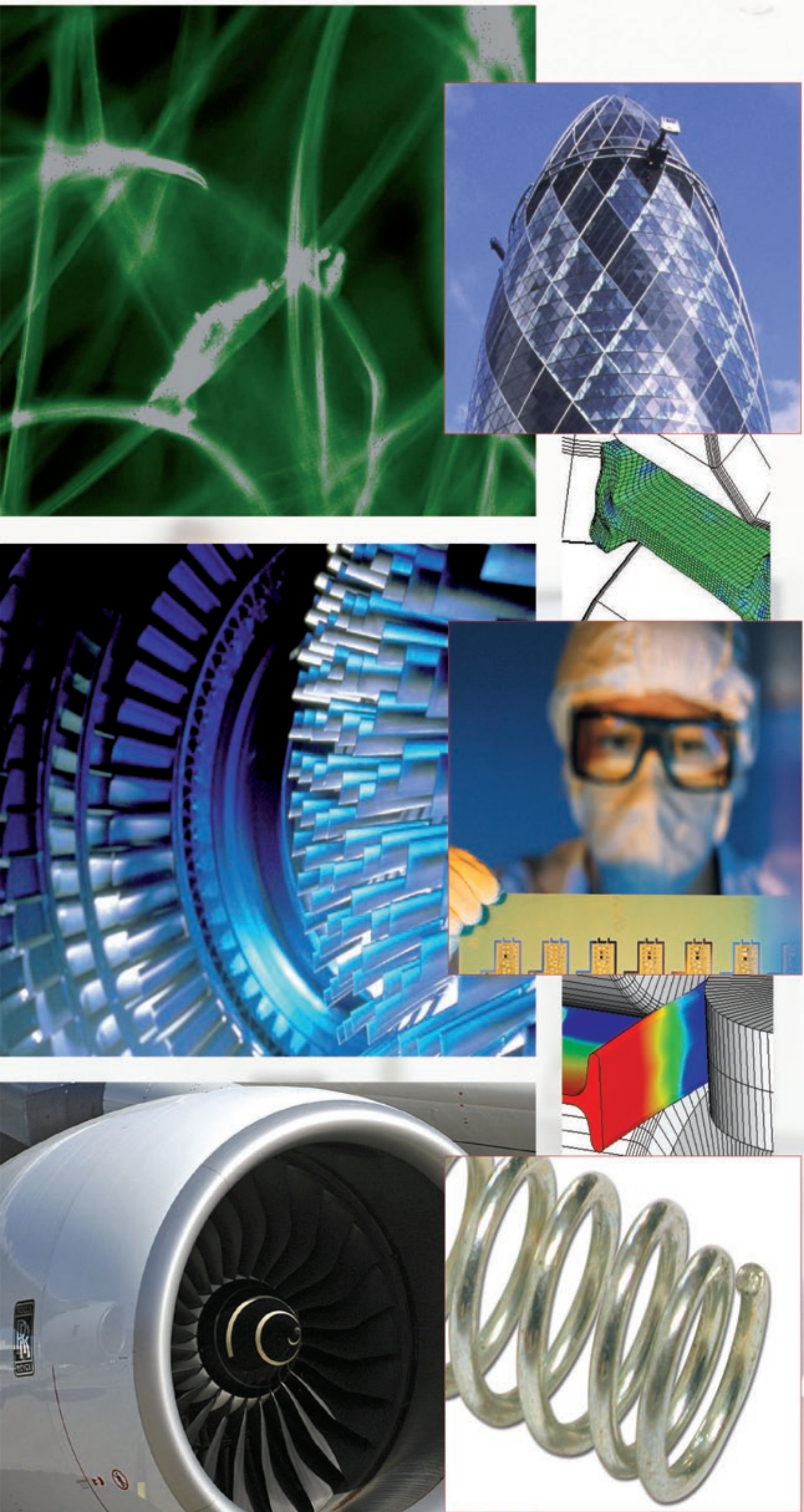
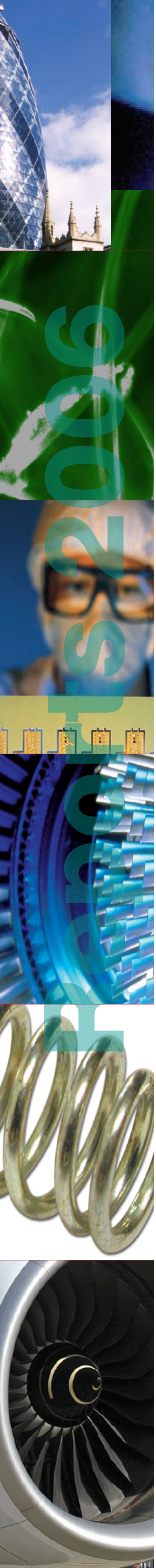
Materials UK
Owned by the materials community

Science & Technology



Report 2006



Foreword

Materials are an essential part of our everyday lives. They underpin everything we need for daily life, from home to work and leisure. New materials have a huge impact in all the areas that make life liveable, from transport, defense, security, information and communications technology to advanced manufacturing. The continued growth in the use of materials, together with the challenges posed by health, climate change, energy supply and the quest for sustainability bring pressures on innovation to bridge this conflict between satisfying society's demand and what is sustainable.

The Science &Technology Task Force of the Materials Innovation and Growth Team are an essential part of the process of identifying new opportunities for industry, government and academia in forthcoming technology. It stands as a signpost to the future. It cannot insist that this direction be followed but it can point the way.

This series of reports will significantly improve the thinking on new directions for materials, materials exploitation with a sustainable future whilst identifying further opportunities for national stakeholders.

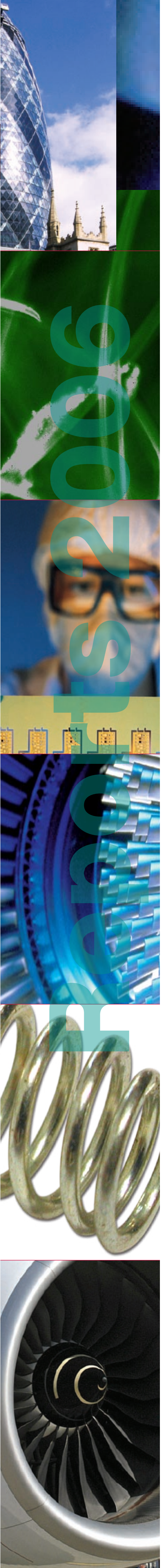
The Science & Technology Task Force has a long track record of being a major influencer within the UK technology sector and with the combined expertise of this Task Force, I would expect this record to be enhanced further. Under the umbrella of the new body, Materials UK, which will unite the materials community under a common vision then the Science & Technology Group will have an increasingly important role to play.

I thank all the members for their time and effort. I wish also to express my thanks to the Institute of Materials, Mining and Minerals who facilitated this exercise and to the Department of Trade & Industry for their continued support and encouragement.

Professor Graham Davies, FREng
Chairman Science & Technology Task Force
Materials IGT
Picture of Graham Davies [0463507P.jpg]

Co-Chair
Professor David Bott

Secretary
Mrs Jackie Butterfield



Introduction

Materials play an increasingly important role in our everyday lives: the development and application of new materials has a significant effect on our use of energy, our health, our use of communications technology and our security. Innovation is not restricted to new materials it is also relevant to the use of conventional materials in new applications. It is clear that a manufacturing and innovation strategy which highlights advanced materials development is increasingly likely to provide wealth creation, commercial success and improved quality of life.

The Materials Innovation and Growth Team, Science and Technology Task Force is an essential part of the process to identify new opportunities for industry, government and academia. Its recommendations will stand as a signpost to the future.

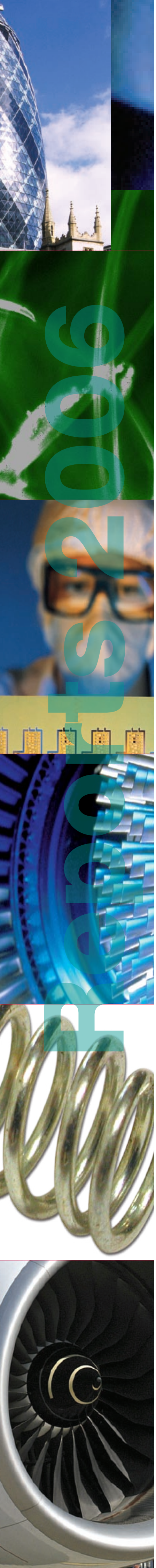
The terms of reference of the Materials Innovation and Growth Team (MatIGT) were to develop a strategy that will enable the UK to optimise the benefits that new materials developments will offer. This group has been charged with determining the strategic directions for materials and processes over 5, 10 and 20-year horizons and aims to secure agreement on a shared vision for the future of an industry that employs over 4 million people in the UK.

The Materials IGT presented its report and recommendations in March 2006.

At its Inaugural meeting, the Science & Technology Task Force, identified a number of priority areas, namely:

- New Materials – subdivided into:
- Structural Materials
- Functional Materials
- Multifunctional Materials
- Biomaterials
- New Processes & Road Maps
- Modelling
- Recycling

A number of sub-groups were formed to consider these areas and develop a series of recommendations for the respective stakeholders.



Methodology

The methodology chosen by the group was to consult the wider community as early as possible in the study and to ensure as wide coverage as possible with a range of stakeholders.

The initial start point for the group was the previous Foresight study, which provided an excellent platform from which to launch the group and further build upon. The format used in previous Foresight exercises was employed whereby the Science & Technology Task Force selected experts in the relevant scientific fields. These experts were then allowed to select their teams and the directions they wished to follow. This was then, regularly, monitored and supervised by the Steering Group.

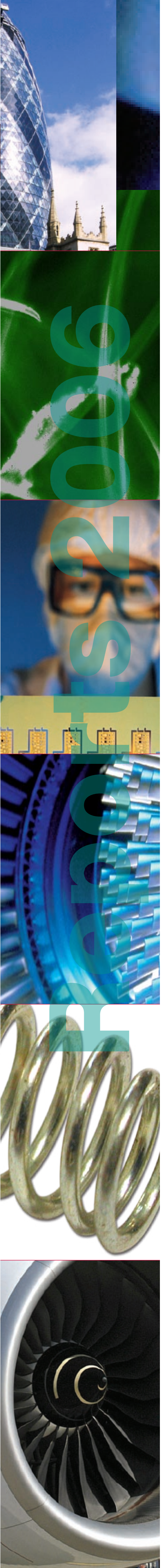
Stakeholder Engagement

In addition to the expert teams a number of specific groups were identified for consultation in order to poll them for their materials science and technology priorities. These were:

- DTI Technology Theme Leaders
- Other Innovation and Growth Teams
- Faraday Partnerships
- Technology Strategy Board
- EPSRC
- EUMAT (European Materials Technology Platform)
- Overseas Technical Attachés

Input has also been collected from industry and regulatory bodies e.g. Construction Products Association and DEFRA.

The wider community contacts gathered at the initial launch meeting and from subsequent meetings were kept informed of the groups activities via email contact and the Materials KTN Web Portal (formerly Advanced Materials Forum (AMF)).



Consultation Methodology

It has been an imperative of the Science and Technology Task Force to consult widely and often. A range of different communications channels have been used, including:

- **Materials World**

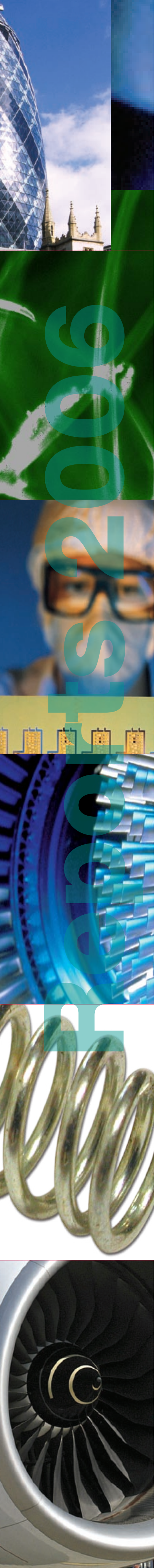
An article was published in the May 2005 Issue of Materials World detailing the work of the group and seeking contributions from the wider community.

- **Materials KTN (formerly Advanced Materials Forum)**

Presentation and discussion material has been made freely available to all members of the Advanced Materials Forum through the Materials IGT Pages.

- **Town Meeting**

A Town Meeting was held on Tuesday 7th June 2005 at the Institute of Materials, Minerals and Mining in London. Over 60 representatives from the wider materials community came together to discuss the future issues surrounding materials science and technology. Delegates from industry, academia, materials manufacturers and end-users were represented at the meeting. The task group chairs gave their views on the direction of each task group and the attendees were asked for their inputs. Seven breakout groups met in the afternoon of the event and formulated a list of issues for each area. These are now recorded on the Materials KTN for further comments. The feedback from the delegates was that this was a very successful meeting which succeeded in prioritising the important aspects of materials technology.



Recommendations

Priority Recommendations

The Materials IGT Science and Technology Task Force has commissioned and produced a comprehensive set of reports which highlight the state of the art in the materials sector. From these reports the Steering Group have distilled five imperatives which need to be acted on now if the UK is to retain and enhance its competitive position in the world in this important industrial sector. The individual reports provide the detail and further recommendations in their own technology areas and are published separately. The five imperatives are:

1. It is imperative that the UK develops a National Materials Network[1]

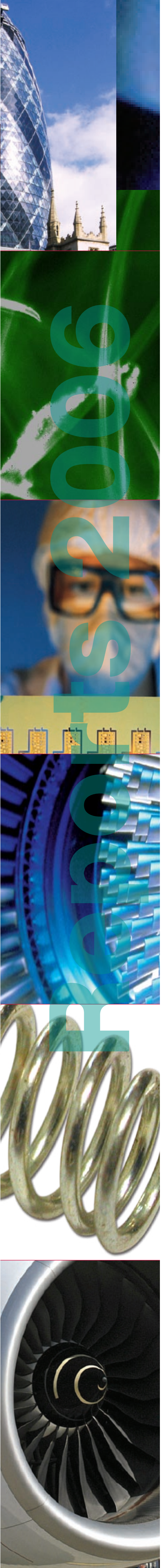
The debate on the formation of a National Materials Network has been resolved. The network should facilitate access to resources and enable optimum use of existing facilities, eliminate the need for duplication of expensive equipment and make more efficient use of existing infrastructure. In addition such a network should provide central co-ordination and signposting of materials research, services and equipment, whether located in industry, government or academic laboratories, to SMEs and other potential users.. A network should also have the advantage of being brought in to service as quickly as possible. This initiative would require the commitment of government, academia and industry. Priority needs, services & facilities should be identified and existing networks strengthened and supported. It is strongly recommended that energy materials, semiconductors and composites are priority areas for such support.

Action required by Government/ Industry and Research Councils. To be effective £50m over 3 years is needed to support and enhance the network.

2. Continuity of Funding is essential if Materials Innovation is to be nurtured and brought to fruition[2]

The structure of research and development funding mechanisms in the UK must be reviewed, in order to provide continuity of funding for materials initiatives over extended periods. Consideration must be given to "phased" funding schemes which would give a fixed level of funding during the initial development phases of a scheme, the funding then continuing for a further period of time but gradually scaled down as industry support is gained and as the project and innovations are brought to market. This would facilitate the transfer of research and development out of the laboratory and into industry. Aligned with this, mechanisms to fund technology demonstrators are also required. Materials-related research and application-driven exploitation is often high risk and lack easily identifiable funding

[1] This was an issue that was also prioritised by the Assets and Infrastructure Working Group of the Materials Innovation and Growth Team.



streams, putting the UK at a serious disadvantage over its major competitors, in getting new technologies to the market. In return for this funding, the IPR, technology and industry stays in the UK, creating new markets, wealth and future employment.

From numerous reports on the support of innovation in the UK, the EU and worldwide it is imperative that other funding models must be considered, the most important being:

Small Business Innovation Research Program (SBIR):

SBIR is a highly competitive funding program in the USA that encourages small business to explore their technological potential and provides the incentive to profit from its commercialisation. By including qualified small businesses in the USA's R&D arena, high-tech innovation is stimulated and the United States gains entrepreneurial spirit as it meets its specific research and development needs.

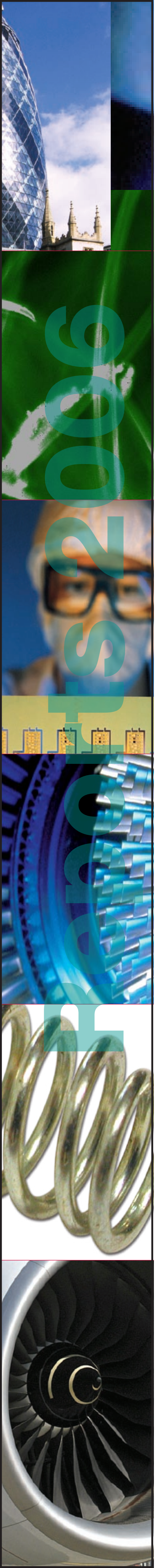
Following submission of proposals, agencies make SBIR awards based on small business qualification, degree of innovation, technical merit, and future market potential. Small businesses that receive awards or grants then begin a three-phase program.

- Phase I is the startup phase. Awards of up to $100,000 for approximately 6 months support exploration of the technical merit or feasibility of an idea or technology.
- Phase II awards of up to $750,000, for as many as 2 years, expand Phase I results. During this time, the R&D work is performed and the developer evaluates commercialization potential. Only Phase I award winners are considered for Phase II.
- Phase III is the period during which Phase II innovation moves from the laboratory into the marketplace. No SBIR funds support this phase. The small business must find funding in the private sector or other non-SBIR federal agency funding.

The US SBIR funding model should be investigated with a view to implementing a similar system in the UK. State Aid rules will require amendment for this model to be implemented. Small business funding mechanisms require a higher level of funding if they are to be effective in the market place. This issue was highlighted in the Foresight review of spin out companies.[3]

2. This was an issue that was also priotitised by the Impact & Policy Working Group of the Materials Innovation and Growth Team

3. http://www.iom3.org/foresight/Spinout%20report%20web.pdf



The Defense Advanced Research Projects Agency (DARPA)

DARPA is the central research and development organization for the US Department of Defense (DoD). It manages and directs selected basic and applied research and development projects for DoD, and pursues research and technology where risk and payoff are both very high and where success may provide dramatic advances for traditional military roles and missions.

This is a very successful model for the funding of academic, industrial (including SMEs) and government R&D. Key elements of the model include strong, autonomous, Programme Managers seconded from academia and industry, as technical experts in a particular field; large targeted budgets for a relatively long period (typically >5 years) but bounded against a criterion of success; and strong and competitive involvement of the SME industrial community.

Government Procurement Strategy

A much more intelligent use of government procurement is required to drive innovation in the materials sector. This issue has been raised several times in various for a; however, now is the time to implement the recommendations of the recent strategic review of these processes to ensure maximum benefit is derived from the UK research and development base. The changes would also provide economics of scale through the use of more uniform standards.

Action required by Government, both the DTI and the Treasury

3.Materials for Energy must be a priority for R&D Funding by the DTI/Treasury and the Research Councils

The DTI should set up a task force to address the materials for energy issues. There is an urgent need to establish a sustainable approach to energy, in terms of production, usage, conservation and management whilst at the same time meeting strict economic and environmental targets.

Priority must be given to the research, development and modelling of materials for energy applications. Energy is one of the highest priority sectors which can ensure the successful development of the UK economy. This hugely important area impacts on all classes of materials and encompasses all methods of energy production including coal, oil and gas; nuclear fission, fusion and decommissioning; fuel cell technologies; renewable energy sources; green issues and energy conservation.

The development of future energy technologies will not be possible without a complete strategy for materials.

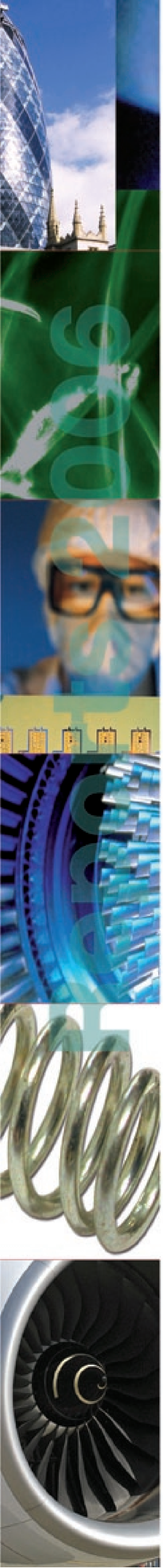
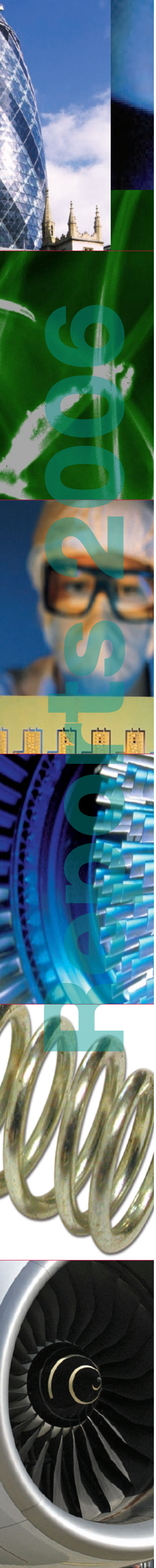


Table 1 shows the impact of materials technologies in the area of Energy.

Table 1.

Energy	Plant/ components	Structural Materials	Functional Materials	Multifunctional Materials	Biomaterials
Generation *Conventional and advanced fossil*	*e.g.* Steam turbines Boilers Gas turbines Gasifiers Fuel cells Hydrogen from coal Coal liquefaction	Steels Alloy steels Superalloys Ceramics Composites Coatings	Activated carbons Filters Interconnectors Membranes Sorbents Chemical looping materials	Structural health monitoring systems Diagnostic Smart materials Catalytic filter materials	Anti-corrosion biofilms
Generation *Nuclear*	*e.g.* Boilers & turbines Decommissionin g/ storage Reactor vessels Fission/fusion materials	Steels Alloy steels Superalloys Ceramics Composites Coatings	Filters, Active carbons	Structural health monitoring Materials for remote robots Self-repair materials SMART materials	
Generation *Renewable*	*e.g.* Wind turbines Tidal power Hydro turbines Biomass plant Heat exchangers Fuel cells	Composites Polymers Steels Superalloys Ceramics Coatings	Photovoltaic Thermal materials (Geo and Solar) Fuel-cells materials Anti-fouling coatings	Photovoltaic materials Piezoelectrics Fuel-cell materials Catalytic Filters Conducting membranes Solid Electrolytes Thermoelectrics Power harvesting Structural health monitoring SMART actuation materials	Biofuels Biomimetic structures Biohybrid materials Anti-corrosion biofilms
Transmission	*e.g.* High conductivity applications Insulators	Ceramics Polymers Composites	Piezoelectric materials Superconductors		
Storage *Electrical*	*e.g.* Batteries	Ceramics Non-ferrous alloys	Electrode materials	Electrodes and Electrolytes Materials for integrated power systems	
Storage *Hydrogen*	*e.g.* Pipelines Compressors Pressure Vessels	Steels Alloy steels	Carbon Nanostructures Activated carbon membranes		
Conservation	*e.g.* Lightweight structures Thermal insulation	Composites Ceramics	Photochromics Electrochromics Thermochromics	Smart packaging Thermal management Energy harvesting	Biodegradation

In addition to the above, effort should also be made to recover and develop the knowledge-base of high integrity structural materials for future power generation, much of which has been lost over the last 20-30 years following the privatisation of the CEGB and the lack of investment in nuclear plant.4



Action required by DTI/Treasury, Academia /Research Councils and Industry

4. Materials for Sensing and Diagnostics must be supported

Sensors and Diagnostics has been identified as a critical growth area, with materials technology fundamental to its development and application.

Priority must be given to the research, development and modelling of materials and technologies for sensing and diagnostic applications. This has been highlighted as a key theme which will play a significant role in all aspects of our lives both now and in the future, including: security, both personal and homeland; energy; transportation; healthcare; the built environment and communications and IT.

It is recommended that a Steering Group be set up immediately to review the field and to set priorities for materials R&D in the UK. Those sensor applications that have the greatest promise should be prioritised for further research funding.

It cannot be emphasised enough that materials are the essential ingredient of Sensing and Diagnostic technologies. Increasingly these will lie in the categories of functional and multifunctional materials, and their combination and interdisciplinary work is required in order to model and develop materials and related technologies.

Key to bringing these materials to market effectively will be the optimisation of lower cost processing technologies (e.g. direct writing technology), their successful integration into systems and structures, and improvements in their subsequent lifetime and reliability.

The recently established DTI Smart Materials, Surfaces and Structures Network (SMART.mat)[4] will address these issues in consultation with industry and the science and technology base.

[4] http://www.smartmat.org

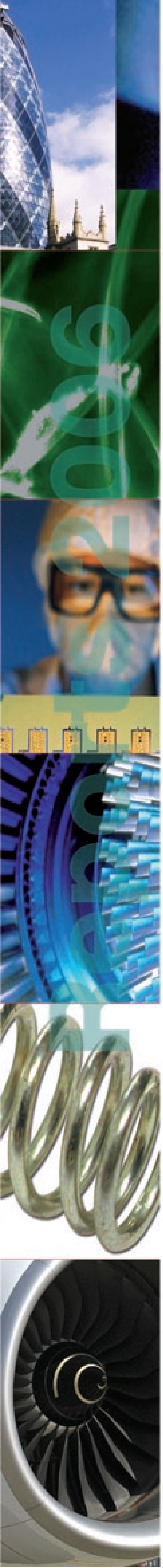
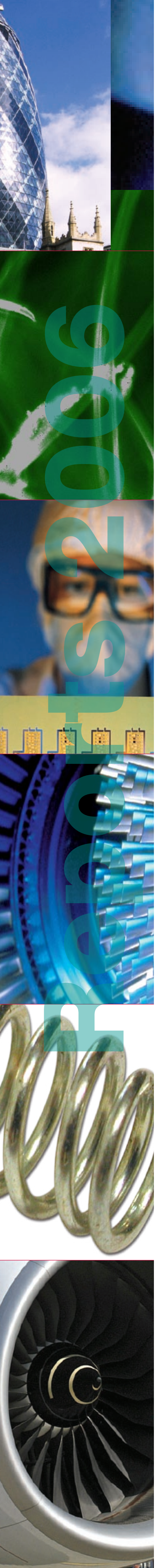


Table 2 shows the impact of materials technologies in the area of sensing and diagnostics.

Sector	Structural Materials	Functional Materials	Multifunctional Materials	Biomaterials
Healthcare	Implant wear / prosthetics	Telemedicine/ robot surgery Body signs	Health monitoring 'wearables' Remote sensing Biocompatible materials	Assays Drug delivery systems Intelligent Implants
Energy	Embedded Sensors Structural Monitoring On-line sensors	Coated Systems Heat, Pressure, temperature sensors	Diagnostic Coatings Structural Health Monitoring systems	Waste management
Construction	Lifetime measurement	Concrete ageing	Structural health monitoring/ diagnostics	Microbial hazards
Transport	Composite monitoring	Heat, pressure, wear Asset management Proximity alarms	Integrated sensors/ actuators Self-diagnostics	Driver alertness Environment quality
Retail		Produce lifetime Stock management	Smart packaging Sports equipment Product Tagging Printable power	Antifouling Biosensing
Communications	Asset management – proactive fault reporting	Magnetic Optical Network security		Biomimetic networks
Security	Structural/building management – earthquake sensors	Smoke detection Gas detection Identification	Anti-counterfeiting Offender tagging Biometrics	Biometrics Biohazard detection
Agriculture Food			Product Tagging Smart Packaging Antimicrobial surfaces Food processing sensors	

Action required byDTI, Academia /Research Councils and Industry



5. Holistic Modelling of Materials Lifecycle and Length Scale are imperatives for funding

The holistic modelling of materials on length and lifecycle scales will facilitate the development of new materials and processes in a timely and more cost effective way.

Modelling the continuum, particularly on the meso scale is an area in which enormous benefit can be derived for example in the area of joining technologies.

Whole lifetime predictive modelling, cradle to grave is key to the development of new materials as well as to sustainability, recycling and re-use. The development of generic models in this area would be particularly valuable.

Active interest and involvement from industry is vital in this area.

Action required from Research Councils / Academia and Industry

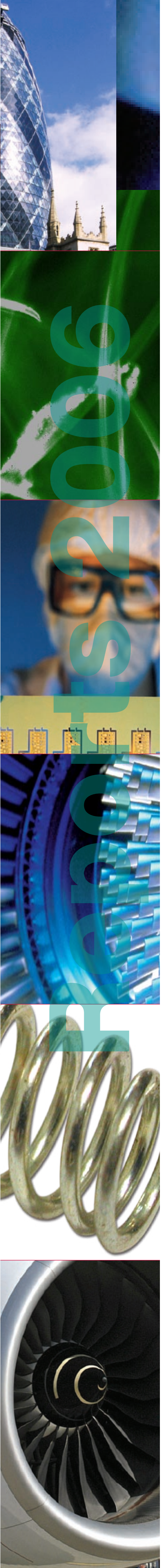
Further Recommendations

In addition to the Task Force's five major imperatives it was felt important to identify other specific priorities which also need urgent action if the UK is to remain competitive in the materials industry.

a) Support for Structural Materials R&D is essential to ensure that the UK's environmental, sustainability and security initiatives and targets are met.

Of all material classes, structural materials, directly and indirectly, make one of the greatest contributions to employment and GDP in the UK. They represent a highly diverse and strongly multidisciplinary area, with links to numerous industrial sectors such as aerospace, energy, construction, automotive, leisure, security and defence. Structural materials comprise a number of classes such as metals (ferrous and non-ferrous), composites (eg. Ceramic, metal and polymer matrix), construction materials (eg. Glass, concrete, steel, ceramics, wood) and others such as structural & refractory ceramics and polymers. Whilst the range of materials may be diverse, many common technical challenges have been identified:

- the need for materials to withstand more aggressive environments eg. Extreme temperatures, stresses, impact & weather conditions.
- the requirement to reduce environmental impact both in their production, end-use and recyclability.
- the need to understand complete materials 'systems' (eg coated components, sandwich structures, composites, joints)
- the need to improve the modelling of materials through the full life cycle (alloy design, production, processing, manufacture and end-use) including lifetime prediction.
- the requirement for better NDE and condition monitoring of structural materials and their manufacturing processes.



- the drive for lower cost through innovative production and processing methods.
- the need for technology transfer between materials sectors and novel alternative uses for existing materials.

Historically, significant benefits have been gained by ‘incremental’ developments in structural materials. This philosophy must be maintained and supported, whilst an environment for the development of applicable ‘disruptive’ technologies is encouraged in the longer term through the UK research base.

Despite the UK being world leaders in many sectors involving the development and utilisation of structural materials, such as in aerospace, energy, F1 racing, etc, they generally have an image of being ‘low-tech’ which impacts on the level of priority and support they receive and also on the recruitment into the sector. Materials UK (MatUK) and the Materials Knowledge Transfer Networks (KTNs) should raise the profile of structural materials and promote an ‘integrated’ approach involving industry, research councils, government and Regional Development Agencies (RDAs). A sustainable long-term strategy should be put in place that will ensure the promotion of the structural materials sector, provide increased added value through the development of cross-sector synergies, facilitate technology transfer and ensure the alignment of R&D priorities. All of this must be underpinned by a sustainable funding strategy.

Strong market drivers currently exist to develop value added products across a number of sectors. The support and development of the UK as a world leader in many aspects of structural materials will provide an excellent opportunity to exploit these markets.

Action required by Government(DTI)/Research Councils/Industry

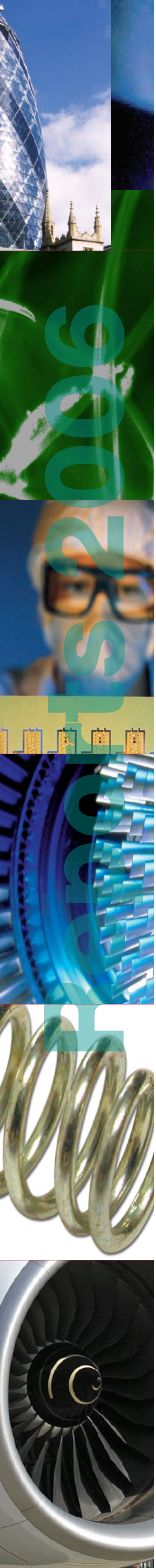
b) As the next big step in product development, Multifunctional Materials demands investment in both basic and applied research and development

Multifunctional Materials represent a highly diverse and strongly multidisciplinary area, with links to functional, structural and bio-materials topics. Strong market drivers exist to develop added value products across numerous sectors, including aerospace and transportation; healthcare; packaging; energy; 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
- Structural / power generating materials.

As the next big step in product development, they 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.



The area of biomimetics, which aims to draw inspiration from nature, is ripe for innovation and future exploitation of Multifunctional Materials.

The SMART.mat Network will be particularly relevant and important in this area, and will help to facilitate technology exploitation in consultation and collaboration with industry and the science and technology base.

Action required by the Research Councils /DT/industry

c) Support for Biomaterials is essential as a healthcare priority, particularly for the development and refinement of bioresorbable and bioactive materials

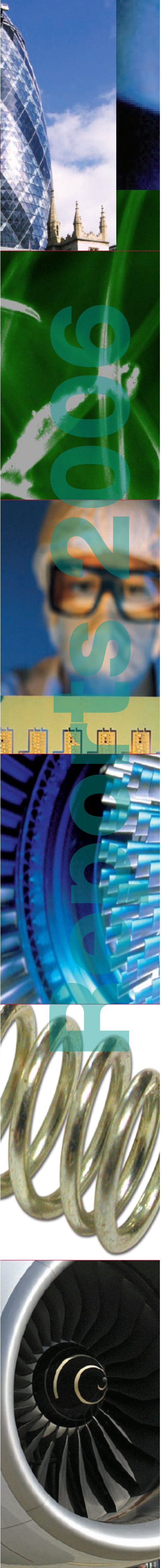
Bioresorbable polymeric materials have already been used as part of surgical intervention procedures. Fundamental materials design and concepts are already in place, so it is likely in the next 5 years that new materials with controlled interfacial properties and predictable degradation will enter the market, initially for conventional surgical use, but subsequently as scaffolds able to provide structural integrity for a defined period until the body's own regeneration process can replace lost tissue architectures. As part of this development, degradable systems will be designed for controlled release of bioactive components to enhance tissue repair and regeneration. Progression to this commercial stage will depend upon refined manufacturing and production techniques of existing materials.

Novel manufacturing will further extend the functional, structural and multifunctional repertoire of existing, clinically acceptable biomaterials, with adaptation of processing technologies from other materials sectors. With avoidance of many of the regulatory hurdles using existing materials, new biomaterials products will emerge within 5 years, many incorporating bioactive components, with retained stability because of more biologically compatibles process development.

Action required by Government(DTI)/Research Councils

d) Nanotechnology must be further supported to drive innovation through to industrial exploitation

It is recognised that this is not now a new area of technology. However, given the UK government's existing investment in nanotechnology, it is now imperative this is brought to fruition and industrial exploitation. Funding must be maintained to ensure this occurs. A great deal of scope still exists for innovation and development in this area and it pervades all areas of materials. There will be increasingly important innovative ideas arising in the areas of nanomaterials, nanomedicine and nanobiosciences. There should be a continuing programme of development and support for exploitation of nanotechnology in order to bring the industrial applications to maturity.



Action required by Government(DTI)/Research Councils/Industry

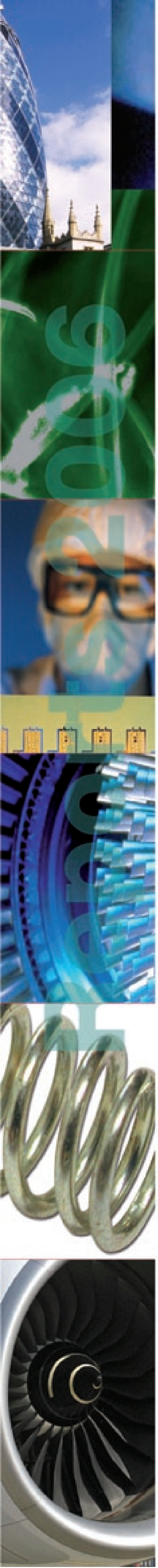
e) The Materials KTN must facilitate the engagement between designers and materials technologists which will lead to new and innovative applications of materials

There should be greater interaction between materials scientists and engineers and the design community in order to disseminate knowledge and information on the capabilities of materials. A forum should be available to facilitate this engagement at which information can be exchanged to encourage new and innovative applications of materials.

An example, where this has been successful and to the great benefit of the UK economy, is the interaction between specifiers, designers and the steel community in the UK to promote the use of steel in construction. This has resulted in the UK taking a lead in this innovative application of steel to the construction industry.

The Materials and Design Exchange programme (MaDE) has begun this process and should be supported and encouraged to expand this initiative.

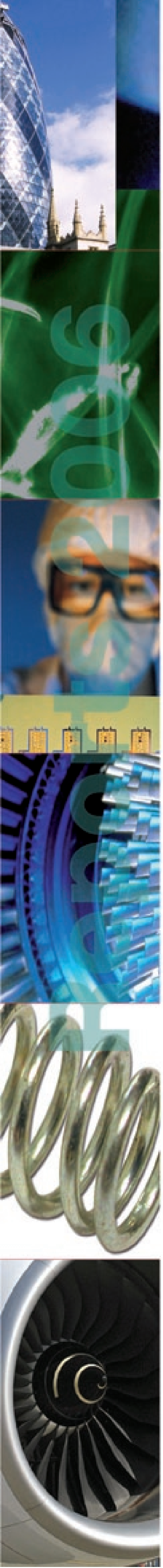
Action required by Government(DTI)/Industry



Conclusions

The Science and Technology Task Group of the Materials Innovation and Growth Team has used its combined, broad-ranging expertise, supplemented by extensive and sustained consultation, to derive the following five key recommendations:

	Recommendation	Action On
1	It is imperative that the UK initiates a National Materials Network/Centre	*Government/ Industry and Academia*
2	To ensure Materials Innovation is nurtured and brought to fruition, continuity of funding is essential	*Government*
3	Materials for Energy must be a priority for R&D funding	*Academia /Research Councils and Industry*
4	Research & Development in the area of Materials for Sensors and Diagnostics must be supported	*Academia /Research Councils and Industry*
5	Holistic modelling of materials lifecycle and length scale are imperative	*Academia /Research Councils and Industry*



We have also identified a number of emerging issues for additional consideration.

	Recommendation	Action On
a	Support for Structural Materials R&D is essential to ensure the UK's environmental, sustainability and security initiatives and targets are met.	*Government(DTI)/Research Councils/Industry*
b	Multi-functional Materials is an emerging technology area that needs support	*Research Councils / Government(DTI)/ Industry*
c	A continuation of support for Biomaterials is essential, particularly for the development and refinement of bioresorbable and bioactive materials	*Government(DTI)/Research Councils*
d	Nanotechnology needs to be further supported as innovation moves to industrial exploitation	*Government(DTI)/Research Councils/Industry*
e	Design interaction with Materials Scientists and Engineers must be fostered	*Government(DTI)/Industry*

Moving Forward

Arising from the recommendations of the Materials Innovation and Growth Team, a new body, Materials UK has been formed to take forward the recommendations of the Materials Innovation and Growth Team. (See http://www.matuk.co.uk/)

The work of the Science & Technology Task Group with continue under the banner of Materials UK and the main task of the group will be to further the develop and drive the recommendations described in this report.