Appendix 5

New Materials Technologies

I. GENERAL TRENDS

5.1 In recent years, a series of technological breakthroughs have been achieved in developing new materials for a wide range of purposes. These advances have taken place in various materials (including metals, ceramics, composites and polymers), either through developing new types of material or by applying new processing technology to existing materials. In particular, there has been a swing away from metals to ceramics and polymers, a trend which has occurred despite the many kinds of coating being developed to improve metal conservation qualities (such as greater resistance to abrasion and corrosion) and thus to extend the 'life' or use of the final product. Among polymers there has been a gradual movement from those based on petroleum feedstock towards alternative feedstocks, and more significantly, towards ceramics based on common elements (such as oxygen, silicon, calcium).

5.2 Although many of the new materials technologies are still at the R & D or demonstration stage, and are not likely to be used to any significant extent for at least a decade, the above trends imply that resources needed for some future major materials will be available to all countries, rich or poor, whether petroleum-endowed or not. It thus seems possible that in the longer term, a mixture of polymer-based and ceramic-based low-temperature composites could be produced in most if not all countries—including developing countries—using relatively low-cost technology appropriate to each country's own conditions, with all the ensuing advantages that this would entail.

5.3 New materials and process technologies cover a diverse and expanding field. They include: base materials, both organic (such as plastics and rubber) and inorganic (for example ceramics, new cements, metals and alloys) which possess improved purity, structure and composition; reinforced composites which mix fibres in conjunction with base materials to strengthen or enhance them; and new processes, including methods of forming close to final shape, methods of joining parts—such as adhesives—and providing surface treatment to metals and materials to improve their durability. A number of these techniques are still in the early stages of development and are unlikely to be widely used for several decades. However, some of the more mature technologies are likely to be important in the shorter term, either for their potential in creating materials for completely new uses or as potential competitors to existing materials or production processes. Six groups of new materials have received particular attention in this respect, and in the next section we briefly comment on their development and applications.

II. SELECTED DEVELOPMENTS

High-strength low-alloy steels

5.4 One of the most important sectors where new technology is being developed and applied is the iron and steel industry. Here, high-strength low-alloy (HSLA) steels have been developed by using only minor additional alloying agents to enhance the technical qualities of steel in terms of combinations of strength, toughness, formability, ductibility and weldability. These steels are benefiting user industries in several ways, notably in reducing the amount (and therefore the cost) of metal needed to carry a given load. HSLA steels are particularly suited for applications in road vehicle wheels, bodies and structural parts, in other aspects of transport such as building ships, railroad freight cars, bridges and pipelines, as well as in manufacturing heavy equipment, including cranes, and assembling prefabricated buildings.

5.5 The technology for producing HSLA steels is already commercialised, though still being refined. It produces higher value-added products than plain carbon grades of steel and is a more cost-effective process. HSLA steels are consistent with materials conservation, in that less material is needed per unit of final product, and with energy conservation, in that the weight to load ratio is reduced. Their production does however require a deeper application of metallurgical principles and tighter control of production practices than in the case of ordinary carbon steels, and the optimum use of HSLA steels in industrial applications requires designers to be well informed about the particular properties and characteristics of the material. This higher level of skill requirement may be an important constraint on the effective use of HSLA steels in developing countries in the near future but should be overcome in time.

Powder metallurgy

5.6 Powder metallurgy involves the production of metal powders which are compressed, and sprayed or sintered as necessary, to produce steel strips or near final shapes of components and parts. The technology is well established, but is going through a revival because of a combination of technical advances and economic considerations.[1] In general, the powder route towards metal production is taken when it is the only way to process the material (as in making cemented carbide cutting tools); when powders offer lower processing costs (as in making engineering components and parts from expensive alloys by producing near net shapes from powders which are subsequently forged); and when powders offer superior properties in the manufactured parts.

5.7 Most big steel companies are moving towards powder metallurgy to produce steel strips and thus dispense with the ingot phase. The process promises large savings as it needs only one-third of the plant required for the conventional process.[2] Powder metallurgy represents a highly flexible development in process technology and is especially suitable for producing large numbers of identical parts. The rapid solidification technique has led to improvements in the mechanical properties of many alloys based on aluminium, nickel and steel. Though much of the technology is oriented towards the needs of industrial countries, opportunities exist to develop uses suitable for developing countries; for example, producing sheets by rolling metal powders requires less capital investment than by conventional means. A further advantage is that entry into the technology can be undertaken on an incremental basis, starting in a limited way and subsequently expanding processes and products.

Composites

5.8 'Composites' is a generic term describing engineering and structural materials built up of several components having different properties. One example are the new fibres, such as carbon, boron and polyamide, with high tensile strength, high modulus elasticity and low density, which when embedded in a resin matrix provide composite materials with strength-to-weight and modulus-to-weight ratios far above all previously established levels.[3] Such materials include polymer matrix composites (such as reinforced plastics); metal matrix composites (for example those combining fibrous ceramics with metals); and other composites (including fibre-reinforced ceramics or new cements incorporating polymeric additives) which are largely at the R & D stage.

5.9 Not only is the spectrum of materials wide, but so is the range of technologies needed to produce and apply them; from the conventional (such as glass fibre) to the very advanced. Unlike conventional materials, which are usually fabricated into components from milled materials, composites are normally fabricated directly into the required shape. Thus, working with them requires a high degree of integration of materials design, mechanics, structural design, fabrication and non-destructive testing as an iterative process. Success depends on the combined abilities of the designer, structural analyst, materials specialist and fabrication engineer. Non-destructive testing is specially important, since some flaws can be detected only during processing.[4]

5.10 These requirements could constrain the production and use of many composite materials in developing countries. Nevertheless, the composites' wide range of applications, the compatibility of their production technology with the requirements of small and moderate sized markets, and their widespread substitution possibilities, make some of them particularly suitable for developing countries. In certain cases, their production may require only low-cost, locally-available resources and be labour intensive compared with conventional materials production. One example of this are the fibre-reinforced structural materials, where local fibres (such as sisal or bamboo) can be used; another is glass fibre, which involves an already mature technology. For developing countries in general, a graduated approach to new materials is needed, perhaps using, say, glass fibre-reinforced plastics as an industrial base on which to build expertise in other advanced fibre-reinforced composites over a longer term.

Polymers

5.11 Polymer materials, in addition to their use in polymer matrix and other composites, are now well established in a variety of other uses as substitutes for a range of traditional materials (notably timber and metals). Advances in this field are continuing, particularly in the use of polymer fillers (organic or inorganic) which reduce requirements for petrochemical feedstock, and in process technology which saves energy and lowers costs. Developing countries possess a range of materials which could be used as fillers: examples include slag or quartz sand for inorganic fillers and agricultural waste for organic ones. Current R & D could, in the long term, lead to the large-scale production of plastics from biomass, and thus enable many developing countries to become self-sufficient in this basic industrial material.

Engineering ceramics

5.12 Engineering ceramics are a category of fine ceramics which have been developed at high temperatures, usually from compounds including such elements as silicon, carbon, oxygen, nitrogen, aluminium and zirconium. They are light, stiff, resistant to corrosion and friction and have low thermal and electrical conductivity, properties which are increasingly attractive in engineering applications. The technology to produce them is costly, however, and still mainly at the R & D stage, although research is widening the number of new materials (such as oxides) which can be used to form ceramics of engineering quality. Their potential applications include use in advanced diesel and gas turbine engines, cutting tools, process plant, medicine and dentistry.

Electronic materials

5.13 The rapid advances in the microelectronics sector owe much to developments in materials processing, and the creation of new materials has enabled microelectronics applications to be extended in several directions. One prominent example is the use of optical fibres in telecommunications and information networking.

5.14 New materials processes have been used in the manufacture of semiconductors, based largely on silicon and gallium arsenide, and research is continuing into superlattices.[5] Further advances in microelectronics depend on the development of materials to improve electronic devices (for example, by increasing the speed of flow of electrons while reducing power dissipation) and electronic components (including materials for improved luminescent displays, new alloys for component interconnection, encapsulation materials).

5.15 Research into new electronic materials is taking place almost entirely in developed countries and, at least in the medium term, the impact on developing countries is likely to be restricted to these countries' use of the resultant materials.

III. GOVERNMENT SUPPORT

5.16 The development of new materials remains a high-risk activity involving long lead-times and depending on government financial support. Most of the R & D is related to the defence, nuclear and engineering sectors.

5.17 Information on government support for new materials R & D is somewhat fragmentary, but a recent report[6] indicated that in the United Kingdom approximately £50 million a year is spent on this activity by government-sponsored R & D institutions. (Total R & D expenditure by UK manufacturers was approximately £3.5 billion in 1981, but it is not known what proportion was on new materials technologies.) In the United States government support for materials R & D is estimated at over £750 million per annum, with basic research funding estimated at 30 per cent and applied research funding at 60 per cent of the total.[7] About £66 million of this was spent on engineering ceramics. In Japan, MITI's project on basic technologies for future industries is the country's most important programme of this type. Funded at around £300 million per annum over at least eight years, it embraces R & D into new materials, electronic devices and biotechnology. Total Japanese R & D into new materials is probably in excess of £200 million a year.[8]

IV. IMPLICATIONS FOR DEVELOPING COUNTRIES

5.18 Since the term 'new materials' is not a precise one, market size cannot be determined. But these materials are likely to have significant economic effects over the longer term. One major impact is likely to be on the markets for traditional materials; the development of new materials may have a considerable impact on demand for commodities and thus on developing countries' exports. This effect could be specially marked for those countries whose export earnings are dependent on a few commodities (such as copper, bauxite, tin, timber, cotton, jute) which could eventually become obsolete through the development of new materials. There is an implication here for those commodity producers to institute advanced R & D programmes to find new uses for such commodities. The key to a niche in the market place must be continuing R & D. It is conceivable that new materials technology could lead to the development of complementary uses for traditional materials, and thus enhance the demand for commodities. Over the longer term, countries that have acquired the technology for producing new materials might be able economically to use these materials to substitute for imports or embark upon exports, with favourable repercussions on their economies. Doubtless all three effects will occur, but at this stage it is impossible to judge which will be the more important.

NOTES*

1. Epremian (1982), p. 13.
2. UNIDO (1982) ID/WG. 341/1, para. 9.
3. Epremian (1982), p. 7.
4. Ibid.
5. Interleaved thin layers of semiconductor materials or of impurities introduced into a semiconductor to tailor specific electrical properties.
6. UK Government, Department of Trade and Industry (1985).
7. Ibid., Annex 3.
8. Ibid.

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* Complete references to the works cited are given in Appendix 10, Selected Bibliography.