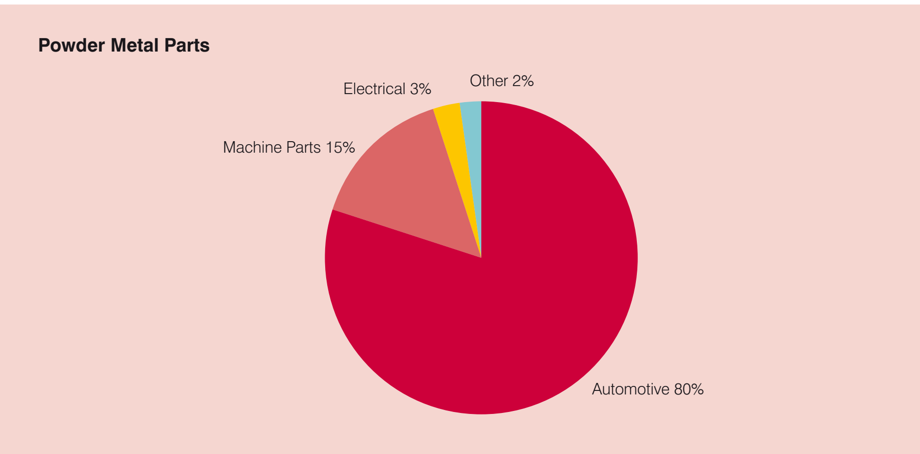
(c) Technical textiles [38]



(d) Engineering ceramics [39]



(e) Powder metals [40]



Appendix 4 – Materials roadmaps

Figure 10 is a compilation of materials-related road-maps which have been produced in the last 3 years under the auspices of the Materials KTN and elsewhere, showing potential linkages into other current Technology Strategy Board Key Technology Areas, Application Areas and Innovation Platforms (all also have generic links to High Value Manufacturing).

Figure 10 – Materials-related roadmaps

Title	Date	Source	Reference	Technology Strategy Board linkages
Advanced Ceramics	2004	Powdermatrix	http://amf.globalwatchonline.com/epicentric_portal/site/AMF/menuitem.e16ae87d77c6ca799c860610eb3e8a0c/	Electronics, Photonics and Electrical Systems
Powder Metals	2004	Powdermatrix	http://amf.globalwatchonline.com/epicentric_portal/site/AMF/menuitem.e16ae87d77c6ca799c860610eb3e8a0c/	Transport (Aero)
Hard Metals	2004	Powdermatrix	http://amf.globalwatchonline.com/epicentric_portal/site/AMF/menuitem.e16ae87d77c6ca799c860610eb3e8a0c/	
Magnetics Sector	2004	Powdermatrix	http://amf.globalwatchonline.com/epicentric_portal/site/AMF/menuitem.e16ae87d77c6ca799c860610eb3e8a0c/	Electronics, Photonics and Electrical Systems
Particulate Materials for Power Generation	2008	Powdermatrix	http://tinyurl.com/yowf52	Energy
Composites in the Aerospace Industry	2006	National Composites Network	http://www.ncn-uk.co.uk/DesktopModules/ViewDocument.aspx?DocumentID=561	Transport (Aero)
Composites in the Automotive Industry	2005	National Composites Network	http://www.ncn-uk.co.uk/DesktopModules/ViewDocument.aspx?DocumentID=574	Transport, Low Carbon Vehicles
Composites in the Construction Industry	2006	National Composites Network	http://www.ncn-uk.co.uk/DesktopModules/ViewDocument.aspx?DocumentID=564	Low Impact Buildings
Composites in the Marine Industry	2006	National Composites Network	http://www.ncn-uk.co.uk/DesktopModules/ViewDocument.aspx?DocumentID=569	Transport
The Metal Matrix Composites Industry	2006	National Composites Network	http://www.ncn-uk.co.uk/DesktopModules/ViewDocument.aspx?DocumentID=579	Transport (Aero)
Composites Foresight Report	2007	National Composites Network/ IOM3	http://www.ncn-uk.co.uk/DesktopModules/ViewDocument.aspx?DocumentID=632	Transport, Low Impact Buildings
Carpet and Floor Covering	2004	TechniTex	http://amf.globalwatchonline.com/epicentric_portal/binary/com.epicentric.contentmanagement.servlet.ContentDeliveryServlet/AMF/Roadmaps/Carpet%2520and%2520Floorcovering%2520Technology%2520Roadmap%2520-%252021st%2520November%25202007.doc	Environmental Sustainability

Title	Date	Source	Reference	Technology Strategy Board linkages
Technical Textiles	2004/2005	Technitex	http://amf.globalwatchonline.com/epicentric_portal/site/AMF/menuitem.dcabd10ea22a3a71d50fb3f2ebd001a0/	Various
Tissue Engineering Scaffolds	2005/2006	Technitex/ Medical Devices KTN/ Polymer Innovation Network	http://amf.globalwatchonline.com/epicentric_portal/binary/com.epicentric.contentmanagement.servlet.ContentDeliveryServlet/AMF/Roadmaps/Tissue%2520Engineering%2520TRM%2520write3.doc	Biosciences; Medicines and Healthcare
Antimicrobial Materials	2008	Technitex	http://amf.globalwatchonline.com/epicentric_portal/binary/com.epicentric.contentmanagement.servlet.ContentDeliveryServlet/AMF/Roadmaps/Antimicrobial%2520Roadmap%2520Draft%25203.doc	Biosciences; Medicines and Healthcare
Smart Materials	2006	SMART.mat	http://amf.globalwatchonline.com/epicentric_portal/binary/com.epicentric.contentmanagement.servlet.ContentDeliveryServlet/AMF/smartmat/SMARTMATtrmREPORT.pdf	Various
Smart Textiles	2006	Smart Textiles Network	www.smartextiles.co.uk/workspace/upload/Project_Ideas.pdf	Biosciences; Medicines and Healthcare; Creative Industries; Electronics, Photonics and Electrical Systems
Titanium	2006	Meta4	http://amf.globalwatchonline.com/epicentric_portal/site/AMF/menuitem.96a163f6d127672b1006a0108380e1a0/	High Value Manufacturing
Surface Engineering	2006	Meta4	http://amf.globalwatchonline.com/epicentric_portal/site/AMF/menuitem.96a163f6d127672b1006a0108380e1a0/	High Value Manufacturing
Biomedical Surface Engineering	2006	Meta4	http://www.namtec.co.uk/uploads/docs/1187184150SEG_Biomed_Report.pdf	Biosciences; Medicines and Healthcare
Thermal Management Materials	2006	Advance	http://www.faraday-advance.net/news.php?article=73	Transport; Electronics, Photonics and Electrical Systems; Energy
Structural Ceramics (DRAFT)	2008	SCERN	http://portal.surrey.ac.uk/portal/page?_pageid=992,1150918&_dad=portal&_schema=PORTAL	High Value Manufacturing

Title	Date	Source	Reference	Technology Strategy Board linkages
Using science to create a better place	2007	Environment Agency	http://publications.environment-agency.gov.uk/pdf/SCHO0407BMNT-e-e.pdf.	Environmental Sustainability; Nanotechnology
Materials for Energy	2007	EU Specific Support Action – "SMART"	http://www.smart-ssa.net/c3/index.php?index=22 (ISBN 978-3-89336-477-0)	Energy
Materials for Security	2007	EU Specific Support Action – "SMART"	http://www.smart-ssa.net/c3/index.php?index=22 (ISBN 978-3-89336-477-0)	Various
Biomaterials	2007	EU Specific Support Action – "SMART"	http://www.smart-ssa.net/c3/index.php?index=22 (ISBN 978-3-89336-477-0)	Biosciences; Medicines and Healthcare
Materials for Packaging	2007	EU Specific Support Action – "SMART"	http://www.smart-ssa.net/c3/index.php?index=22 (ISBN 978-3-89336-477-0)	Environmental Sustainability
International Roadmap for the Packaging Industry	2006	Faraday Packaging Partnership/PIRA/ Cambridge U	www.faradaypackaging.com	Environmental Sustainability
High Tech Textile Materials	2007	EU Specific Support Action – "SMART"	http://www.smart-ssa.net/c3/index.php?index=22 (ISBN 978-3-89336-477-0)	Various
Foresight Vehicle		DTI	www.advantagewm.co.uk/clusters/mapping/WM_Transport_Foresight_Vehicle_Technology_Roadmap.pdf	Low Carbon Vehicles
Glass Technology		US Department of Energy	www.oit.doe.gov/glass/pdfs/glassroadmap.pdf	High Value Manufacturing
Steelmaking		American Iron and Steel Institute	www.oit.doe.gov/steel/roadmap.shtml	High Value Manufacturing
Materials		US vision 2020 Chemical Industry of the Future	www.chemicalvision2020.org/pdfs/materials_tech_roadmap.pdf	Various
Alumina		The Aluminium Assoc. (US)	www.oit.doe.gov/aluminium/pdfs/alumina.pdf	Transport; Low Carbon Vehicles

Appendix 5 – A world-class science base

The UK has a world-class science base in advanced materials, which is ranked fourth in the world behind the USA, Japan and Germany, in terms of total numbers of papers and citations.

Total UK University research funding for materials research is at least £95 million per annum. This includes approximately £60 million from EPSRC, £7 million from other UK Research Councils, and the remainder from other sources, including industry and the EU.

EPSRC funds individual research projects across all UK HEIs. However, in practice, most research grants are held in a relatively small number of institutions; as shown in Figure 11 (2002-2007).

The EPSRC Materials Programme categorises its portfolio into six sub-programmes; the distribution of funding, as a percentage of the total Materials Programme budget, has remained fairly consistent over the last five years:

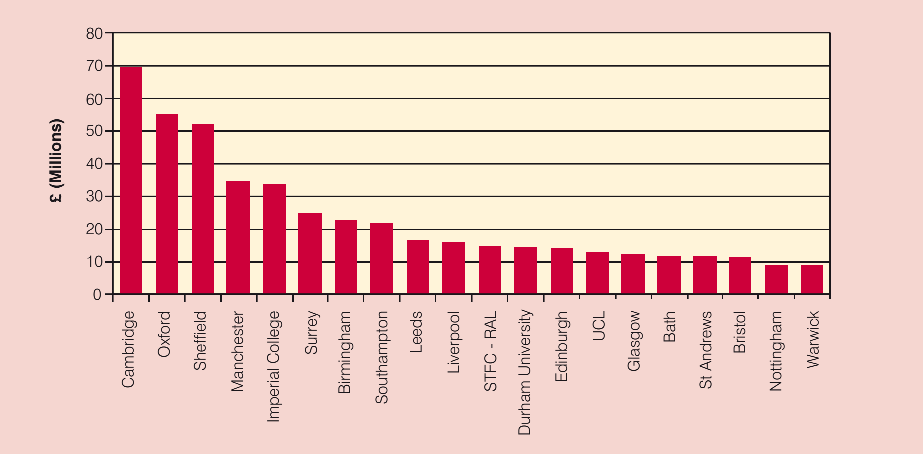
- Structural ceramics materials and inorganic 12%
- Structural polymers composites and polymer 20%
- Metals and alloys 15%
- Superconducting materials and magnetic 10%
- Electronic materials 20%
- Photonic materials 23%

There are currently about 600 Principal Investigators holding research grants from the Materials Programme, from a wide range of departments including Chemistry, Physics and Electrical Engineering, in addition to Materials.

Over the past five years, 1,259 stakeholder collaborations have been recorded on EPSRC-funded materials projects; over this period, industry has contributed around £72.5 million in cash and kind towards projects funded by the EPSRC Materials Programme.

Evidence submitted to a recent International Review of Materials in the UK has shown that international "best with best" collaborations are taking place with materials researchers in the USA, Japan and the EU in the areas of: nanotechnology; materials for extreme conditions; chemical engineering; catalysis; and computational science, and that UK materials scientists are excelling in interdisciplinary work.

Figure 11 – A strong UK materials science base



Appendix 6 – Technology Strategy Board programmes

A6.1 Collaborative R&D

Each of the Technology Strategy Board CR&D Calls, with the exception of Autumn '06, has had a core generic Materials theme. This has led to some 90 projects with a total value of around £100m. Each of the Calls has been oversubscribed by several times, indicating a strong materials-related capacity within the UK science and technology (S&T) and industrial bases and that the Calls were timely. The industrial participants, including both end-user organisations and their supply chains, also cover a wide range of market sector interests, indicating strong and multiple opportunities for exploitation.

Materials-related projects have also been supported under other Call themes, again demonstrating the pervasive nature of the technology. For example, eleven projects (~20%) funded under the Micro and Nanotechnology (MNT) Programme have a core materials theme, representing a total value of around £7.5m. In addition, six materials-based MNT Centres have been established to facilitate technology access. Similarly, in the Energy sector, seven current materials-related projects have a total value of around £10m. More recently, a call for 'Bioactive Materials' projects under the Biosciences and Healthcare KTA, in Spring '07, led to the support of eleven projects with a total value of around £13m.

A6.2 Knowledge Transfer Networks

Networking is important within the materials sector, in connecting the broadly-based stakeholder community and catalysing collaborative business activity. This is currently undertaken primarily by the Materials KTN, which has had a successful first two years. With a membership of around 7,000 via a nodal structure, it has made a difference in respect of the Technology Strategy Board's priorities related to knowledge transfer, innovation and performance. There are a number of examples where KTN support has already led to direct business benefits, primarily through the implementation of a small-scale pilot 'proof-of-concept' (SPARK Award) scheme (see Section 4). A review of networking is currently underway.

A6.3 Knowledge Transfer Partnerships

There are circa 50 projects within the current Knowledge Transfer Partnership (KTP) portfolio of around 1,000 projects, which fall within the broad scope of the Advanced Materials KTA. This is in line with expectations based on the number of KTAs over which projects span and supports both the view that materials technology is important to industry and that there is a good innovative science base in this area. A further 68 materials projects were completed between 2003 and 2007. These attracted circa £4m of government grant support and have led to significant direct business benefit; with a £30m overall increase in annual profit reported by the industrial participants.

Appendix 7 – Glossary

ACARE	Advisory Council for Aeronautics Research in Europe
AeIGT	Aerospace Innovation and Growth Team
AIN	Aerospace Innovation Network
BERR	Dept for Business, Enterprise and Regulatory Reform
BSI	British Standards Institute
CMC	Ceramic Matrix Composite
CR&D	Collaborative Research and Development
DIUS	Dept for Innovation, Universities and Skills
DA	Devolved Administration
EngD	Engineering Doctorate
EPES	Electronics, Photonics and Electrical Systems
EPSRC	Engineering and Physical Sciences Research Council
ERA-NET	European Collaborative Network
EU	European Union
FMCG	Fast Moving Consumer Goods
GDP	Gross Domestic Product
GVA	Gross Value Added
iCASE	Industrial CASE Award
IGT	Innovation and Growth Team
IOM3	Institute of Materials, Minerals and Mining
IP	Innovation Platform
KAA	Key Application Area
KT	Knowledge Transfer
KTA	Key Technology Area
KTN	Knowledge Transfer Network
KTP	Knowledge Transfer Partnership
MatIGT	Materials Innovation and Growth Team
MatUK	Materials UK
MMC	Metal Matrix Composite
MNT	Micro and Nano Technologies
MOD	Ministry of Defence
NATS	National Aerospace Technology Strategy
NDE	Non-destructive Evaluation
NMP	Nanosciences, Nanotechnologies, Materials and New Production Technologies
NMS	National Measurement System

NMI	National Measurement Institutes
NPL	National Physical Laboratory
PMC	Polymer Matrix Composite
PV	Private Venture
R&D	Research and Development
RC	Research Council
RDA	Regional Development Agency
RTO	Research and Technology Organisation
S&T	Science and Technology
SHM	Structural Health Monitoring
SME	Small and Medium Sized Enterprise
SRA	Strategic Research Agenda
TRL	Technology Readiness Level
UK	United Kingdom
UKTI	United Kingdom Trade and Investment

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