MATERIAIS FOR SOCIETY①

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ABSTRACT

The present paper is an address by Sir Collyear, John F · Eng FIM, the first president of the British Institute of Materials, to the Nonferrous Metals Society of China. It mainly describes the following topics: the eternal importance of engineering materials in economic prosperity and the burgeoning opportunites that lie ahead, the steps needed to turn these opportunities into achievements, and the role of the Institute of Materials in this great and worthy prospect.

Key words: dmaterial, science, engineering, society

1 INTRODUCTION

It is a great privilege and pleasure to give this address here in Beijing. I am here as the first President of the British Institute of Materials and it gives me an opportunity to outline the convictions that I personally hold about how to progress further in the business, science and engineering aspects of materials. I do not know much about materials science and materials engineering here in China but of course I hope to have some better understanding by the time I leave. In this talk I shall be concentrating on the scene in Britain but the key messages have,I believe, world-wide significance.

I will divide this address into three topics: Firstly, the eternal importance of engineering materials in economic prosperty and the burgeoning opportunities that lie ahead.

Secondly, the steps needed to turn these opportunities into achievements.

Thirdly, the role of the Institute of Materials in this great and worthy prospect.

2 MATERIALS AND ECONOMIC PROSPERITY

Materials technology is a key enabling area for economic and social well being. Materials with new and improved properties and innovative methods of processing them give industries competitive advantage to achieve sales around the world. The products lead to better medical care, enhanced safety infrastructural projects, improved and safer transport, sporting and leisure facilities and more environmentally friendly operation. In Britain this is rarely understood in the home, schools, government and to some extent business at large. It is important for scientists and engineers to take the necessary actions to help others to understand what technology does to improve the quality of life in society. In return society will respond by encouraging its able children to become scientists and engineers, and also will ensure that sufficient resources are made available to achieve the reliable and innovative

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use of materials.

It is the responsible, informed and innovative use of materials which is important. Yes, there is intellectual challenge in understanding the behaviour and properties of materials in different conditions. Yes, we must consider carefully the environmental effects of economic activities based on materials and other technologies. Yes, we must develop recycling opportunities if we are to ensure a prudent and rational utilization of natural resources. But it is by the better and more efficient use of materials that we can improve the quality of life, conserve energy, combat pollution and protect the environment.

Recent examples include polymers for automobile bodies which combine greater strength with lighter weight and have effected a 5%reduction in fuel consumption and therefore in exhaust emissions. Another example is the carbon fibre rope for tethering offshore oil and gas platforms. This rope is five times lighter than steel and will enable fuel extraction to be undertaken in much deeper water than before, hence increasing the UK's, and the world's, usable reserves of oil and gas.

In history the human archaeological ages are known in the West by the material which man learned to produce and use during those periods-starting with the Stone Age then into the Metal Ages, of Copper, then the Bronzr Age, the Iron Age and the Steel Age which was part of, and facilitated the Industrial Revolution. Since then materials.have become, slowly and progressively, more sophisticated through the application of scientific methods to established industries involving improved techniques of alloying and blending, improved and new methods of processing, complex assemblies of two or more component materials, and combinations of all of these. I believe we are now moving into a period where unprecedented ideas and opportunities exist for new materials and processes. There is a combination of science and engineering push and of customer need which holds promise for remarkable advances in the use of materials for the benefit of mankind.

Consider first the push from science and engineering. Materials science and materials engineering are moving from well understood classes of homogeneous materials to composites, laminates, and coatings used usually for their mechanical properties and to functional materials used for example in microprocessors, memories, superconductors and other systems. The traditionally different disciplines of metallurgy, ceramics, rubber polymer and glass technology, and solid state physics have come closer together with each other and with engineering to produce a cross-fertilization of ideas, an economy of concepts and, with the developing power of applied quantum mechanics, a common understanding of most of the physical properties of materials. We have reached the stage where quantum mechanics is beginning to explain engineering properties such as intrinsic brittleness or ductility of crystals, and we are within sight of a unified science which starts at the periodic table and Schrodinger's equation and ends at practical materials and engineering use.

In processing, the availability of cheaper computing power, itself the result of materials development, and an improving understanding of the underlying science has led to the development of mathematical models whose use can speed up the sequence from the laboratory through the pilot stage to production, where it facilitates process optimization and improves control of the process leading to reduced costs, improved quality and shortened lead times. These techniques are being applied to the traditional areas such as casting, welding and rolling in addition to the new ones of composites and super-plastic forming.

Now consider the consequences of what the customer wants and will pay for which can take many forms and I will give four illustrations. First, the long term rise in energy costs and also the environmental implications have meant that materials with high specific rigidity and lightness have become key drivers in design specific rigidity and lightness have become key drivers in design and materials selection not only for aircraft and aero engines but also for cars, and they are moving into previously conservative areas for materials selection such as bridges and sports stadia.

Secondly small amounts such as grams or even micrograms of material can determine the performance and specification of large and /or complex pieces or equipment. Silicon microelectronics is perhaps the classical established example but there are others such as the laser diode in a compact disc player or optical fibres in telecommunication systems. There are also products where the cost of the materials of which they are made, is a small percentage, sometimes less than 1%, of the product cost. Numerous examples of this exist in the biomedical field ranging from tooth brushes through hip joint implants to spectacle frames and heart valves. Value added is high; the drive is for improvements in properties and longer performance life. One example here is the use of implants where the cost of material is a secondary-but not an entirely irrelevant-consideration. Offering great potential for inclusion in this category in the future are superconductors, materials able to conduct electricity with virtually no loss of energy in the process. The stiumulus to this field has been the discovery of oxides based on copper oxide containing additions of yttrium and barium which are superconductors at 90K, that is 13 K above the boiling point of liquid nitrogen. Further development of these materials may lead to new propulsion and levitation systems for transport, improved power transmission lines, faster computers and wider availability of nuclear magnetic resonance scanners for medical use.

The third area of customer need is from improved performance. Th aeroplane, helicopter and more recently the spacecraft industries have pioneered the development of materials with higher specific modulus-stiffer-and specific strength-stronger. Honeycomb and composite structures have been introduced in the search for increased strength at lower weight. Duralumin is giving way to the aluminium alloys with small amounts of lithium and superplastically forming, saving tens of thousands of liters of fuel per year on a large modern aircraft. Titanium has been introduced into air frames and gas turbines with improvements in strength, heat resistance and corrosion performance. It has also been used in the chemical industry as a replacement for stainless steel.

In aero engines the performance at any time has been constrained by the limits in strength and temperature capability of materials available. Through the progressive replacement of aluminium and steel by titanium and nickel we have seen savings in weight and increased operating temperatures so that we now have engines with a thrust-to-weight ratio of 10:1 for military engines. Further improvements in performance will depend on the development of fibre reinforced metals and ceramics for use in compressors and turbine blades and eventually perhaps throughout the engines.

However, it is not just in these well known high performance sectors that new strong materials are beling exploited. It is happening in the sporting field and even there it is not just at the highest level of competition that designs using new materials are beling introduced. In running, tennis, squash, cycling, surfing, canoeing and boating, and skiing more and more emphasis is being placed on enjoyment with freedom from injury. In sports shoes, feet experience brief forces of 30–40 g when the heel meets the ground and then forces of 2–3 times body weight as the load transfers to other parts of the foot. As a result, the modern sports shoe has a complex structure of polymers and rubbers to achieve the desired cushioning, wear and support characteristics. Racquets for tennis and squash no longer use wooden frames but instead have fibre reinforced polymer frames giving increased power, and claims of improved safety in squash and of reduced incidence of tennis elbow. In the recent 4,000 m individual pursuit event at the Olympic Games, the winner, Boardman, Chris, rode a bicycle of novel design. It had a single piece frame made from a carbon fibre reinforced resin matrix composite for greater stiffness, and pedals chainset and seat were made of titanium alloy. This was a very successful illustration of imaginative design made possible by exploiting new materials.

The fourth area of customer need comes from environmental considerations and renewed concern about the finite supply of the natural resources of this planet Earth. Consider the problems of recycling. The push for products which perform better and last longer leads to more complex components involving laminations, honeycomb structures, coatings and multi-material assemblies and in turn these make it more difficult to separate and re-cycle materials. Materials engineers and designers face major challenges if they are to move away progressively from the cradle-to-grave approach. Under this approach resources slide down the well established cycles of recovery for metals or polymers and are re-used in a lower grade capacity. We should move increasingly to the cradle-to-cradle approach with the target being re-use to produce the same component. This will necessitate changes at the initial design stage for example to facilitate dis-assembly and separation, or to lable the chemical content of composites. At the same time the scientists and engineers concerned with processing encounter tightening legislation on discharges to air, into water and on to land. A greater emphasis on avoiding problems during the processing operations can be expected to replace the ″end-of-pipe- solutions often used today.

International agreements on the environment tend to get tougher, driven by countries which have lived with stringent standards for some time, and which exert great influence in the negotiations. Quite simply they have the experience, technology and commitment to meet the tougher standards. These countries also tend to be leaders in the technology for sale in their own and other markets. We in the UK see the need to ensure good contacts between industry and policy-makers to ensure a longer view is taken of the way international standards and technologies are developing. In parallel, discussions of the more pressing near-term issues will embrace the implementation of the Environmental Protection Act in Great Britain under which operators need to apply BATNEEC-the Best Available Techniques Not Entailing Excessive Cost. The standards authority BSI has recently published BS7750, a new British Standard for environmental management systems to provide a framework for organizations to manage their own environmental performance using a quality systems approach that can be audited and is capable of certification. BS7750 can also be used to enable industry to prepare itself in advance for the adoption of the eco-audit regulation, proposed by the European Commission.

The continuing importance of steels which with concrete comprise the most important structural materials in the developed world is self-evident. Annual production of steel lies typically between 700–800 million metric tonnes per year and there is an abundant supply of iron, and most of the alloying elements used in steel, in the Earth's scrust. Some forecasts predict that overall demand will decrease by the beginning of the next century, but remember the steam effect on sail. The excellent all-round properties of steel-its strength, toughness, weldability and the well established recycling and re-use industry, will ensure that it will continue to be used to build the large scale structures such as ships, oil platforms and buildings. New manufacturing methods have produced a range of high strength low alloy steels, bake hardening steels, ultraclean steels, and advanced coated steels which to the car industry offer improvements in weight, and therefore fuel performance, higher quality and lower costs, improved styling and also better corrosion resistance for longer life. New techniques for direct reduction of the ore are environmentally beneficial and the industry has made developments giving large energy savings. I have no doubts of further advances being made as steel fights back.

Carbon fibre composites and aluminium alloys are making significant challenges for automobile body production. The recent announcement of the aluminium space-frame automobile illustrates the challenge with lightness, reduced tool costs, shorter design to production times, and improved scrap value. The challenge from titanium to replace stainless steel in some applications will also be interesting to follow.

What can we expect in further new applications over the coming decades? Some of these I have already mentioned, but let me speculate again. Composites of metals and ceramics used throughout gas turbines giving engines which can operate at higher temperatures, are lighter, and, having fewer parts, more reliable? High grade thermoplastic polymers competing with steel for use in pipe lines. May be developments in steel to turn the tide? Ceramics used more widely in the reciprocating internal combustion engine. Alloys and composites of titanium aluminium or magnesium used not only in the aerospace industry but more widely in bicycles, chemical plant and power lines. Sporting performances further enhanced by equipment made from polymer fibre reinforcements, in tennis, fishing, golf and other sports.New medical and dental treatments to replace teeth and bone joints damaged by disease and wear, and artificial organs for use in reansplant operations. Engineering polymers used more widely in cars and other products.

Smart or intelligent materials have begun to feature in the literature. There is no agreed simple definition of what is covered by this title at this stage but at the simplest level is the rope which, like humans, changes colour when subject to excessive strains and gives warning of possible failure. Or the shape memory alloys which change shape with a temperature change, as exploited in garments which recover their shape after washing. Or consider a structure such as an aircraft wing, a bridge pylon or parts of a chemical plant with fibre optic wires embedded to detect the early stages of structural failure. Signals could then pass to a microprocessor also embedded which would assess the information and then operate actuators to help the structure to protect itself. And then eventually the stage where the sensors, actuators and control are not embedded systems but formed by being built up on the atomic scale.

Through the science of biomimetics, we are learning how nature has evolved to produce structures to withstand environmental stresses and modify themselves in response to changes and damage. There are opportunities to use these in other structural engineering applications. After all wood is one of the best known fibre reinforced composites and its cellularstructure is more complex than any synthetic cellular composite currently available. It has been designed and optimized by Nature over a long period and we have much to learn from the results of trial and error buried in the evolutionary process.

3 WHAT IS NEEDED TO BRING THESE OPPORTUNITIES TO REALITIES

So what needs to happen to ensure that the people, economies and industries of the world benefit from these and numerous other opportunities that arise from the fuller exploitation of materials.

In Britain, first we need more engineers who can show the flair and ingenuity to conceive, design and make the products exploiting this new understanding. At times it seems that too many engineers believe that materials have intrinsic properties which are isotropic; that materials are homogeneous and free from defects. Materials scientists know that properties are controlled by microstructure and chemical composition, and rarely homogeneous. We need to build into the education of managers with responsibilities ranging widely in engineering, and including the purchasing functions, an appreciation that properties are a consequence of the microstructure and composition which in turn depends on the manufacturing process; and that consistency of properties can be ensured not only by inspection of the quality of the finished product but preferably by building control into the process, often by comparison with a mathematical model.

A most serious weakness in the training of engineers is usually the lack of coverage of non-metallic materials, their properties, processing, ageing and service performance. Whilst this remains they are unlikely to know when they need to seek specialist advice. Engineers need the ability to understand and apply the advice. In turn this will help them to develop a more systematic approach to materials selection which takes account of all of the relevant factors including functional requirements and total life costs of systems rather than selection which operates on a component by component basis and uses established practise as the main criterion. Have you the same problem in China?

Consider next the training of materials scientists and materials engineers. In the UK we produce annually roughly 500 graduates and 100 technicians in these subjects. A wide range of curricula is possible within the accreditation criteria and this diversity is widely supported within the UK materials community. A recent questionnaire showed there is some disquiet about the quality of quaduates beling produced and the decrease in provision of education for materials technicians. In general, industry had little direct influence on curricula and even when consulted had difficulty in persuading academia to make rapid changes due to the nature of the course-planning process. Perhaps the change to modular courses which is happening in most universities and polytechnics will result in a better match between industrial need and course provision. Have you achieved a satisfactory balance?

So much for the course. But how do we ensure we attact good quality students into science and into these courses, a pertinent question at a time when in Great Britain we are faced with a down-turn in the number of school-leavers electing to study materials science. First in Britain we need to extend our support of the Engineering Council initiative in schools; to convince pupils-and teachers and parents-that engineering is a worthy profession which enhances the quality of the lives of themselves and their families. Secondly within that framework that materials science and materials engineering offer an intellectually satisfying challenge and career opportunities in industry, government, academe and other sectors.

The need for improved technology transfer was highlighted in the report on the 《Wider Application of New and Improved Materials and Processes》 published in 1985. It was produced by a government committee of which I had the honour to be chairman. This report identified a ten-point framework for accelerating the use of new materials. Many of these points have been taken up but slowly and not always in the way envisaged at the time. The recent Materials Matter programme by the Department of Trade and Industry (DTI) has been targeted on raising awareness and application of new materials within manufacturing industry and particularly in the small to medium sized enterprises. Co-ordination and collaboration have been developed in research programmes with increased emphasis on industrial links. I was pleased to learn that DTI is continuing with a second programme of awareness and other technology transfer activities.

The formation of the Materials Commission in the government agency, the Science and Engineering Research Council (SERC), responsible for allocating finance to Universities to support research, and the establishment of its interdisciplinary research centres in superconductivity, semi-conductors, materials in high performance applications, polymer science and technology, and biomedical materials show the importance attached to a properly-coordinated approach to materials research. Materials technlology requires a multi-disciplinary approach to advance. Materials science and materials engineering need to progress together; it is the feedback from engineers and users which illuminates the science of materials and its extension. Research in universities has an underpinning role and I believe that any system of fund allocation should be based on a proper interaction between the scientific and engineering requirements.

More needs to be done on raising awareness, on the availability and accessibility of validated information on materials properties, on the development and dissemination of engineering dessign methods and on the provision of database systems which can be used by designers lacking materials expertise.

4 THE INSTITUTE OF MATERIALS

Let me now tell you something about the Institute of Materials, its provenance, what it does and its future objectives. The Institute of Materials was formed on lst January 1992 from the Institute of Metals, itself the result of earlier mergers of the Iron and Steel Institute, formed in 1869, the (non-ferrous) Institute of metals, formed in 1908, and the Institution of Metallurgists, the professional body, formed in 1945. Its objectives are:

(1) to promote and develop;

1) all aspects of the science technology and use of materials;

2) the practice and study of materials science and technology;

(2) to further and coordinate education in these areas;

(3) to maintain and increase the level of professional competence of Materials Engineers and Materials Scientists;

The Plastics and Rubber Institute, the Institute of Ceramics, and the British Composites Society are being incorporated into the Institute of Materials so that by the beginning of 1993 we shall have roughly 20,000 members. other British bodies are in discussion with us about developing working relationship and we shall be open-minded to proposals for other bodies in the materials field to join us.

Our first and foremost objective is to continue to provide our members with the kind of service and support that they need in order to maintain and improve their professional and career prospects etc. As members and their employers show increasing recognition of the need for continuing education and training throughout an active career, we must ensure that training needs are properly identified. Provision of courses making full use of the increasing range of information technology will be supported with proper account of geographical, technical and other factors. We have an active programme of conferences and seminars, promoting the exchange of ideas and pooling of expertise across the field of materials-metals, polymers, ceramics, composites and others. The programme is the result of the dedicated work of technical committees of members supported by an experienced. Conference Department with full-time staff members. We are active members of the Engineering Council along with other engineering institutions and shall collaborate in its review of the structure of the Engineering professional institutions. We have good contacts with many national and international bodies. We shall maintain these and extent them where appropriate. We shall evolve easy access bridges for those individuals in related fields to contribute to our endeavours.

With the utmost priority we shall seek to attract more people particularly the younger scientist, designer and engineer into membership. Grass roots involvement of members in the activities of the Institute will be encouraged. A carefully formulated organizational structure will allow for vital regional inputs and also for specific materials inputs. The Institute will be a catalyst for emerging concepts, nurturing them but not neglecting our traditional activities and this includes ensuring that the interests of those members whose fields are in the main stream of existing materials (perhaps 95% of material usage) feel well served by the Institute. A corporate associateship will be examined to help develop a closer interaction with industrial companies.

Through our membership of FEMS-the Federation of European Materials Societies and our worldwide bilateral links we shall develop our international role. There are opportunities in East Europe, West Europe, South Africa and elsewhere. Proposals for the Institute to co-ordinate and provide policy advice to government and its agencies have been made. They will be positively considered and carefully developed.We have a successful publishing department which is responsible for producing books, learned and other journals, and teaching software. Its activities will be expanded where and when suitable opportunities are identified.

I hope I have managed to convey something of the excitement I feel about the current state of materials science and materials engineering, and also on the challenge and opportunities facing our profession and the Institute. We have achieved much but we have so much more to offer society. It will be an interesting and I hope rewarding time for all those involved. I hope that through this address you have a better understanding of the materials scene in Britain. Perhaps it will also inform the internal discussions which I am sure you are having on these topics.