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Expert Group Meeting on
Materials Policy Issues

Bangalore, India, 11-13 December 1991

REPORT*

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Contents

I INTRODUCTION

The Expert group Meeting on Materials Policy Issues was held in Bangalore, India, from 11-13 December 1991.

It was organised by the United Nations Industrial Development Organisation in cooperation with National Materials Policy Project, TIFAC/Department of Science and Technology, India, and Asian and Pacific Centre for Transfer of Technology (APCTT).

The Meeting was attended by 16 experts from 6 countries, in their personal capacity, representing expertise in various aspects of materials policy. The list of participants is attached as Annex 1.

The main objectives of the Meeting were the following:

- to exchange experiences accumulated by developed and developing countries in materials policy formulation and implementation;
- to identify common elements of a policy framework concerned with advanced and upgraded conventional materials and common approach to cooperation in this area;
- to discuss the mode and scope of international cooperation and work and recommendations and joint follow-up activities for strengthening the technological capabilities for developing new materials and their utilisation through formulation of national materials policies.

Opening of the Meeting

In opening the Meeting, the Director of the Technology Development and Promotion Division, UNIDO, welcomed all the participants and also drew attention to the valuable work and substantive support of the National Materials Policy Project, and Asian and Pacific Centre for Transfer of Technology in organising and holding the Meeting. He stressed the importance of materials policy formulation and implementation and expressed the hope that the meeting would address the different dimensions of this question.

The rationale for the Meeting

The Director of the Technology Development and Promotion Division of UNIDO pointed to the fact that UNIDO places heavy emphasis on capability build up in developing economies. The onset of new scientific and engineering capabilities in the field of materials has resulted in an enhanced capacity to engineer materials for specific uses. This is a very powerful tool which can be used to meet industrial, medical, environmental and other needs. Not only can entirely new materials be produced but existing and traditional materials can be upgraded. This has important implications for developing economies, hence the emphasis on building up indigenous capabilities to improve conventional materials and processing technologies as well as to utilise locally available resources in doing so. The process necessarily requires an interdisciplinary approach, cutting across the physical and social sciences, involving as it does several materials, industries, producers and users. Further, materials issues must be looked at in the context of sustainable development strategies.

The question then arises as to what constitutes 'materials policy' and what role the government can play in this. In many cases the materials industry has received support within the framework of national science and technology policies. In other cases a national policy framework has evolved exclusively concerned with materials issues (eg India's National Materials Policy Project). Nevertheless, given the complexity of the subject matter and the pace of technical change, it is felt that countries can benefit from an exchange of information regarding the experiences of both developed and developing countries in materials policy formation and implementation, providing an opportunity to identify both common problems and approaches, and potential areas for fruitful international cooperation. In this UNIDO can play a catalytic role, and this forms an important rationale for the meeting. The latter must also be viewed as part of the continuing process to promote the establishment of an International Materials Assessment and Applications Centre (IMAAC), the function of which is to provide the global institutional framework, sorely lacking at the moment, enabling developing economies to address materials issues in a comprehensive and unified approach. These and many other issues were addressed by the meeting (see Sections III and IV) leading to the conclusions and recommendations outlined in Section V of this Report.

<u>Election of Officers</u>

The participants unanimously elected Professor R. S. Ganapathy, India, as the Chairman of the Meeting.

<u>Adoption of the Agenda</u>

The Meeting reviewed the Provisional Agenda and approved it. A timetable for the Meeting was also drawn up.

<u>Presentation of papers</u>

Experts from six countries presented their papers reflecting experiences in the area of national materials policies in such countries as Brazil, the European Community, India, Japan, Malaysia, Mexico, Republic of Korea, Singapore, Province of Taiwan and the United States of America. The papers identified basic elements in materials policy and its formulation and implementation in countries at different levels of socio-economic development. UNIDO's Programme on Technological Advances in the area of new materials has been reviewed as well as other activities related to the subject.

II MATERIALS POLICY ISSUES: AN OVERVIEW

Recent years have witnessed major transformations in the scientific and engineering foundations of materials design, characterisation, testing, processing and applications. Materials are emerging as a science-based high technology sector with serious implications for innovation, competitiveness, growth, employment, the global division of labour, trade patterns and the environment.

Materials Science and Engineering (MSE) integrates the structure synthesis/processing- properties-performance continuum and provides, thereby, an inter-disciplinary, unified approach across all classes of materials. This has opened up vast potential for the improvement of traditional materials as well as for the design of knowledge-intensive advanced materials tailored to specific end-use requirements. The building of a critical minimum mass of MSE capabilities at the level of the firm, industry and the economy is becoming an issue of central importance for competitive survival in the 1990s and beyond. These considerations lead directly to the proposition that, in some form or another, materials policy has emerged as an issue of critical importance on the international agenda.

World industry is currently undergoing deep restructuring, a process further enhanced by the diffusion of information technologies and, increasingly, new materials across products and industrial processes. A complex international and regional redivision of labour is emerging in which economies at different levels of industrial and economic development are shifting towards more sophisticated and higher value-added products and processes. The process is led by the reorientation of industrialised advanced countries (IAC's) in Europe, Japan and North America towards higher value-added products and advanced manufacturing technologies, closely followed by Newly Industrialised Economies (NIE's) such as Republic of Korea, Province of Taiwan, Brazil and Mexico, and second tier NIE's and emerging economies such as India, Malaysia, Thailand and Nigeria. The evidence increasingly points to the fact that new materials are beginning to play a central role in the competitiveness of national branches of industry; in trade and investment flows; in the location and sourcing strategies of multinational corporations; and in national economic and military security considerations. Given the critical importance of materials synthesis and processing in underpinning technological advance across most industrial and military fields, the formulation and implementation of appropriate materials strategies has not only been recognised as a matter of urgent priority by many governments around the world but has also made substantial progress in many such cases of recent.

Following the landmark publication of Materials Science and Engineering for the 1990s by the National Research Council, the United States is now moving towards[1] developing a strategic, goal-orientated planning approach to materials R&D involving industry, universities and government laboratories. Intensified and sustained efforts are being undertaken within the European Community to improve industrial and materials technologies. Here, the emphasis is on identifying community wide trends and needs in materials technologies, and in creating the appropriate framework for the private sector to undertake market orientated research and development. Advanced materials have been identified as a critical new technology underpinning the restructuring of Japanese industry towards high technology into the next century. Advanced materials strategy in Japan is pursued in a systematic, coordinated and long-run approach, involving close government-industry collaboration. Similar strategies and priorities are emerging in Republic of Korea and Province of Taiwan. At the same time, countries such as Mexico, Brazil and India have displayed a remarkable degree of strategic awareness of the issues involved and have made steady progress in mobilising domestic scientific and technological capabilities in materials research, development and application. In many ways they have moved faster and more consistently

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[1] Materials Research Society, A National Agenda in Materials Science and Engineering, Pittsburgh, Pennsylvania: USA, February 199[illegible].

in the materials field than many developed economies. It is clear then that materials strategy is now beginning to be recognised as an important policy area across economies at very different stages of socio-economic development, level of scientific and technological capabilities and resource endowment. Consequently, there arises a pressing need to further our understanding of the varied response of countries, institutions and corporations to the new scientific and technological development in materials.

Materials strategy in developing countries, whatever their size, is beginning to address the problem of building up inter-disciplinary MSE and institutional competencies in order to utilise and upgrade existing resources, and/or develop new materials for production and use at different stages of the production cycle. Here, several issues arise as to the type of information required; the nature of the institutions involved, and whether new ones are needed; the mechanisms for implementation and managing the transition; the interdisciplinary nature of Materials Science and Engineering R&D; educational programmes; training and continuous retraining of human resources; competition policy; protection of intellectual property rights; technology transfer and role of multinational corporations; standards and testing and evaluation procedures; the role of the government versus the market; the role of advanced materials in addressing development needs; and, the relation of new materials to energy and environmental considerations.

Such issues are common to all economies and emerged in different forms in the case-studies discussed at the meeting. Below we bring together in more detail, those issues that cut across economies as well as those that are specific to each case study.

III <u>COUNTRY CASE-STUDIES</u>: Presentations and discussions[2]

The country case studies and presentations offer a richly instructive tapestry of experiences and mechanisms by which economies have began to respond to the new materials and manufacturing conditions.

<u>THE EUROPEAN COMMUNITIES</u>

Professor Dr. Czichos paper provides an overview of the present status and trends in materials technologies in Europe. It is based on a comprehensive and in-depth study[3] conducted on behalf of the Commission of the European Communities, entitled "Industrial and Materials Technologies: Research and Development Trends and Needs". The paper stresses the importance of materials for future technological and economic developments. But more than this, it points to the need to view industrial and materials technologies

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[2] The country-case studies will be published shortly in a forthcoming book based in the main, on the Proceedings of the Meeting. See Lakis C. Kaounides and R. S. Ganapathy (eds), "Advanced Materials Technologies: Strategies for Growth", Institute of Materials, London/UNIDO, Vienna. Institute of Materials Publications, London: January 1993. In this section therefore we offer a very brief outline of the papers and points raised in the discussion.

[3] Professor Dr Horst Czichos, in cooperation with Professor Dr R. Helms and Dr J. Lexow, <u>Industrial and Materials Technologies: Research and Development Trends and Needs</u>, A study for the Commission of the European Communities, Bundesanstalt fur Materialforschung und -Prüfung (BAM), Berlin, 1991. Forschungsbericht 181.

in a systems approach, as part of a 'total product cycle'. This approach entails an integrated view of materials, from the raw material processing stage, to the engineering of materials, the design and fabrication of products, its performance, testing and assessment, and finally, the disposal of, or, preferably, the recycling of waste. In order to increase the value of products and engineering structures, R&D should result in materials of high consistency, quality and reliability, and with improved processability, performance and durability.

In order to ascertain the current state of industrial and materials technologies, their basic technological needs and development trends within the EC, a questionnaire was sent to 700 institutions in all countries of the European Communities, and, in addition, interviews with experts were conducted from EC countries. The results indicate that industrial and materials technologies considered are of paramount technological and economic importance for the EC, and can support industrial competitiveness through the application of novel materials, advanced design and manufacturing routes and high quality strategies. Key industrially relevant goals and benefits include[4] (i) costs reduction, (ii) long-term performance, (iii) energy and materials savings, (iv) environmental compatibility, (v) recycling.

Professor Dr Czichos presented a number of interesting results from the questionnaires to EC industry, universities and research organisations. Firstly, a broad spectrum of industrial branches within the EC are interested in R&D in industrial and materials technologies, namely:

- Chemical Industries
- Electrical Engineering
- Motor Vehicles
- Aerospace
- Civil Engineering

In terms of priority themes for R&D, the majority of respondents identified the following topics as of overall (medium term) importance, namely cost reduction, environmental compatibility and energy and material saving. In the area of industrial products which may result from an intensified R&D effort, the following topics are of paramount importance; recycling; long term performance; and functional purpose.

In the field of materials, the main interest of those who replied was in composites (30%), ceramics (20%), metals and alloys (19%) and polymers (17%). In composite nearly half of the entries was in the field of polymer matrix composites. In the area of design techniques suggested for R&D, materials-related concepts were identified as of great importance (50%), whereas computer-aided techniques (CAD, Finite Element Analysis, and Expert Systems) and general design rules were viewed as of lesser but comparable importance (around 22% each). Nearly 24% of the respondents suggested improvements in general manufacturing technologies, and a significant number of replies showed interest in further R&D in conventional fields of manufacturing and processing technologies (eg casting, forging, joining and machining), and in some advanced technologies such as CIM, mass production

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[4] See Industrial and Materials Technologies, 1991, BAM:Berlin, ibid, p.xi. A detailed presentation of the results of the results of the questionnaire, the interviews with experts, and overall conclusion for future R&D in the fields of industrial and materials technologies in the EC is contained in the aforementioned study.

techniques and powder metallurgy. Such developments in manufacturing and processing technologies are viewed in conjunction with the relevant materials or products associated with them. Finally, for the improvement of competitiveness of industrial products and associated technologies, advanced testing and evaluation techniques are required in order to ensure that the materials in question perform their functions. R&D work in the EC in this field concerns techniques for quality control and non-destructive testing and evaluation. Another area of interest focuses on R&D with respect to standardisation of test methods and process control.

In the mid 1980s the EC launched a framework for Community Research and Development which contained the following industry and materials-related programmes:

- BRITE, Basic Research in Industrial Technologies for Europe
- EURAM, European Research on Advanced Materials
- Raw Materials
- Programmes of BCR on applied metrology and chemical analyses

Such programmes were meant to increase industrial competitiveness and have contributed quite substantially to advances in, and, to the intensification of multilateral R&D in industrial and materials technologies within the EC. The first round of these programmes (1988-1992) were assessed by expect committees leading to several suggestions underlying the continuation of programmes in the next round. In raw materials, there is a need for a coherent R&D, policy to prevent Europe from becoming a 'dematerialised society' and improve the balance between basic and manufacturing industries. With regard to the EURAM programme a reorientation is recommended towards the improvement of traditional materials, the development of new materials, and the promotion of more established materials, while cooperation between producer industry and user industry may prove even more necessary than hitherto. The BRITE programme should continue its orientation towards established industry and production technologies which are the largest employers in Europe. Given the strong R&D base in Europe but weaknesses in technological and production application more emphasis should be given to the economic implication and strategic management of projects. Importantly, projects must be "market pulled" and not "pushed" through by researchers. At the same time sectoral policies or support for specific industrial sectors must be avoided. Instead, research programmes for generic ('basic') technologies which are critical for many industries and common to several branches must be continued. Overall, it should be pointed out that the intensified and sustained European Community research programmes in industrial and materials technologies, while identifying the needs and trends in these areas, emphasise the creation of the appropriate framework which would induce the private sector to undertake market orientated research and development. The second phase[5] of the Community's research and technological development programme in the field of industrial and materials technologies (1991-94) was agreed on 6th May 1991.

[5] For more information contact Commission of European Communities, Directorate XII (Brite/Euram).

THE UNITED STATES OF AMERICA

In the light of the Japanese challenge to high technology industries a lively debate[6] is now under way in the USA as to the need to develop an 'industrial' or 'growth' policy in the context of which strong support is to be provided for pure and applied scientific research and hence a firmer foundation for technical advance. In January 1992, the Bush administration raised the US science budget by 7% to US$ 13.4 billion and launched new initiatives in advanced materials (with an allocation of US$ 1.82 billion, in 1993, compared to US$ 1.66 billion in 1992) and biotechnology (which is to receive $4.03 billion in 1993, compared to $3.75 billion in 1992). US science policy is currently undergoing a shift[7] with a distinct emphasis on the commercial application of research.

Several reports[8] recently have laid special emphasis on advanced materials as critical to US competitiveness. The Panel on National Critical Technologies, laid special emphasis on the acquisition of material synthesis and processing skills. Synthesis and processing was also singled out by the National Research Council's <u>Materials Science and Engineering for the 1990s</u>, published in 1989. This theme was echoed by the follow-up report[9] of the Materials Research Society which evaluates the progress and requirements of implementing the Research Council's recommendations. In the words of the Materials Research Society, the US now needs to move towards developing a "strategic, goal-orientated planning approach to materials R&D, involving industry, universities and government laboratories".

Professor McLaren's informative paper on US national materials policy takes as its starting point what it considers to be the most important policy conclusion of the 1989 study by the National Research Council referred to above, namely that <u>synthesis and processing are critical to the US for achieving international leadership in materials over the next decade</u>. These constitute the key research objectives in the fields of materials over the next ten years. In that case, the question arises as to what funding patterns will be instituted which would make use of existing scientific talents and realise the required research effort. At the same time, his paper examines the parallel issue of what programmes are actually in place in the US and how they have evolved in order to accommodate the changes in materials science and engineering.

If universities and industry are to work cooperatively then government initiatives are essential. In 1972 the Nixon administration put into effect

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[6] See 'Industrial Policy', Cover Story, Business Week, April 6, 1992.

[7] See Lakis C. Kaounides, "Advanced Materials in High Technology and World Class Manufacturing: The materials revolution and the competitive challenge from Japan and SE Asia in the 1990s", Special Report, Economist Intelligence Unit, London, (forthcoming, November 1992), Ch. 1.

[8] <u>Report on the National Critical Technologies Panel</u>, Washington, March 1991; US Department of Defense, <u>Critical Technologies Plan</u>, March 1990; US Department of Commerce, <u>Emerging Technologies</u>, Spring 1990.

[9] Materials Research Society, <u>A National Agenda in Materials Science and Engineering</u>, Pittsburgh, Pennsylvania:USA, February 1991.

the R&D incentives programme. This evolved into the present[14] form of the National Science Foundation (NSF) - Industry-University-Government Research Centres (IUCR). Probably the most important measure was the Justice Department's Anti-Trust Guide Concerning Joint Research Ventures, in 1980, which enabled companies to come together and discuss research without violating anti-trust laws. In 1986, another important government measure to stimulate research was the Uniform Federal Patent Policy Act which meant that patents could accrue to universities for their use, and, could then be extended to the use of industry, including anything developed under NSF funding.

Of the early experimentation in IUCR centres, only the MIT Polymer Processing Centre has survived and remains today the best example of successful university-based research consortia, and it forms the model for almost all NSF-university (IUCR) centres. At the end of Fiscal Year 1989, 41 such centres were in operation, 22 of them being self-supporting. Around 10 are at the planning stage. Total financial support for the IUCR centres amounts to $45 million from NSF, industry and state sources. NSF support amounts to $3m for all centres. Regional or state support has become a significant factor, in an effort to develop and attract high technology industry to these states. An example of this is the support provided by the state of New Jersey (Commission on Science and Technology) to the NSF ceramics processing centre at Rutgers University, matching the industrial contribution on a 1:1 basis in research funds and 2:1 in the provision of funds for high technology.

Another initiative by the NSF was launched in 1985 in order to support the engineering-orientated programmes (ERCs) of the US. Congress appropriated $9.5m over a five year period to support six new high technology engineering process-orientated programmes.

The Centre for Ceramics Research (CCR) at Rutgers University has evolved over the last 10 years and constitutes a partnership between the university, industry, the federal government and the state government. Interestingly, although it was at first feared that CCR would end up doing more applied research at industry's request, in fact industry insisted upon CCR doing basic research. With the acquisition of advanced equipment and facilities the centre could attract a very strong faculty and research team. The CCR is interdisciplinary in nature, with participation from the University's Ceramics Department, Chemical Engineering Department, Electrical Department, Mechanics and Materials Science, Chemistry, Physics and Fibre Optic Materials Programme. Sponsors send post-doctoral researchers to the CCR labs and vice versa. The criteria for research are that it must be generic, fundamental research, have pertinence to sponsors, match with faculty capabilities and interest and be suitable as thesis research. All partners provide an input and obtain an output. The NSF provided the initial need money and an independent evaluator for the centre. Amongst other outcomes the NSF seeks to achieve scientific progress through these centres, achieve maximum use of government money for such progress and an interchange between university and industrial scientists. Industry provides operating funds and scientific expertise while obtaining greater knowledge of the university and fundamental science it can apply to

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[14] The NSF programme establishing industry-university cooperative research centres began in 1978 in order to fill a perceived need for more basic research and to assist the greater interaction between universities and industry.

its technology. The state provided high tech equipment, buildings, a critical mass of operating funds and peer review, while obtaining a potential for new companies, jobs, better reputation and a better educational system. The University provides faculty, students and facilities, while engaging in meaningful fundamental research addressing pertinent problems in industry, enhancing its reputation, receiving financial support for research and high-tech facilities and attracting outstanding researchers from around the world.

JAPAN AND SOUTH EAST ASIA

Regional and industrial restructuring and the role of advanced materials

The paper[11] by Lakis Kaounides examines the rising importance of advanced materials in the process of industrial restructuring in Japan and SE Asia over the last two decades. In his presentation the author expressed the view that scientific and technological developments in the field of materials must, of necessity, be integrated into the far reaching transformations under way in world industry. Ever since the first oil shock of 1973, industry has been restructuring towards high value-added sophisticated products and manufacturing processes. At the same time new methods of organising production, such as JIT and TQC, and new flexible production technologies (CAD/CAM, FMS, CIM) are diffusing in manufacturing industry, partly in response to new market conditions. Markets have become global, characterised by an intensification of competitive pressures, faster product renewal, and high quality, technologically sophisticated customised products aimed at specific niches of an increasingly fragmented and differentiated world market demand. It is in these new manufacturing and technological circumstances that industry from developed and developing regions must compete in the 1990s and, in which, the implications of the development and application of new materials must be located. Materials strategy is thus inseparable from overall industrial strategy and efforts to incorporate new materials not only into leading edge technologies but also into product and process design throughout manufacturing industry.[12] New materials scientific and engineering capability acquisition and build up must therefore pay close attention to (1) materials processing and fabrication technologies, (2) the channels and mechanisms for the effective transmission of new materials R&D into the productive sphere and commercial application, (3) the needs of user industries and of the market as driving forces for materials development and, relatedly, (4) the mechanisms for integrating materials and product design between suppliers and users in the context of world class manufacturing (WCM). After all, it is in the context of the coercive forces imposed by the world market that firms and industries in economies such as Republic of Korea, Province of Taiwan, Brazil, Mexico, India, Nigeria and so on must increasingly compete.

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[11] In its original form prepared for the Meeting, the paper contains country case-studies for Japan, South Korea, Taiwan, Singapore and Malaysia, together with an overview of UNIDO activities. In the revised and much condensed version for the UNIDO book of the Proceedings only the cases of Japan, South Korea, and Taiwan are included, in the form of three separate chapters.

[12] L. Kaounides "Advanced Materials in World Class Manufacturing: The next source of competitive advantage", Paper to be presented at the British Academy of Management Conference, Management into the 21st Century, September 1992. The incorporation of new materials early on in the design of products and processes confers superior functional performance characteristics, higher quality and total system cost advantages through new conceptualisations and re-design of product and associated manufacturing and assembly processes. We have called this Materials-based Simultaneous Manufacture (MSM).

With the acquisition of higher labour-skills and the inexorable rise in real wages in the NIEs of SE Asia, the path of export orientated industrialisation (EOI) of the 1970s and 1980s, based on the simple formula of combining cheap labour with foreign technology acquisition and licensing, is now facing serious constraints. Industry is shifting to higher value-added and more technologically sophisticated products and industrial processes. However, many firms in the region, in their attempt to move toward more sophisticated, higher value-added activities and compete in the world market, have been hampered by the lack of critical raw materials, pure powders, components and parts as well as by the lack of in-house expertise and resources in the conduct of R&D, and, importantly in engineering design. Both engineering design and pure and applied research were badly neglected during the earlier labour-intensive phase of industrialisation and this is currently proving a serious handicap in economies such as Republic of Korea and Province of Taiwan. Major efforts are under way to correct for this.

Access to critical technologies, parts and components, from abroad, entering a range of sophisticated industries is proving either impossible or very expensive. It has, therefore, become obvious that the restructuring and transition to high-technology activities necessitates the acquisition of a critical minimum mass of domestic and in-house materials synthesis and processing capabilities. Consequently, considerable emphasis has been placed in both Republic of Korea and Province of Taiwan on the need to increase national materials synthesis and processing skills. As these competences grow it becomes easier to attract, access and absorb technologies from abroad. It must be noted though that while total external dependence or reliance on foreign parts and components is tantamount to economic suicide, neither is total self-reliance on materials science and engineering possible or desirable at the level of the firm, the industry or economy in today's technological circumstances. Hence, internal or in-house competence building, external mechanisms via inter-firm cross-border alliances and technology flows and access to a fast changing global pool of scientific knowledge go hand-in-hand. Policies to promote domestic competence in materials-related fields are influenced to a considerable degree by a range of other domestic policies, such as the degree of liberalisation, protection of intellectual property rights, mergers and acquisitions policies, and open door policies to foreign investment and technology flows. **Advanced materials comprise the majority of the ten (10) national projects[13] identified in 1990 as urgent priorities to be supported and promoted by the Republic of Korean government. A similar strategic emphasis on over ten critical high technology sectors has emerged in Province of Taiwan. On the other hand, the small size and nature of Singapore's economy, has necessitated that emphasis be placed on advanced materials applications rather than development, together with the provision of supporting and maintenance services for companies in the aerospace and microelectronics sector. Singapore's government is currently encouraging large multinational corporations in electronics and chemicals to set-up local R&D and design centres in the context of a long run strategic objective vision into the next century which envisages Singapore as a major international centre for scientific and technological excellence.** In the new Strategic Economic Plan prepared by the Economic Planning Committee of the Ministry of Trade and Industry which is based on the view of 700 companies the aim is for Singapore to achieve the goal of becoming an advanced developed nation by the

[13] These have now been incorporated into the 'Highly Advanced National Project' launched in 1992. See below.

year 2030. In the process it plans to double annual expenditure on R&D from 1% of GNP in 1990 to 2% of GNP by 1995, compared to 1.8% of GNP in Republic of Korea and 1.3% of GNP in Province of Taiwan. The government is to allocate up to $2bn to an R&D fund the aim of which is to develop skills, manpower and technologies specific to industry's needs. In addition 200 foreign research scientists and engineers are to be recruited annually over a fiver year period. The recruitment is to be undertaken by the newly formed National Science and Technology Board (NSTB) whose function is to promote industry driven R&D. The NSTB will encourage more private sector R&D through tax incentives and allowances, and strengthen the technological and manpower base of Singapore by building several world class research facilities and associated tertiary institutions and physical infrastructure, at the Science Park.

The development and application of new materials by national and foreign firms relies on extreme environment, complex instrumentation, measurement and characterisation technologies provided by very well equipped and manned national standards and materials research institutes, already in place in Singapore (SISIR), Province of Taiwan (ITRI) and Republic of Korea (KSRI). Such institutes are acquiring a pivotal role in the industrialisation strategies of these economies in the 1990s.[14]

The restructuring of industry in Japan and the 1st tier NIEs has opened up opportunities for the rise of resource-based and labour-intensive activities in 2nd tier NIEs such as Malaysia and Thailand, and the economies of Indonesia, the Philippines, China and Vietnam. Many firms from Japan, Republic of Korea, Province of Taiwan and Singapore are withdrawing from their high wage locations and relocating plants and unskilled segments of the production process to the low cost economies of the region. What seems to be emerging therefore is a very complex intra-firm and intra-, and inter-industry division of labour, in which firms retain high-skill, critical component production and segments of the assembly process within Japan, while relocating other segments and sub-assemblies to 1st and 2nd Tier NIEs and other labour abundant, low wage economies in the region. Nevertheless, as the productive forces, skills, wages, and markets are growing in several 1st Tier NIEs, foreign direct investment of greater sophistication is encouraged to come in, in order to meet domestic demand in consumer durables, and certain high performance materials such as chemicals and metals specialities and engineering polymers. The need for higher quality and high performance materials is therefore increasingly felt in the region in response to changing demand and locational patterns in user industries, as in electronics and automobiles.

Malaysia has displayed a remarkable growth in manufacturing industry in recent years, with electronics emerging as the most important and dynamic component of the industrialisation process. The rapid growth and deepening of the electronics industry has been accompanied by a greater demand for sophisticated devices and components, some of which are now beginning to be produced domestically. The government has recently drawn an Industrial Technology Action Plan (March 1991) while MIMOS (Malaysian Institute of Microelectronic Systems) is beginning to address domestic needs to microelectronics component and device design and fabrication. The need to build-up MSE capabilities though goes further, especially in a resources rich

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[14] Note here the efforts of UNIDO to promote the setting up of an international.

economy such as Malaysia. This is so in order to utilise the new scientific and engineering knowledge (1) to utilise domestic resources to meet development needs in an environmentally compatible manner, (2) to upgrade local materials and processing technologies so as to meet higher quality requirements by user industries, (3) to defend domestic primary products against in roads by new materials (eg develop new uses for tin, copper, or improve the properties of natural rubber in competition with synthetic rubber) and (4) utilise domestically available mineral resources which can be used in advanced material production (eg zircon and xenotime, a by product of tin, or niobium and tantalum in slag). **Thailand**, following closely behind Malaysia, as one of the most dynamic manufacturing bases in the region, is laying particular emphasis in the promotion of domestic materials, parts and components industries to meet the requirements of final goods industries in consumer durables, including electronics, and engineering. This is seen as essential in order to enhance backward linkages, create a coherent industrial base and eliminate bottlenecks and shortages from the side of materials (primary and processed metals, petrochemicals and plastics), energy and components. Although advanced materials do not, as yet, pose a discernible presence in the composition of materials requirements in the economy, the very process of industrialisation and opening up to the world market is accompanied by more stringent technical specifications and quality assurance for materials and components. It is inevitable, therefore, that MSE will increasingly be called upon to upgrade locally available materials in the metallurgical, chemical, ceramics and other traditional industries of Thailand. Nevertheless, locational decisions by foreign companies to set up operations in Thailand, will, in the 1990s, be influenced not merely by the quality of local available materials and intermediate inputs, but also by the degree of easing of the severe infrastructural bottlenecks, the development of maintenance and supporting industries, the setting up of commonly accepted and uniform testing and measurement standards and the availability of high precision materials characterisation technologies.

As industry restructures globally, the new materials and manufacturing environment is beginning to exert pressure for the articulation of materials strategies and responses by both private and public sector institutions in countries at very different stages of development and shifting positions in the evolving regional and international division of labour. Clearly the early delineation and implementation of what is feasible and desirable from the point of view of materials development and utilisation in a particular economy is critical in today's fast changing scientific and technological circumstances. There are cumulative gains from learning by producing and/or using, while severe penalties await late entry, which may in fact become impossible in some areas. Japan understood the importance of new materials very early on, with long run strategies in place since the early 1980s. Republic of Korea and Province of Taiwan, drawing upon a large pool of domestic scientific capabilities, have laid considerable emphasis on the acquisition of advanced materials capabilities in recent years. Below we briefly look at the strategic orientation and mechanisms of implementation in each of the three economies, starting with Japan.

JAPAN

Microelectronics, new materials and biotechnologies are the three leading edge technologies identified in the early 1980s as providing the foundations for the rejuvenation of maturing branches of the industrial structure together with giving birth to a whole new array of high-tech industries pulling the economy into the next century. The promotion of new materials development and use forms an integral part of a long-run strategic approach to reorientate Japanese industry towards high-technology and knowledge-intensive production. The role of new materials in underpinning both technical change in all leading-edge technologies as well as conferring competitive superiority in manufacturing industry is very clearly recognised in both the private and public-sectors. Advanced materials are therefore seen as of prior. strategic significance to a successful reorientation towards high technology and the attainment of competitive superiority in the world market. Hundreds of Japanese companies entered new materials in the mid-1980s and the emphasis in recent years is on commercialisation of materials already developed and related to existing technical strengths of the companies concerned.

The Japanese government[15] plays an important role in formulating science and technology policy. There are four institutions responsible for the formation and implementation of science and technology policy. These are:

1. **Prime Minister's Council for Science and Technology (CST)**: It is the foremost institution in Japan in this area, and recommends long term national policy objectives. Key recommendations to the Prime Minister are of critical importance to the future direction of science and technology.

2. **The Science and Technology Agency (STA)**: It provides research and planning input to the Council. Amongst its major responsibilities are the management and conduct of science and technology activities in basic research and advanced fields of science. Work is carried out at research institutes attached to the Agency and semi-autonomous public organisations (eg RIKEN). The Japan Research and Development Corporation (JRDC) has the function of encouraging the commercialisation of promising R&D at universities and research institutions.

3. **The Ministry of Education, Science, and Culture (MONBUSHO)**: It accounts for nearly half of all government R&D budget of ministries and agencies across all areas of science and technology.

4. **Ministry of International Trade and Industry (MITI)**: It has a central role in the formation and implementation of industrial policy, but is also active in the promotion of industrial R&D. Within MITI, the Agency for Industrial Science and Technology (AIST) sponsors a number of projects which aim to develop technologies with potential commercial value, and research is carried out mostly in 16 national and regional industrial research institutes administered by AIST.

The CST formulated a Government R&D plan for materials science and technology in October 1987. R&D in the field of advanced materials is mainly the responsibility of three ministries, namely MONBUSHO, MITI and STA. MITI's policy is co-ordinated by the New Materials Policy Office set up in 1984 and is carried out by AIST. MITI's Fine Ceramics Office co-ordinates policy on fine ceramics. STA's policy on new materials concentrates on the conduct of

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[15] "The Science and Technology Resources of Japan: A comparison with the United States", US National Science Foundation, NSF88-318.

basic research, mainly through RIKEN, the national research institutions at Tsukuba Science City and the JRDC.

There are two major groups of MITI long term R&D programmes, both of which accord large importance to new materials. The majority of projects under the "R&D Project on Basic Technologies for Future Industries" relate to new materials.

There are a large number of research projects on new materials in the public sector co-ordinated from above by MITI and STA. Although there is a measure of coordination of new materials policy and of the role of the public and private sector, within and between MITI, STA and MONBUSHO, it is informal and not entirely satisfactory according to officials. Nevertheless the approach is systematic, comprehensive and of a long term, committed nature.

Republic of Korea

In early 1992 the government of the Republic of Korea launched the 'Highly Advanced National Project', known widely as the G7 Project, aimed at bringing the country's scientific and technological capabilities to the level of the G7 group of nations by the year 2000. The government faced with inflation, rapidly rising labour costs and a large trade deficit, is keen to promote a shift towards high value-added, high-technology products and industrial processes, and establish the country as a major scientific and technological power, challenging Japan and Western nations by the early 21st century. To achieve this, indigenous capabilities in a range of high technologies are deemed essential, and to this end the government, through science and technology ministries, is planning to spend more than $3,000 million over the next ten years, with a matching investment of funds from private industry[16] The Project supports seven major technologies which are near the market, namely next generation integrated semiconductors (256-megabit DRAM by 1996, and 1-gigabit by 2000), an area of existing Korean expertise, Integrated Services and Data Network, HDTV, the electric vehicle, intelligent computers, antibiotics and chemicals for agriculture, and advanced manufacturing systems. A second part of the project supports seven more fundamental or basic technologies, including advanced materials, next-generation transport systems and biotechnology.

Between half and three quarters of the research is to be undertaken by institutes affiliated to the Ministry of Science and Technology. The Korea Institute of Science and Technology (KIST)[17] moved from carrying out contract research for industry in the 1960s to the conduct of long term research of importance to the national interest, and several new institutes have sprung from it. Much of the research on advanced materials is to be conducted by KIST which has recently been reorganised, with the existing Advanced Materials Group upgraded to an Advanced Materials Division. The major materials research areas are under study at the moment and the final plans will emerge in July 1992.

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[16] In 1991 total science and technology R&D by government and industry stood at around 2% of GNP and this is expected to rise to 3.2% of GNP by 1996.

[17] In 1971 it merged with the Korea Advanced Institute of Science and Technology (KAIST) a graduate school of scientists and engineers, subsequently an important university producing over 700 graduate scientists and engineers per year. The two institutions were split again in 1989.

In order to serve the more immediate needs of industry, the government set up in 1989, the Korea Academy of Industrial Technology (KAITECH)[18], which reflected a shift away form simply emulating the US approach to scientific research, namely the setting up of world class research institutes. Rather, the lesson drawn from Japan was that what is required is emphasis as production engineering skills. KAITECH therefore promotes, funds and coordinates near-market research between government, industry and the universities. Both KIST, and its affiliated institutes, and KAITECH will play an important role in implementing the HAN Project, which forms a first attempt by the Republic of Korea to coordinate the research activities of all science and technology related ministries and institutes, in order to avoid, amongst others, overlap in research efforts and other inadequacies of the research funding system.

Province of Taiwan

Province of Taiwan is very much aware that other economies in the region are restructuring towards high value-added production. Government officials therefore emphasise the need for Province of Taiwan to upgrade skills, restructure towards high value-added, sophisticated production, and promote the advancement of science and technology through the conduct of indigenous R&D and the acquisition of technology from abroad. Industry though, in contrast to the Republic of Korea, is highly fragmented with a proliferation of many small firms which face serious difficulties in mastering the skills and resources necessary for effective R&D. The Industrial Technology Research Institute (ITRI) was established 20 years ago, is the main R&D institute in Province of Taiwan, and its tasks is to assist industry to upgrade technologically. Given the current emphasis on high technology the role of ITRI has acquired even greater significance, acting as a central mechanism for transmitting science and technology R&D to private industry. In essence its function today is to assist industry to restructure towards high technology.

The Province of Taiwan aims to achieve the status of a fully industrialised economy by the year 2000, with the following strategic sectors at the forefront: Advanced materials, sophisticated consumer electronics, information systems, telecommunications, automation technologies, aerospace and environment technologies. Considerable effort has been expended in identifying the most promising technology areas, and foreign consultants have been brought in to set strategic objectives in all areas of high technology.

The National Science Council is responsible for setting up national policy on science and technology, through conferences, meetings, liaison with other government institutions, along the lines of the US National Science Foundation. A major objective consists in attracting high technology to Province of Taiwan, and the NSC decides on what type of high technology will be relevant to the Science Park. An important consideration is to remedy the shortcomings in the conduct of private R&D with the aim of raising the share of private-sector R&D in total outlays to 60% by 1995. Moreover five national labs have been set up to enhance basic scientific research in the 1990s. The NSC organises the various research programmes, their allocation across research institutes and decides when programmes will eventually merge. For

[18] KAITECH provides 70% of funds, at zero interest loans, for near market research between university and industry scientists (eg on HDTV), with the rest coming from private companies involved with research. See Nature, Vol 354, 21 November 1991.

example, in optoelectronics, it decides (by consensus, meetings, visits to industry) which research is to be undertaken at university labs, at ITRI and or private industry.

Materials technologies were already identified as of key importance by the NSC as early as 1978. The recent emphasis on high technology industries has added impetus to this area, as a high technology sector per se and as the foundation for the promotion of materials-related technologies in the 1990s. The objectives of advanced materials research are arrived at in collaboration with universities and ITRI. Advanced materials R&D spending in 1990 was third in importance out of total R&D spending, after Information Technologies and Energy (given large import dependence on the latter). There exist considerable opportunities for the development of polymer based advanced materials in the Province of Taiwan, where the building up of domestic base and key technologies will involve licensing, in-house R&D, cross-border strategic alliances, and the utilisation as well as future development of key technologies at ITRI's Materials Research Laboratories and Union Chemical Laboratories together with the Chung Shan Institute.

MEXICO

Professor Valladares excellent paper is a frank and informative discussion of the difficulties faced by an industrialising economy in the formation and implementation of coherent science and technology policies. As such it is essential reading for many developing economies.

Scientific policy in Mexico is the responsibility of the National Council of Science and Technology (CONACYT) formed in 1970, whereas public higher education policy calls under the Secretariat of Public Eduction (SEP). When President Salinas came to power in 1988, a new National Development Plan for the period 1989-1994 was drafted, and as a result all government institutions, including CONACYT and SEP, were required to reformulate their respective programmes, which would guide their actions over the remainder of the six-year period of the present administration, in order to conform to the guidelines set by the National Plan.

With the change of president at the end of 1988, CONACYT also changed General Director, and the new administration adopted the policies recommended by the Organisation of American States. New materials was a priority policy area, together with biotechnology, electronics and informatics, water, the environment and the problem of extreme poverty. These priority policy areas were also adopted by the Secretariat of External Relations (SRE) and in 1989 Professor Valladares was asked to elaborate a programme in Materials Science which would contain recommendations for bilateral and multilateral international cooperation both for scientific projects and technological cooperation. The 1991-1994 Programme for International Cooperation in Materials Science and Technology was submitted to SRE in 1991.

A condensed version of the recommendations which refer to the establishment of linkages and collaborative projects with developed economies such that would foster Mexico's (i) human resource development in relation to research capabilities and (ii) human resource development in relation to industrial capabilities in ceramics, metals, polymers and semiconductors appears in part IV of his paper. An important consideration here is the fact that liberalisation measures have left industry wide open to competitive pressures from the world market. Although scientific research is already undertaken at universities, linking basic research to industry has acquired greater importance and urgency at the moment. At the same time research and development by industry has become essential in meeting the competitive challenge.

Meanwhile, in 1991 the administration of CONACYT changed once again and with it the overall policy framework. This of course immediately points to the need for science policy formation and implementation which is of long term nature, rather than dependent on specific individuals, and which reflects the underlying development needs of Mexico. The stipulation of priority areas has been abandoned, with present policies focusing on excellence and quality of projects in basic sciences, and usefulness of projects for applied science and technology. This approach tends to strengthen and develop existing areas of excellence. In basic science, there is, clearly, no substitute for excellence in research, and the main criterion for financial support is the quality of the project. However, this approach neglects the need to delineate certain strategic research areas deemed of critical importance for the long run development of a country. In the area of applied research and technological development, the participation of industry is deemed essential for any project approved by CONACYT. Here again, although the market must play an important role in industrial and technological research and development, this overlooks the need to identify those critical technology areas deemed essential for the future advancement of the country and which can be launched and promoted via the political decision-making process as opposed to complete reliance on market forces.

Finally, it should be pointed out that due to historical reasons, institutions of higher education in Mexico are autonomous. They are therefore free to decide how and when to use their budget allocation received from the government. The SEP supports both the universities ordinary budget and their extraordinary budget, as well the 40 or so Technological Institutes of higher education. On the other hand CONACYT is charged with the responsibility of establishing a national science policy. Thus policy formation and implementation requires negotiation and reconciliation of the interests of all the participants involved. Scientific policy formation in the areas of materials involves many institutions, including CONACYT, SEP, the National Autonomous University of Mexico (UNAM), the public state universities the technological institutes, industrial groups and certain other sections of society. The number of researchers in materials in Mexico amounts to no more than 300, a number insufficient for the needs of the country. At UNAM, the most developed of the educational establishments, there is the Institute of Materials Research, the largest in the country dedicated to materials, with little over 50 researchers. UNAM has in total around 100 materials researchers, other universities have a further 50 and the rest are distributed in public institutions, in specific industrial sector research institutes created by CONACYT, such as the Mexican Institute for Research on Iron and Steel, and research groups in Mexican industries. The building up of human resources in materials science and engineering research at academic and other institutions has therefore become an urgent priority for Mexico.

BRAZIL[19]

Brazil is richly endowed with both traditional materials and several elements of the periodic table that enter new advanced materials categories. This offers vast potential to employ advanced processing technologies and quality control to upgrade traditional materials such as steel and aluminium to meet the more stringent requirements in manufacturing user industries domestically, regionally or globally. But, additionally, there are considerable opportunities for Brazil to establish substantial domestic processing and engineering capabilities in the extraction and fabrication of an array of advanced materials destined for functional and structural applications in downstream industries or the export market.

Despite the considerable importance posed by traditional and emerging materials in Brazilian GDP and export structure, policy in this area was diffused in a multitude of government institutions until the mid-1980s. The establishment[20] of the Ministry of Science and Technology in 1985, brought with it central policy formation in the areas of science, technology, informatics, biotechnology but also the development of a "national policy for research, development, production and application of new materials...and other sectors of advanced technology" (Cassiolato, 1988). Since then, new materials have been identified as a priority area, with special importance attached to materials such as metals and metallic alloys, quartz (given Brazilian large reserves and its role in fibre optics), advanced ceramics, engineering plastics, and composites.

Several agencies of the Ministry of Science and Technology (CNPq, FINEP, INT and SEI) together with leading Brazilian scientists were charged with the responsibility of drawing a preliminary set of proposals and plan of action on new materials which was sent for approval to the Government. The National Commission on Materials, set up a 2-year plan of action on materials, which was approved by the Government. Most of the proposals were in fact subsequently implemented, at least on the expenditure side. Nevertheless, policy making in these areas has been suffering as a result of the fortunes of the Ministry of Science and Technology, which, since its inception, was fused into the Industry and Trade Ministry, lessened in importance as a lower rank Secretariat, and then more recently transformed into a Ministry again. Following the recent elections and the inauguration of the new President, in mid-March 1990, the Ministry was transformed back into a Secretariat, but with direct access to the President, and a prominent physicist[21] and rector of the University of Sao Paulo was appointed to head it. A new head was also appointed for the Secretariat's most important body, the National Council for Scientific and Technological Development (CNPq), with a promise of increased funding. But clearly such uncertainties and vicissitudes in government policy

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[19] For an early comparison of South Korean and Brazilian strategies in advanced materials, see Lakis Kaounides, "New Advanced and Improved Traditional Materials and Processes: The revolution in materials science and engineering and its strategic implications for developing economies in the 1990s", UNIDO Document, Vienna, December 1990.

[20] For details of the materials situation in Brazil and related policies in recent years see: Jose E Cassiolato, "Policies for newly industrialised countries: the case of Brazil", ATAS Bulletin, Issue No 5, May 1988. R. C. Villas-Boas, "Brazil's National Policy on New Materials", UNIDO, IPCT.57 (SPEC.), 14 April 1988. H. M. Martins Lastres, "The Impact of Advanced Materials on World Development", Advances in Materials Technology, MONITOR, UNIDO, Issue 16, January 1990.

[21] Professor Goldenberg has recently been appointed in charge of the environment.

towards a critical Ministry and its associated bodies can prove disastrous for the formation and implementation of a coherent strategy in science, technology, and the materials field, and is in marked contrast to the long-term planning, single-minded and unwavering pursuit of materials strategies in Japan, and increasingly in the Republic of Korea.

At the same time though, excellent work[22] has been accomplished by two innovative bodies in the materials field, the Secretariat of New Materials set up on 1987, located within the Ministry of Science and Technology (now itself a Secretariat) and, until recently under the Office of the President, and, by the Nucleus for the Study and Planning in New Materials (NMAT), set up in 1986, conveniently located within the vast scientific, technical ad metrology/testing infrastructure of the National Institute of Technology (INT). Such bodies comprising of multidisciplinary teams of scientists, engineers and economists are indispensable in monitoring scientific and technological trends, accessing, assimilating and assessing rapidly evolving materials information and data, and offering guidelines to industry and government. National think-tanks and/or strategic planning and policy making instruments in materials research, and in technological and industrial development are becoming a necessity across the differentiated array of developing economies and can serve as nodal points in a regional and international materials network under the umbrella of IMAAC.[23] Not only is the Brazilian example to be emulated elsewhere, but the importance of a semi-autonomous, multidisciplinary, competent and flexible materials secretariat and associated study groups or think-tanks will become even more evident within Brazilian industry, scientific community and government in the 1990s.

Over the last two years Brazil has embarked upon a major programme of enhancing quality and competitiveness in the private sector (with, for example, the privatisation of steel firms). Industry is to participate in the international market on the basis of quality and price, as compared to the strategy of 4-5 years ago whereby certain new areas were identified and promoted with the aim of improving competitiveness. Within the materials field programmes exist for the development and production of special alloys, special raw materials for microelectronics, and ceramic materials and powders with the aim of selling them abroad to users. Materials programmes form a relatively small part of an overall World Bank loan of $500 million aimed at industrial upgrading. Another programme refers to Human Resources for Technological Development, with expenditures of $40m per annum. Industry and government cooperate in identifying areas of interest in materials research, with priority given to relevance for industrial development. It must be noted that Brazil possesses not only large and increasing domestic markets in high technology industries utilising sophisticated materials and components, but also a range of high-powered research institutes, industrial laboratories and university departments engaged in frontier scientific research (eg in advanced

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[22] See, for example, Helena Maria Martins Lastres, coordinator, et. al., "Novos Materials, Capacitacao e Potentialidades Nationais em P&D", INT/NMAT, Rio de Janiero, 1988, which contains a comprehensive coverage of Brazilian institutions, personnel and research programmes in new materials, relevant companies, etc.. And, several other monographs and studies on trends in materials science and technology. In fact NMAT provided the analytical and research input that went into the formation of a national materials policy and the 2-year plan formulated by the National Commission on Materials. Both the NCM and NMAT were established in 1986.

[23] The International Materials Assessment and Applications Centre (IMAAC) is a major UNIDO Project promoted as a result of the recommendations of two international Expert Group Meetings in 1987 and 1989. See UNIDO's activities below.

ceramics at the University of Sao Carlos).

INDIA

Professor Ganapathy's presentation and paper raised a vast array of pertinent issues,of critical importance to the assessment and evaluation of the materials situation in an economy and the formulation of appropriate materials strategies for the future. Until the 1980s materials policy in India was supply orientated, preoccupied with expanding capacity in many basic commodities in order to overcome shortages which arose out of import difficulties as a result of foreign exchange constraints. In the late 1980s, emphasis shifted onto demand management focusing on pricing policies, materials conservation and greater efficiency in the use of materials. Nevertheless no specific statement existed on materials policy, while materials were not looked at in an integrated manner encompassing key issues which as substitution, conservation and new applications. It has become increasingly obvious that materials at present constitute a major paradigm shift in economic growth, with advanced materials R&D constituting the dominant trend in the materials field. There is an urgent need therefore to look at all aspects of the materials production cycle, integrating supply and demand trends and placing them in an international context taking account of the global restructuring of industry.

In a serious and concerted attempt to address the complex and interdependent array of issues in the materials field, India initiated the National Materials Policy Project, which commenced in April 1990, to be completed by March 1992. The Project is an inter-disciplinary effort involving industry, government and science and technology institutions. Funding came from the Steel Authority of India, and the infrastructure is provided by the Technology Information and Forecasting Council (TIFAC) of the Department of Science and Technology. The following materials were selected for detailed study: wood, leather, ceramics, electronic materials, polymers, aluminium, iron and steel, light alloys, composites, and coatings. For each such materials, the Project has undertaken a detailed analysis of the following aspects: demand and supply; materials intensity of use and economic efficiency; management of the materials cycle; synergy between R&D, production and use; technology development and diffusion; comparative advantage and competitive positioning of India; restructuring of institutions. The Project has already prepared several reports, papers and studies on the basis of analytical work and several workshops organised over the last two years.

A central issue facing India is the potential for improvement of the properties of existing materials, and here technology plays a central role in the transition. India possesses a large and high-level scientific infrastructure and much research work is done on materials properties, structure and characterisation. Some emphasis exists on application and production of new materials, but much more emphasis on processing and materials applications is required. The Government has recently liberalised technology and this implies that a much greater inflow of relevant technology may be expected in the future. On the other hand India may possess a comparative advantage in contract research given that R&D costs are a tenth of comparable effort in the US and that the manpower is of a high calibre. It must also be noted that large vertically integrated research programmes exist in atomic energy, space and defence, where significant developments in materials are taking place but with few spin-offs to the rest of the economy.

The management of materials information is another important issue. Users, for example, require more information on materials availability and properties. A related problem is the flow of information between research institutes. In India, the flow of information and coordination between R&D institutes, university and government agencies is poor, with the consequence that each does not know that the other one is doing.

The role of the Government constitutes a central issue in the materials arena. At present the materials effort in India is diffuse and uncoordinated, with institutions constrained by inertia rooted in strong historical traditions. In this context and given the developments in the materials field, what ought to be the role of Government? Should the Government set the policy parameters and intervene to resolve problems in materials? Currently, the Government does not possess a long term vision of what constitute the major technologies of the future and the implications for Indian institutions, industry and the economy. Ought, therefore, the Government's role to be redefined to include the setting up of a long term national strategy and vision on major new technologies? In this context, should it define clear objectives for industry, university and R&D institutes research programmes, as well as mechanisms for their implementation? Another role for the Government may be that of coordination or orchestration of the research activities of the laboratories and institutions engaged in materials related scientific and technological research. The linking of university and industry research would be an important component of this.

Finally, where domestic demand is low should or can new advanced materials be developed? In India it is very important that existing materials be developed first. But as industry grows and opens up to foreign competition, the need for specific knowledge intensive advanced materials may arise. Therefore the issue of domestic, scientific and processing engineering skills to meet this need will surface at that stage. In addition, the liberalisation of markets will exercise strong pressures for the supply of high quality materials, thus raising the issue of quality assurance, and domestic testing and evaluation procedures to the forefront of Indian materials policy.

MALAYSIA

The 1980s in Malaysia were declared the Decade of Resource-based Industries. The basic elements of this strategy comprise of the export of higher value-added products, maximising the use of local materials and substituting for imported materials or components. Foreign companies wishing to set up in Malaysia were required to adhere to a 30% local content.

The Industrial Research and Development Policy, formulated by the Ministry of Science, Technology and the Environment more recently, provides guidance as to materials management with emphasis on (i) Upgrading the quality of local materials; (ii) Searching for and creating new applications of local materials; (iii) Utilising and managing waste materials.

The policy is then imposed on the relevant research institutes such as the Standards and Industrial Research Institute of Malaysia (SIRIM); Palm Oil Research Institute of Malaysia (PORIM); Forest Research Institute of Malaysia (FRIM); Mine Research Institute of Malaysia (MRIM); Rubber Research Institute of Malaysia (RRIM); Local Universities.

The Malaysian government forecasts a rapid growth in the demand for materials due to the growth of the manufacturing sector and the fact that foreign companies have not yet reached the 30% local content requirement. As part of the effort to meet projected materials consumption needs, the Government has allocated M$39,827,000 for materials research and development for the period 1991-1995, a sum which is small in comparison to the sums allocated for manufacturing technology. This is due to the severe limitations posed for materials research by the existing research institutes. There are currently 29 research institutes and institutions of higher learning in Malaysia, but only nine possess materials research programmes, and even less are involved in advanced materials. A further M$50 million has been allocated for local small scale industries to encourage them to develop new products and processes on a 50:50 basis.

In February 1991 the National Technology Action Plan was established in order to upgrade industrial technology. A Cabinet Committee on Science and Technology chaired by the Prime Minister, has been established, and a National Council for Scientific Research and Development has been formed under the Cabinet Committee to advise the latter on science and technology. Two permanent committees were formed under the Council, one of them entitled the Standing Committee on Development and Management of Science and Technology, which comprises of five working committees, namely on Biotechnology, Advanced Materials, Microelectronics and Information Technology, Advanced Manufacturing and Non-Conventional Energy. The working committee on advanced materials is expected to formulate future policy on activities in this field. It is proposed that an Advanced Materials Research Centre be established with the following objectives. Firstly, to undertake scientific research on advanced materials in order to understand structure-properties relationship, optimise properties and develop new materials. Secondly, undertake technological research on advanced materials in order to develop processing techniques and fabrication of advanced materials components and products and find new applications for already developed materials and components.

The case of Malaysia highlights a central issue facing resource rich developing economies in the 1990s. Is it necessary or possible for such economies to possess an advanced materials research programme, and if the answer is in the affirmative, what form should it take. It is likely that the emphasis should lay in engineering and processing skills in materials. A materials data base together with the creation of a national focal point for materials research and characterisation in the context of regional linkages of centres of excellence would prove useful. It is as well to note that the ASEAN Committee on Science and Technology (ASEAN COST) already has a sub-committee on Materials Science and Technology, promoting the co-operation between countries in the region in the field of materials.

NIGERIA

Nigeria is beginning to confront the necessary structural adjustments of the commodity sector ushered in by the materials revolution. Traditionally, Nigeria has been exporting a range of primary commodities to developed economies where they were further processed and incorporated into final goods. Such commodities include, tin ore, columbite, lead ore, petroleum, rubber, wood and leather. Whatever the merit of such a division of labour, the revolution in materials science and engineering has opened up a new potential for the upgrading of traditional materials as well as posing the threat of substitution from advanced organic materials and loss of export markets.

Reorganising the importance of materials for industrial development Nigeria took the important step of establishing the Raw Materials Research and Development Council (RMRDC) in 1988. Further materials policy statements by the Federal Government are incorporated in the Science and Technology Policy, the Agricultural Policy and the Industrial Policy, but Nigeria has not yet articulated an overall national materials policy framework.

The Federal Ministry of Science and Technology has formulated the National Science and Technology Policy which states the objective that "exploitation, processing and utilisation of the nation's materials resources shall be programmed in such a manner as to promote self-reliance and enhance exports". A central aim relates to the need to ensure adequate raw materials supply for industry. In order to achieve this, it is also recognised that it is necessary to develop new materials which provide the foundation of all new technologies.

The Raw Materials Research and Development Council hosted the First Meeting of the Action Committee on Raw Materials of the Group of 77 developing countries in 1989. In addition, the Council, in conjunction with the National Institute for Policy and Strategic Studies organised a workshop on National Policy on the Development and Management of Raw Materials in Nigeria in 1990. The recommendations are expected to form the basis for the National Policy on Raw Materials. The Council not only formulates policy but also is charged with the responsibility of implementing some of these policies. A survey of Nigeria's material resources, human resources and facilities and equipment related to processing has been undertaken and documented in the Council's data bank. Moreover the Council also sponsors raw material research in R&D organisation and academic institutions. There are twenty six R&D institutes in Nigeria and some of them are required to conduct materials development. Many of Nigeria's universities also conduct research on various materials, through the appropriate departments. Further, linkages have been established between various government agencies and international organisations and other Governments in the field of materials development (eg in August 1991, a memorandum of understanding was signed with Egypt, under which Nigeria's research centres will have access to facilities and experts from Egypt's Central Metallurgical Research Institute).

UNIDO'S ACTIVITIES [24]

As early as 1979, the United Nations Industrial Development Organization established a programme to promote specific technological advances in developing countries. The programme is the UNIDO Programme on Technological Advances which offers advice and guidance to developing countries in emerging technologies and is intended to help them to build up their technological capabilities carefully and selectively. For the biennium 1992-1993, the programme is focusing mainly on new materials, biotechnology, informatics, marine industrial technology, advances in manufacturing technology and solar photovoltaics.

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[24] Updated after the Expert Group Meeting held in Bangalore

The programme in the field of new materials includes:

- information analysis and the monitoring of technology trends in selected materials;
- support national policy and programmes in the field of advanced materials;
- promotion of programmes for international/regional cooperation, including establishment of international/regional centres of excellence and networks of materials technology centres in the regions.

New materials and the policy implications for developing countries have been the subject of special meetings since 1982. The development of a programme on new materials has been the outcome of the Discussion Meeting on Advanced Materials for Developing Countries, Vienna, 7-10 December 1987. For the first time the subject of materials was treated in a trans-sectoral fashion, emphasizing the role of materials in developing countries through the utilization of natural resources; upgrading, substitution and recycling; and the application of high science to develop new materials for specific industrial needs in developing countries.

The revolution in materials science highlights the enormous tasks, analytical needs and informational requirements now embracing the whole materials field across both producers and users in industry. Such tasks are beyond the means of a single specialized research institute, professional society, firm, or ministry. Therefore, UNIDO pays much attention to mobilizing international and regional cooperation, including the creation of international/regional centres of excellence, networks, etc, in order to help developing countries in building up an adequate level of technological capabilities for engineering new materials for specific needs and applications.

A major development in the area of new technologies for UNIDO was the recent establishment of an International Centre for Science and High Technology (ICS) located in Trieste, Italy. The Centre consists of three components:

(i) an International Centre for Pure and Applied Chemistry;

(ii) an International Centre for Earth and Environmental Sciences; and

(iii) an International Centre for High Technology and New Materials.

ICS carries out research in its respective fields as well as runs training programmes. Formally launched in July 1988, the ICS project has been developed with great speed regarding the forecasts which allowed to start the pilot activities at the end of 1989.

Particular prominence in the ICS activities is given to the necessity of making available to the researchers from developing countries the experimental laboratories with advanced equipment for their research with the aim of enabling them to obtain the experience and know-how not always available in their own countries, thus contributing towards the reduction of the "brain-drain" towards industrialized countries. In more than a year activity of the ICS project, which proposes to forge permanent links with centres of excellence in other countries, endorsing at the same time the ties of international cooperation already in existence, has attracted much interest and support at an international level and in particular among the scientific community. A big component of the ICS activities is devoted to new and advanced materials. The programme is being implemented by the Centre for High Technology and New Materials.

The idea of the establishment of an International Materials Assessment and Application Centre (IMAAC) for an in-depth analysis and promotion of the national use of materials was put forward at the Discussion Meeting on Advanced Materials for Developing Countries, Vienna, 7-10 December 1987, and was reflected in its recommendations.

There is at present no institution at the international level which addresses the issue relating to the development and use of diverse materials including new and advanced materials in a trans-sectoral and integrated fashion. Such an institution would provide a forum and functions as protagonist for international cooperation based on an integrated approach to the development and use of materials, which also facilitate the promotion of activities relating to the application of modern science and technology to the development of materials based on local resources and capabilities in developing countries.

The Government of Brazil has been interested in the establishment of IMAAC, therefore, a joint mission was undertaken in October 1989 by a UNIDO and a Brazilian expert. The mission report strongly recommended the establishment of the Centre as being necessary, feasible and timely and it suggested that the preparatory work should be done for this purpose. At present, the first project for preparatory work has been formulated and presented to the Brazilian Government for consideration.

The variety of advanced materials stretches from materials that have already achieved the practical application to those that are being developed. They require more sophisticated and systematized techniques for testing and evaluation. Especially in the case of new materials, advanced evaluation technologies are necessary for their development production and practical application. However, activities associated with the development and establishment of widely recognized evaluation methods are slow and dispersed in the developing countries. Therefore, a proposal was made to establish an International Centre for Materials Evaluation Technology (ICMET) in the Republic of Korea. At present, the feasibility study has been completed and a pilot activity phase project formulated. Both documents were presented to the Government of Korea recently for its consideration.

The establishment of a centre for materials research and development is being promoted in the Arab region as well. It is foreseen that the work programmes of all centres would have strong linkages and be complementary to each other as well as to other UNIDO's programmes in the area of advanced materials.

The Discussion Meeting on Advanced Materials for Developing Countries, Vienna, 7-10 December 1987, emphasized also the importance of establishment of and strengthening national materials technology centres in developing countries through improving their capabilities to apply the latest advances in materials technology, to utilize and to add value to their own natural resources. It also recognized the value of a necessity for international/regional cooperation in this respect and recommended the networking of materials technology centres.

Such type of a network should consist of multi-materials institutions including centres of excellence and function as a network based on an integrated approach to the development and use of new and advanced materials and related technologies in a trans-sectoral fashion. The aim of such a network is to strengthen technology capability in the field of new and advanced materials in developing countries in order to meet the most acute needs of all countries of the region.

At present, the preparatory phase project for the establishment of a regional network of materials technology centres in Asia has already been completed and next phase is being planned for further development of the project. Similar projects for the Latin American and African regions will start early in 1993.

It should be emphasized that materials issues are today multidisciplinary in nature and trans-sectoral in impact. Many countries have already set up a national policy framework exclusively concerned with materials issues. They are, however, still in their early stages and need to be modified to take account of the variety of both the advanced and traditional materials involved and the pace of technological change.

It has, therefore, become essential to organize the Expert Group Meeting on Materials Policy Issues which was held in December 1991 in Bangalore, India. Similar expert group meetings are planned to be organized at a regional level in Asia, Latin America and Arab countries. Other activities in this field are planned and promoted as well.

These are just some activities of UNIDO's programme in the area of new and advanced materials. Besides this, a number of studies has been prepared covering main problems faced by developing countries in this field. These studies used to lay the basis for long-term projects and programmes and are a part of an overall work programme of UNIDO in the field of new and advanced materials.

IV <u>ISSUES ARISING</u>: Generic and Country-Specific

Following the deliberations of the Meeting on individual country case-studies and lessons to be drawn from them, the meeting turned its attention to the task of identifying a large array of pertinent issues which cut across economies, albeit acquiring modified forms when set in concrete national contexts. The discussion below lists the main points which arose under each specific subject heading. It is by no means comprehensive and should only be viewed as a useful starting point for further work in this area.

1. SUPPLY AND DEMAND CONSIDERATIONS

- Resource Assessment: A detailed inventory of locally available resources, reserves and grades is an essential first step for prudent policy formation.

- Economic feasibility of entering at any stage in the material production cycle:

Raw materials availability domestically is not necessarily a deciding factor in fostering advanced materials capabilities. Advanced materials need not be limited to or by local resources.

There is no general prescription with regard to which materials, parts and components should be produced by developing economies. Each country can engage in the production of some or purchase of others in accordance with economic, technological and strategic considerations specific to each sector and economy. Developing economies with adequate raw material resource endowment ought to consider the costs and benefits of exploitation and downstream processing and fabrication. Several considerations arise:

- The extent to which the material should be processed before export in order to enhance value-added, linkages and foreign exchange earnings.
- The level and expected growth in demand by downstream user industries. Lack of domestic demand may preclude the development of specific materials especially if mainly aimed at the export market.
- The degree to which the technologies adding value to the raw material are available or can be developed domestically.
- The requirements, accessibility and implications of technology transfer from abroad.
- If technology is not available domestically it may be developed at a regional level. This includes processing and characterisation/testing technologies, in materials such as carbon fibre, pure ceramic powders, crystals etc.
- On the other hand, while technology is available, it may not be utilised by the private secto , for a wide variety of technical and non-technical reasons, including the level of demand. Socio-political factors may be involved.
- Learning by using and producing advanced materials are important elements and may necessitate an early strategic entry at specific stages in the production cycle of a material.

- A catalytic role for the government:

India used to produce mixed rare earth oxides, but now, with government support, pure neodymium oxide is made. The latter is utilised in the production of neodymium magnets, at present in government laboratories. This raises the important question of the appropriate role of the government at both the supply and demand ends. The government can perform a necessary role as a <u>catalyst</u> for the development, acquisition and utilisation of new technologies provided the appropriate institutional linkages, information structure and market incentives are in place. Fiscal and monetary policy measures will impinge on industrial investment, R&D and technology acquisition. At the same time, public purchasing activities and materials procurement policies will have a direct bearing on the feasibility of domestic materials development programmes.

- Substitution and conservation requirements for specific materials and natural resources.

- Trends in Intensity-of-Use: Intensity of use (consumption per unit of GNP) may be declining when viewed at the early stage of the production cycle, but may be increasing when measured at the higher value-added end of the market.

- Income and price elasticities of demand must also be considered in the relevant export markets.

- Availability of strategic components and parts: These simply may be unavailable in the world market. Import dependence on such components may be inadvisable for some high technology industries.

- UNIDO advisory services: Guidelines and information can be provided to member countries as to processing technology developments in specific materials, regional demand patterns, conservation requirements etc.

2. SCIENCE AND TECHNOLOGY

- The Emerging Unified Approach of MSE Across All Materials and the Preconditions for Effective Implementation: MSE in the 1990s comprises of the structure-synthesis/processing-properties-performance continuum and its application across all classes of materials. It is an interdisciplinary approach and contains both a pure scientific and an applied engineering component. The most critical policy problem in the coming years concerns the acquisition and building up of a critical minimum mass of MSE capabilities across firms, industries, and research and academic institutions in both developed and developing economies. A parallel concern is the provision of advanced characterisation technologies, without which new materials development is impossible, and standard testing and measurement procedures. The government has a role in the provision of the necessary infrastructure and measurement technologies, too expensive for the private sector to undertake single handedly.

- Building institutional capability in materials synthesis and processing: The problem of the appropriate balance between pure scientific research and applied research and engineering considerations - although recent developments have raised the relative importance of pure science, it is the case that too much emphasis can be placed on it to the detriment of processing and commercial application. The government can either outline an overall programme/framework or engage in active support of specific programmes. In effect, the government can pull or push certain technologies, depending on the stage of their development. MITI in Japan supports projects of a long term nature, too costly or risky for private enterprise.

- Technology forecasting and assessment: In many economies the appropriate interdisciplinary institutions necessary to engage in the analysis, forecasting, assessment and elucidation of policy implication of the direction and pace of materials-related technological advance are either not in place or require strengthening. Another area of importance here is the planning of R&D activities at the level of the firm, the industry and the economy. In many cases, the lack of autonomous R&D capabilities in the private sector acts as a serious constraint in the current technological and market conditions, and is therefore a policy priority.

- Impact of technology, technology transfer and assimilation capacity: Current circumstances are characterised by rapid technical change and fast flows of technology across national boundaries. Access to new technology and ability to assimilate and effectively utilise it is important in the competitive race. A degree of in-house technological competence is necessary for successful technological alliances, joint ventures and licensing from abroad.

  The protection of intellectual property rights is critical in attracting foreign capital and technology. Similarly, in conditions of fast change in new materials technologies, patent protection considerations rise in importance. Together with importation of technology, 'Technology Tailoring' becomes an important tool in the efficient exploitation of high quality local resources. The purchase of research from abroad may assist in conserving resources in danger of being depleted or in scarce supply.

- Materials use efficiency: The development and acquisition/adaptation of technologies for waste minimisation and more efficient use of materials and energy in industrial activities both to meet domestic basic needs and in export orientated markets is especially important for developing economies.

- Materials supplier-user relationships: The new circumstances imply a closer integration of materials and product design and manufacture. In many cases the new material and the product are one and the same thing. Materials processing and product manufacturing or assembly must be looked at simultaneously as a coherent whole. A new material is never a straight replacement of an existing material, and costs must be calculated on the basis of total lifetime system costs. Materials producers do not supply a specific material but rather a group of properties required by the user in a specific application. Many changes in materials supply are therefore market-driven or -pulled. Existing materials cannot meet the increasingly stringent performance requirements in a range of high technology applications.

- New research projects: Here the issue of exclusivity or non-exclusivity is important. When government funded research becomes 'non-exclusive' after being transferred to industry, the system is likely to fail. In the EC the owner of the patent is clarified at the start of the project. In Mexico the University has the proprietary right on the research done there, and after transfer it becomes exclusive. In Germany, before initiating the research itself the proprietary rights are determined - it depends on who pays for it. For electronic materials in India, the exclusivity is granted for the initial few years.

The government can conceivably play a key role in promoting R&D as a joint venture between supplier and user. In these circumstances the state will need to engage in both 'market pull' and 'technology push' activities.

- UNIDO's role: UNIDO can play a key role in facilitating the flow of information and the networking of materials - related technological advances across member countries. In this, the new international centres promoted by UNIDO can play an important role.

3. **HUMAN RESOURCE DEVELOPMENT**

- Manpower planning at each stage of the material cycle (both in terms of skills/quality and numbers).

- Training and retraining needs assessment. Integrated, interdisciplinary training. The need for multiskilling especially at higher value-added end of product cycle. The need for new knowledge and skills in new materials production (eg composites) and use.

- The role of engineers: Engineers trained in MSE can bridge gap between pure and applied science. The need to send people abroad to train in materials science and engineering where domestic conditions preclude this.

- The mix of training programmes: Formal (degree/diploma), continuing education and training within industry.

- The generation of MSE departments and curricula given existing capabilities and interdisciplinary divisions and specialisations in higher education and universities.

- Financing of education and training schemes. Role of private and public sectors.

- Brain drain: While the sending of scientists and engineers abroad is desirable, so is their return to the country of origin. Both financial incentives and the research environment and infrastructure must be at a sufficient level to attract and retain scientists and engineers in the home country. The emerging shortages of engineers in developed economies will accentuate the brain drain problem for developing economies in the future.

  In India there are 30 departments in metallurgy, which is still very strong due to the need for metallurgists. Solid state chemistry and physics are moving to materials science and this is leading to a rise in the departments and number of students in the area of materials, but this remains a fragmentary process. In contrast, MSE departments are emerging in the US (eg at MIT) or in Oxford, UK. In MSE the emphasis has been on structure and characterisation, but now processing and properties are becoming more important as the emphasis shifts to tailorability and applications of new materials.

  ASM in the US has facilities for distant education at one tenth of the cost of that at a regular university. This is available only for sponsored candidates.

4. THE ENVIRONMENT AND ENERGY

- The environmental safety and sustainability of each stage in the production cycle of a material must be carefully considered. Future policies ought to examine the detrimental aspects of materials development and use in the past in order that they be avoided.

- New materials processing and utilisation may entail environmental problems (eg Aluminium-Lithium or the non-recyciability of composites). On the other hand new materials can be designed to directly address and resolve environmental problems.

  New materials developed to meet the needs of the environment and sustainable development is a major policy area of the 1990s. Environmental issues will need to be addressed early on at the materials and product design stage.

- Renewable and non-renewable resources: New materials can draw upon locally available renewable and abundant resources and directed to meet basic needs such as housing, irrigation schemes, transport, food packaging and preservation etc.

- Environmentally friendly products may cost more: In some cases these costs may be passed onto an environmentally friendly consumer as the emergence of 'green businesses' in developed economies suggests. In Japan consumers are willing to pay more for environmentally friendly cars.

  Products from developing countries are, in the main, not energy and environment friendly, and this may render them uncompetitive in the world market. Making products and processes more environmentally and energy efficient is costly and difficult because many developing countries do not possess the relevant technologies.

- Pollution control, waste management and recycling activities are central policy considerations in the context of industrial and development strategies of the 1990s. New materials diffusion necessitate the creation of a new range of high technology recycling and waste disposal industries.

  New technologies under way tackle the pollution issue by reducing or eliminating it in the engine itself rather than at the end, while others involve closed loop processes in processing.

  New technologies are required to analyze toxic specimens, determine toxic levels and damage to the environment, and reduce toxic levels.

- Energy conservation has environmental implications.

5. INDUSTRIAL STRUCTURE

- Industrialisation strategy must be closely connected to materials strategy. At the same time materials strategic policy orientation can be reflected in industrial strategy. New materials can be developed which can underpin major new technologies, the rise and competitiveness of industrial sectors and, consequently, the evolution of domestic industrial structure.

- Rationalisation, modernisation and redeployment of industry: Industry in developing economies is greatly affected by the process of industrial restructuring, technological upgrading and relocation of industries and segments of the production process under way for nearly two decades. This affords opportunities but also poses problems. Many developing economies possess comparative advantage in resource-intensive processing activities. Many energy-intensive, pollution-intensive activities, especially in commodity metals and chemicals, are slowly relocated to regions with abundant energy sources or less restrictive and costly environmental regulations.

- Economies of Scale and Economies of Scope: Economies of scale are still important at the early stages of the materials cycle. Further downstream, at the fabrication end, economies of scope and flexible manufacturing methods aiming to meet diversified, high quality materials requirements in end use market segments are now more important. Size of the total market and capacity utilisation remain an important consideration.

- Emergence of the large multi-material, multi-national firm: Traditional materials boundaries are becoming blurred as firms begin to acquire multi-materials and multi-disciplinary competence. In addition, there are strong incentives for backward and forward integration by materials producers and users. Materials producers must get close to the customer to meet needs, specifications, co-development and technical servicing of product and competition from other producers. Many of the leading aluminium, steel and chemicals producers are developing into large, diversified, multi-materials international producers with a presence near the customer in all their major markets.

- Regulation and competition: Competition policy in the areas of vertical integration, diversification, mergers and acquisitions, technology flows and technology collaboration within and between national borders needs to be carefully rethought in the era of new materials. Competition policy, industrial policy and materials policy need to be addressed as a coherent whole.

- Partnerships and consortia in research: Industry-Government R&D partnerships and consortia are an important component of the conduct of advanced materials research and its transmission into the industrial sphere. Although the rationale for this is reasonably clear (eg large costs, complexity, inter-disciplinary requirements, risk-sharing etc) there are many difficulties to be resolved for a successful outcome, as indicated by the varied evidence from the USA, Japan and Europe, (eg in dealing with the pre-competitive stage of research, incentives for firm participation, and dissemination of results).

6. ADVANCED MATERIALS AND THE FIRM

- Materials technology and corporate strategy: How are firms in developing economies responding to the pressures and complexities ushered in by MSE? How are they responding to market pressures from the side of materials users domestically and in the world market? Can we begin to identify discernible pressures for higher materials quality and emerging linkages between suppliers and users in NIEs and other developing economies? Is the question of quality assurance of deciding importance in the locational decisions and sourcing strategies from specific economies by MNCs? What lessons can we draw from the way in which firms, industries and institutions are responding to MSE and the new market conditions in developing economies? How precisely are firms in steel, chemicals, aluminium, ceramics, glass, cement, wood, and so on in the developing world responding to the new materials circumstances?

Companies which have been operating in export markets already have had to meet more stringent quality specifications, but firms in newly liberalised economies and sectors are facing serious difficulties of competitive adjustment. Higher quality can be achieved by cross-border technology alliances (eg in specialty steels, between India and Austria, to produce highest quality for domestic cars).

- Technology acquisition: There are considerable difficulties faced by domestic firms in their attempt to identify, correctly select, acquire and effectively absorb foreign sources of technology. Government institutions can provide assistance in this, as in the Province of Taiwan for example.

  Attracting foreign firms in forming joint R&D and technology alliances presupposes a critical minimum mass of in-house technological expertise in the chosen field.

  Public policy and protection of intellectual property rights play a critical role in attracting or repelling foreign firms.

- Technology and market forecasting capabilities may be limited at the level of the individual small- and medium- sized firm.

- Size of the firm and R&D and design capabilities: A major problem in the ability of firms to survive in to-day's technological and market conditions is the lack of R&D traditions, experience, manpower and resources as well as the lack of in-house product and process design capabilities. This is emerging as a critical constraint in the shift of Taiwanese and in firms of the Republic of Korea towards high-value added and high technology activities aimed for the world market. It has therefore become a priority area for public policy in all its multidimensional aspects.

- Planning for the transition: Firms need to carefully plan the transition to new materials production or utilisation.

- Cost reduction: Materials choice is dependent not only on quality (reliability, consistency, durability) but also on cost. This is especially so at the commodity end of materials production, where advanced processing technologies can confer decisive cost advantage. This is an area that developing economies must pay increasing attention to if they are to retain competitive advantage in large scale production of traditional materials.

The new methods of continuous improvement and quality assurance must also be embraced by materials firms, and the rest of industry in developing economies.

It is important to note that different levels of technological sophistication exist in each industry and there may still be a niche for the use of intermediate technologies in specific activities in developing countries.

- Materials use efficiency: Cost and environmental considerations necessitate closer attention, than hitherto exercised, to the more efficient utilisation of materials by firms in each industry. In India more efficient fuel consumption in the transport industry is mandated due to cost reduction requirements. New materials (eg new aluminium alloys) can reduce weight and hence increase fuel efficiency.

- Protection and liberalisation measures can have a decisive impact on the competitive survival of firms in a materials producing or using sector, especially at the early stages of operation.

- Standards: Standards in testing, measurement and evaluation procedures have become the critical factor in materials development and subsequent diffusion in industry. This is an issue that affects all firms and must be tackled in an economy-wide perspective. Accordingly, national standards and evaluation institutes have acquired a pivotal role in new materials and industrial development in the 1990s. At the same time, the issue of standards goes beyond individual economies and of necessity involves international cooperation in the development of commonly accepted standard testing and measurement methods in ceramics, advanced metals, polymers and composites. Important efforts are under way in this connection between developed economies (VAMAS), and developing economies must consider how best they can tackle the problem at a regional and international level.

V CONCLUSIONS AND RECOMMENDATIONS

The Expert Group believes that the urgency and critical importance of materials policy issues demands national and international cooperation on a continuous, long-term and systematic basis. Therefore, based on the deliberation of the Meeting, it makes the following conclusions and recommendations.

1. DISSEMINATION OF INFORMATION

UNIDO has taken a major initiative in identifying materials policy issues as the theme of the meeting, given that these will be the crucial determinant of materials technology-led industrial development in the remaining years of the decade and into the next century. Dissemination of the documentation, deliberations and findings of this meeting is important for creating wide awareness of the issues and providing assistance to countries in formulating and implementing effective materials policies. For this purpose, the following actions are recommended:

a) Preparation of an edited volume of the proceedings and its publication at an early date.

b) Preparation of a Reference Book (or Handbook) on materials policy which can serve as a useful source of methodologies, approaches, requirements and options for policy formulation and implementation in country specific contexts. The Reference Book may contain state of the art information concerning materials developments, which can be continually updated, as well as background information on specific materials.

c) Continuing technical assistance and advisory services to requesting countries for materials policy formulation and implementation based on the Reference Book and expert services.

2. INTERNATIONAL NETWORK ON MATERIALS POLICY

Mutual understanding of the materials situation and respective policy mechanisms among countries is vital in order to promote international collaboration and industrial development. To promote such understanding, UNIDO needs to support the formation of an International Network on Materials Policy, comprising of individuals and institutions concerned with and interested in materials policy issues. The network's main objectives would include:

a) exchange and sharing of information on different activities;

b) publication of a newsletter outlining policy developments and information on literature, conferences, meetings etc.; the newsletter could offer specialised sections on development in particular regions of the world economy such as Europe, North America, Africa, East Asia, the Middle East, etc.; moreover it could be linked to existing UNIDO information services such as the Advanced Materials Monitor;

c) publication of occasional papers and a regular volume on materials developments and policy issues through a commercial publisher;

d) promotion of "materials" as a significant issue in the agenda of international institutions;

e) organisation of meetings, conferences, etc.

Materials Policy Advisory Panel: UNIDO may also consider the establishment of a Materials Policy Advisory Panel, within the context of the formation of the international network and its stated objectives.

Regional Expert Group Meetings: To facilitate the formation of this network, UNIDO is urged to organise two regional expert group meetings - one in Africa and one in Latin America, on materials policy issues, to identify major regional policy issues and bring together countries in each region in order to share experiences, and to articulate and share common issues and strategies. The outcome of these meetings will increase our understanding of the relevant issues and facilitate the formation of a network as well as meeting its objectives. These meetings will be a natural follow-up to the December 1991 meeting in Bangalore, India.

3. PRIVATE INDUSTRY

The meeting recognises the critical role of private industry in materials research, development, processing, fabrication and application. It is therefore imperative that the private sector should participate, as fully as possible in all the major regional and international initiatives underway and forthcoming.

The meetings deliberations sharply highlighted the close and integrated nature of new materials and advanced manufacturing technologies. Indeed materials are a critical component of technology and therefore play a leading role in industrial development. An important component of materials policy concerns the raising of awareness and the strengthening of private industry's ability to respond to, assimilate and cope with the far reaching changes on the side of materials science and engineering, and, concurrently, on the side of the materials-manufacturing interface. It is incumbent upon UNIDO therefore to promote awareness of issues concerning materials producer-user cooperation and interactions; the acquisition of materials synthesis and processing capabilities; the mechanisms for the transmission of pure and applied research into industrial and commercial application; the design of products and processes which meet energy conservation and recycling criteria; and the development of materials and products standards and testing procedures. In stressing these aspects the meeting is of the opinion that industry's <u>needs</u> and <u>views</u> are of paramount importance and must be actively sought.

4. INITIATIVES IN PRIORITY POLICY AREAS

Far reaching developments in Materials Science and Engineering are expected to result in dramatic changes in the world of materials. Greater understanding at the national and international level is essential, while, at the same time, responses are called for in a variety of areas. The meeting identified the following priority policy areas in which UNIDO needs to undertake **major initiatives** as an extension of its earlier programmes, in order to increase understanding of the trends underway and their consequences; to build a knowledge base in these areas; and, to formulate strategies for international collaboration and capability building. The initiatives may take many forms, consisting of studies, meetings, techno-economic assistance, publications etc. Detailed proposals need to be elaborated on each of the subject matters listed below. The collaboration and close involvement of leading institutions (both governmental and non-governmental) is necessary for the successful outcome of the initiatives:

a) Materials Science and Engineering Research and Human Resource Development.

b) Materials Science and Engineering and Industrial Restructuring.

c) Materials Science and Engineering and its impact on Energy Conservation and the Environment.

d) Materials Science and Engineering and the Protection of Intellectual Property Rights.

e) Materials Science and Engineering and its impact on Performance and Quality Assurance in Industrial Products and Processes.

f) Materials Science and Engineering and its implications for the Producer-User Interface and the Integration of New Materials and Advanced Manufacturing Technologies.

The participants noted that UNIDO's efforts to promote the setting up of international centres in materials (the International Centre for Science and High Technology, Trieste, Italy; the International Centre for Materials Evaluation Technology, Taedok Science Town, the Republic of Korea; and the International Materials Assessment and Applications Centre) are consistent with and supportive of the recommendations made above.

The Meeting concluded with thanks to the organisers and a request for speedy follow-up action in the areas identified above.

Annex I

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Annex II

List of documents

1. **Discussion Meeting on Advanced Materials for Developing Countries**, Vienna, 7-10 December 1987, UNIDO Report, IPCT/.53(SPEC.)

2. **Discussion Meeting on Advanced Materials for Developing Countries**, Vienna, 7-10 December 1987, IPCT/57(SPEC.)

3. **The UNIDO Programme on Technological Advances**, IPCT.39(Rev.2)

4. **The Revolution in Materials Science and Engineering: Strategic implication for developing countries in the 1990s**, Technology Trends Series: No 13, IPCT.131(SPEC.)

5. L. Kaounides: **Advanced Materials and Industrial Restructuring in Japan and South East Asia in 1980s-1990s**, paper submitted to the Meeting by UNIDO consultant

6. M. McLaren: **Developing a Vision for Materials Policy Processing in the 1990s: the Role of National Policy**, paper submitted to the Meeting by UNIDO consultant

7. R. Ganapathy: **Materials Policy Development in India: Emerging Issues**

8. A. Valladares: **Scientific Policies in Mexico for the Development of Materials**, paper submitted to the Meeting by UNIDO consultant

9. H. Czichos: **Materials Technologies in Europe - Status and Trends**, paper submitted to the Meeting by UNIDO consultant

10. R. Salleh: **Malaysian Materials Policy: An Overview**, paper submitted to the Meeting by UNIDO consultant

11. A. Aribisala: **Policy Issues in Nigeria**, paper submitted to the Meeting by UNIDO consultant