Mapping out the future for the road ahead
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The views expressed in this report are the personal opinions of the Panel and Task Force members and do not represent the official views of the Department of Trade and Industry or the organisations they represent.
Foreword from the Foresight Materials Panel

The development and application of new materials has a significant effect on our use of energy and our health, our use of communications technology and our security. In short, materials play an increasingly important role in our everyday lives. It is clear that a manufacturing and innovation strategy which highlights advanced materials development is more likely to provide wealth creation and commercial success.

Foresight is an essential part of the process to identify new opportunity for industry, government and academia. It stands as a signpost to the future.

In this new series of reports, the third phase of Materials Foresight, new thinking is provided for the benefit of national stakeholders.

The Materials Panel wish to record their thanks to the many individuals and companies who have contributed to the development of these reports, and to the Institute of Materials, Minerals and Mining who provided the secretariat for this work.
Executive Summary

The Foresight Materials Panel has set about encouraging companies to grow their businesses through innovation, and the first stage is to produce technology roadmaps that provide sectors with strategies that have been agreed by all parties involved in specific businesses.

Through teams of experts, technology roadmaps provide a judgement on how a business will progress, up to about 15 years ahead, and determine what products or processes will be required to reach the vision. The barriers to achieving the objectives are noted and the technologies needed to overcome those barriers are identified, and are set on a time scale to provide the roadmap.

In the materials and chemicals sectors around 20 technology roadmaps have now been published and are freely available. The following document collates these, since few people seem to be aware of what has already been carried out.

For the future, it is intended that these technology roadmaps, and any forthcoming ones, will be referenced in the Foresight section of the web-site of the Institute of Materials, Minerals and Mining.

Dr Alan Smith
Foresight Materials Panel
Mapping out the future for the road ahead

After all the cost cutting, downsizing and re-engineering, companies are now focusing on what they believe are their core competencies for the future. They have realised at last that cutting costs can only reflect on the bottom line (profit) for a short period. It might provide the fat cats with more cream for a few years but now the realisation is that technological innovation is the only way to long-term growth and security. The real goal now is step-change innovation that is protected by patents.

The UK Government’s Foresight exercise has proved an excellent catalyst for making many industry sectors think in the longer term, but this has been overtaken, to some extent, by ‘technology roadmapping’. Just as President Bush’s well-publicised roadmap for the Middle East problems is a targeted strategy to solve the difficulties there, technology roadmaps are being drawn on by industry to set strategies for future growth.

Motorola first coined the word ‘roadmapping’ decades ago, but only recently has the high-level planning tool been widely adopted by both individual companies and industry sectors as an essential part of their future growth.

Although a number of roadmaps in chemicals and materials have already been produced in the UK and US on a broad range of topics, figure 1, these vary considerably in the way the roadmapping has been carried out. This led a team at the Centre for Technology Management, part of Cambridge University’s Institute for Manufacturing (UK) to devise an easy-to-use roadmapping process, which has been used by the Foresight Materials Panel, based at the Institute of Materials, Minerals and Mining, to produce a technology roadmap for the natural and synthetic rubber industry.

In summary, the process gathers together groups of commercial as well as technical experts, and takes them through the stages illustrated in figure 2. They need to have sufficient knowledge of the markets and the business to say where the topic under discussion is at the present time. The first step is to provide a vision of where they see it going during the next 20 years.

![Figure 2: Technology roadmapping stages.](image)
<table>
<thead>
<tr>
<th>TOPIC</th>
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<th>LEADING SOURCE</th>
<th>WEB REFERENCE</th>
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<tr>
<td>Rubber</td>
<td>Technology Roadmap for the Natural and Synthetic Rubber Industry</td>
<td>Foresight Materials Panel (UK)</td>
<td>Will be available soon through the Institute of Materials, Minerals &amp; Mining (<a href="http://www.irm.org/foresight">www.irm.org/foresight</a>)</td>
</tr>
<tr>
<td>Colloids</td>
<td>A Strategic Research Agenda for Colloid and Interface Science in the</td>
<td>IMPACT Faraday Partnership (UK)</td>
<td>Will be available soon through the IMPACT Faraday Partnership (<a href="http://www.impactpartnership.org">www.impactpartnership.org</a>)</td>
</tr>
<tr>
<td>Low Energy</td>
<td>Technology Roadmap in Low Energy Polymer Processing</td>
<td>Faraday Plastics (UK)</td>
<td>Will be available soon through Faraday Plastics (<a href="http://www.faraday-plastics.com">www.faraday-plastics.com</a>)</td>
</tr>
<tr>
<td>Polymer Processing</td>
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Figure 1: Selection of technology roadmaps in the chemistry and materials sectors.
The next stage is to determine what products or services will be needed to provide that vision. Finally, many of those products or services will not be achievable with the current level of knowledge, so, having identified the technical barriers, a list of technology ‘needs’ can be drawn up. These targets are usually set out over a timescale, where up to five years is considered short-term, the next five year period is medium-term, and anything after that is seen as a long-term goal.

Technology roadmaps differ mainly in the timescale it takes to produce them. Some have been produced with only 15 to 20 experts, reaching their conclusions in a day. The result might be just a single page summary chart that is subsequently circulated to other interested parties and expanded upon to cover a broad range of topics as feedback is received.

At the other end of the scale, there are roadmaps that are drawn up over several days with different aspects being covered by separate panels. The panels’ efforts are then drawn together, before being published in draft form on the internet. A good example is the nanomaterials roadmap, the results of which are illustrated in figure 3.

There are three types of technology roadmaps – ones that cover an industry sector, a specific technology, or just a particular project. Industry sector roadmaps are usually quite broad in their participation and make a large impact. At the other end of the scale the participation in technology roadmaps for a product tend to have fewer participants and a lower impact. Technology-specific roadmaps lie between the two. All are intended to be working documents that are updated as circumstances change over time.

Generally, a technology roadmap becomes part of a company’s research and development strategy, setting the projects on a realistic timetable that can be matched with planned resources. The advantages of such a process include:

- the incorporation of new technology into the business
- key support for a company’s strategy and planning
- identification of new business opportunities for exploiting technology
- provision of top level information on a business’s technological direction
- support of communication and co-operation within a business
- identification of the gaps in technical knowledge as well as the markets
- support of sourcing decisions, resource allocation, risk management and exploitation decisions
- provision, through high level integrated planning and control, of a common reference or framework.

Currently, the 24 UK Faraday Partnerships are deeply involved in roadmapping many topics within their remit, so many more roadmaps should appear during the next few months. In fact, the University of Strathclyde’s distance learning MSc course in Chemical Technology and and Management now includes a section on technology roadmapping. But before you embark on your own roadmapping exercise, you might find that the competition is ahead of you!
Goals
- identify and enable early commercialisation opportunities (catalysis, coatings, electronic and optical displays, medical diagnostics)
- achieve predictability and control of key building block properties (chemical composition, size, shape, morphology, surface chemistry)
- achieve predictability of life-time of nanomaterials under operating conditions
- develop nanostructured materials that replace organic polymers in photonic devices
- develop nanomaterials that increase energy storage in portable batteries by three times

Barriers
- insufficient understanding to enable prediction of needed properties, and how to achieve them
- inadequate characterisation capability
- insufficient knowledge to synthesise complex heterogeneous structures
- achieving directed self-assembly of building blocks and higher assemblies

Priority research
- develop capability to determine applications enabling properties (modelling, synthesis, characterisation and functional testing)
- develop capability to predict and control enabling properties (modelling, synthesis and characterisation)
- expand the type and number of organic and inorganic nanomaterial building blocks to enable new applications
- develop and incorporate self assembly capability at the interface of building blocks
- develop nanomaterial building blocks that enable self-repair of coating structures at the micron and millimetre level

Potential exploitation
- catalysis (broad range, early opportunity)
- separations (sorbents and membranes)
- coatings (early opportunity)
- high performance materials (strong, light weight, thermally and electrically conducting)
- energy conversion and storage
- pharmaceutical and medical materials
- sensors (chemical, environmental, bio)
- optical and electronic displays (early opportunity)