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EXPERTS' WORKING PAPERS*

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PREFACE

Six papers, which you will find included in this publication, have been specially prepared for the UNIDO "Discussion Meeting on Advanced Materials for Developing Countries" held in Vienna from 7 to 10 December 1987.

The objectives of the meeting were:

- To consider the developments taking place in the field of materials and the related technologies, in particular the experiences of some developing countries;
- To discuss the role of materials vis-à-vis the developing countries;
- To discuss the necessary infrastructure for the wide scale introduction of new materials to developing countries.

The meeting also made recommendations as to the measures to be taken at the national and international levels.

For more details please see UNIDO Document IPCT.53(SPEC.)

SOME ELEMENTS OF THE ITALIAN POLICY IN THE FIELD OF MATERIAL PHYSICS

by C. Rizzuto

In the following I shall try to outline a few concepts and suggestions based on the experience in educational and research policy followed in Italy in the field of the Material Physics (which includes Biophysics, Condensed Matter, Atomic, Molecular and Computational Physics).

I shall also outline in some detail the experience of the International Centre on Theoretical Physics in Trieste, whose experience could be used in different fields.

The reason for the interest in the two above experiences is due to the fact that in most developing countries the major obstacles to the utilization of international advanced scientific know-how is due to the small critical mass of the resident scientific community, the lack or dispersion of available facilities and the difficult connection with the international scientific environment, both in terms of the flow of ideas and of the availability of technical support.

A case of co-ordination and growth in a research field: Material Physics in Italy.

The situation of non-nuclear physics in Italy in the 50's was plagued by problems of the type listed above: only six group-leaders with international training existed and a total of about thirty researchers were available by about 1960. Moreover, they were dispersed throughout the nation's universities, from Sicily to the North. Added to this was that the availability of even simple instruments or technologies or servicing, was very difficult outside the major cities.

In the beginning of the 60's, also in view of the growing importance of solid state physics and to balance the overgrowth of nuclear physics, which was historically well established, a decision was taken which determined the evolution of the field of Material Physics.

The decision emerged out of a spontaneous choice of the researchers who decided to co-ordinate on a national basis the possible sources of support, whatever they were and to choose international competitiveness as a reference frame.

Practically all scientific programmes from then on have been discussed on a national basis and presented to financing agencies (both local, national or even international) with the mutual agreement of the community at large and without the acceptance of imposed choice.

Furthermore, a rule was established to encourage junior researchers to spend one or two years at advanced laboratories abroad and to bring back new ideas in which they had been instrumental in setting up; this was complemented by holding an annual two-week national colloquium with national and international teachers. Such colloquia were later extended for laboratory technicians and graduate students.

The above decisions, implemented over a period of more than twenty years, have helped in the growth of a community of over 1,000 whose interconnection and co-ordination is very high (e.g. about 30 per cent of the scientific papers are co-authored by people at different universities). This helps in overcoming the variety and small size of local groups operating on very differing subjects in the 30 universities which presently conduct activities in Material Phycis.

This good co-operational activity has also made it possible to set up a consortium between all universties involved and to set up one common representation vis-à-vis government policies.

If the elements of success are analyzed more deeply one can find two major elements: educational and managerial.

The educational element is based on the personal acquaintance and cameraderie of the various age groups on a national basis, which has been built up through the national colloquia. Somehow the fact of living together for a couple of weeks has proved more important than the actual teaching or learning activities.

The managerial element, which has helped to maintain unity over the years in the absence of a funding authority but which in fact is against the dispersive approach of most funding authorities, is the decision of having a very light centre of co-ordination made up of two secretarial staff and a panel of four to ten researchers who are in charge of information flow and organizing activities related to planning and education.

In the international context the competitiveness of this field of research is ensured, in spite of the absence of large materials science laboratories, because the national network provides a distributory laboratory of sufficient size, which is well connected to internationally available large facilities.

How can this experience be translated into a proposal for the support of advanced use of materials in develping countries?

The starting conditions have a number of points in common: low size (or lack) of existing local facilities and scientific know-how, difficulty in keeping abreast of the rapidly evolving field in the international context, and difficulty in establishing a sufficiently large establishment to cope with local problems.

What seems to be important is to set up a well connected network of researchers who can easily and effectively exchange ideas and interlink with the existing advanced facilities, as well as make use of know-how at the international level for local problem-solving purposes. The evolution and updating of this network must be based on two elements: educational (international schools and seminars) and organizational (co-ordination centre, availability of data and access to advanced laboratories).

Useful boundary conditions and additional contributions seem to be the evolution of an awareness, in the scientific world, of the specific advanced approaches required by many local needs and the availability of either appropriate equipment to be used in small and difficult to service institutions, or of a number of strong centres located in developing countries in a geographical network which could easily be interlinked.

A further important aspect is the connection of the scientific with the techno-economic aspects which should always be taken into account in view of the transfer of scientific know-how in new or advanced products.

A case of international educational efforts: the ICTP

The educational approach could be managed at an international level using the experience gained in the operation of the Trieste International Centre for Theoretical Physics (ICTP).

The ICTP provides an experience which may give a guideline to set up a centre of training and interaction between scientists and technicians from developing countries among themselves and with qualified senior scientists and technicians from developed countries.

The activity of ICTP is based on a very small resident staff and on the availability of appropriate spaces to host lectures and guest scientists who spend periods ranging from one week to a few months. Junior scientists from developing countries spend periods of time at the Institute connected with specific seminars or schools. More extended stays are arranged through the Institute and spent at selected institutions within Europe.

By allowing the use of facilities existing at other institutions, the theoretical courses are complemented by practical and experimental activities: more recently a microprocessors laboratory has been set-up and other laboratories are planned. This has evolved from a previously only theoretical activity.

The numbers of junior scientists involved are up to few hundred per year (depending on the availability of fellowships from the countries of origin and from the Trieste Centre). The visiting scientists have, as a specific incentive, the possibility of meeting and working with other top scientists from around the world, with relatively limited teaching and no administrative commitments, in a sort of short sabbatical period.

The main result of the Trieste initiative is, apart from the direct educational result obtained through the seminars and workshops, the establishment of a network of personal contacts between junior researchers of different developing countries, which is gradually leading to the establishment of more co-operative contacts.

Additionally, the contacts which can be established directly between the scientists and institutions in developed countries bring out the possiblity of being continuously in touch with the international state-of-the-art in a specific field.

It is estimated that, in the more than twenty years of its existence, over ten thousand junior researchers have been through ICTP.

In the following year some advanced "hands on" experimental courses will be tried out, for example one will involve the processing and characterization of the new "high temperature" superconductors.

Conclusion and possible suggestions

The field of science related to the understanding and use of materials is undergoing a very rapid and almost revolutionary growth, which is difficult to follow over a wide spectrum for most, but for the largest and richest countries.

An additional difficulty is that of applying the knowledge evolving from this fast growing area to apparently "less advanced" (and therefore not academically attractive) problems or materials more common in developing countries.

An integrated approach is needed which addresses the various elements of the problem and which can be followed over a sufficiently long period of time to become self-sustaining.

On the basis of previous experience and of an analysis of the problems, we may summarize as follows a series of problem-related steps to be followed under UNIDO sponsorship or in any other international co-operation:

- Education and individual networking; by international schools of the Trieste type where an interconnected turn-over of both developed country experts and developing country researchers is ensured over a sufficient number of groups.

- Periodical informative encounters between people acting as focal points in several developed and developing countries in order to maintain a constant communication and co-operation on the basis of co-ordinated programmes.

- Development of an agreed co-ordination and information centre to act as a catalyzer of cross links between institutions and people in order to improve the effective scientific body of even small and isolated groups.

- Initiatives aimed at improving the availability and mastering of advanced materials know-how and characterization equipment: this could be made through hands-on schools, courses at large laboratories, or "scientific fairs" connected to educational initiatives.

- Initiatives involving inernational co-operation, e.g. in the field of exchange of standard materials or exercises on characterization methods.

- Initiatives calling for support of the developing countries' efforts, e.g. orienting a percentage of already existing projects of developed countries to the development of locally available materials.

To implement the various aspects of the above suggestions it should be possible to find host countries or institutions to take upon themselves the relatively small costs involved in setting up a co-ordination and an educational infrastructure which could be achieved only by a better use of existing initiatives (laboratories, universities, etc.).

MATERIALS TECHNOLOGIES AND MATERIALS POLICIES IN DEVELOPED AND DEVELOPING COUNTRIES

by H. Czichos

CONTENTS

1. Importance of advanced materials for industry and economy

The key role of materials technologies for future industrial developments can best be illustrated by reviewing the major materials developments identified already in the 1979 US National Academy of Sciences five-year outlook as being those likely to have a major impact to society out to the turn of the century /1/. The list includes the following materials and material-related developments:

- Synthetic polymers
- High-performance resin- and metal-matrix composites
- Silicon nitride and silicon carbide ceramics
- Rapidly-solidified superalloys
- Single-crystal engine components (e.g. turbine blades)
- Fiber-optic transmission
- Very-large-scale, integrated-circuit silicon chips
- Bubble memories for computers
- Semiconductor infrared detectors
- Powder metallurgy consolidation techniques
- Precision casting
- Laser treatment of surfaces
- Computer-aided design and manufacturing

The driving forces behind the materials developments are various technological, social, and environmental requirements, as for example:

- Improved performance, integrity and reliability of engineering systems
- Higher durability of products
- Higher efficiency, lower-energy consuming engines
- Light weight, high-strength structures
- High-speed information technologies
- Increased productivity of manufacturing technologies.

In order to fulfill these requirements, there is a continuous need to develop materials with specific functions - mechanical, thermal, optical, electro-magnetic, chemical, biological and electronic.

Progress in materials development will take place within two main types of products:

- Materials development by high technology industries (such as composite materials for aeronautics) are now being adapted for potential use in consumer markets (the most strategically important being the automobile industry);

- the performance of middle or low grade materials is being improved in order to compete with other new materials.

According to a recent French study /2/, the world market for new materials is growing twice as fast as the whole of the world economy. In Table 1 a world market outlook by broad product categories is given.

The OECD nations account for 80 % of the new materials market. Production is even more concentrated, particularly where patents are concerned : the United States, West Germany, Japan, France, Great Britain, Switzerland, Holland.

Of all the developed countries, Japan uses new materials the most heavily (with the highest ratio of new materials sales to GDP). Japan is also very competitive in new steel and ceramics products; the United States is in a strong position on the technical plastics market. Europe has improved its performance in new steel products (France, West Germany) as well as in technical plastics (West Germany and - to a lesser degree - France, Italy and Great Britain).

The new materials under study here are used in the following sectors in Europe:

- Automobiles.................................25 %
- Mechanical engineering......................17 %
- Electrical and electronical engineering.......17 %
- Construction................................15 %
- Packaging.................................... 9 %
- Sports and leisure........................... 4 %
- Aerospace engineering........................ 3 %
- Other sectors...............................10 %.

The different sectors' relative positions change if we examine growth rates of new materials use (see Table 2.) Packaging, aerospace engineering, automobiles, and sports and leisure have the highest consumption growth rates, and packing has the very highest. The high expected growth rate for new materials use in this sector is due, not to an increase in production, but to an expected rapid change in the materials used by this sector. Construction, on the other hand, has been slow to adopt new materials.

2. Material technologies in developed countries

2.0 General considerations

The further development of "New Materials" (in connection with other "New Technologies", like microelectronics or advanced CAM-systems) may have some important implications on the industrial systems in the industrialized countries /3/:

- The intellectual and financial efforts for the development and design phase by the companies increase considerably.

- The connections between the phases of development, design and production of final products are increasingly tighter. This means that the product cycles are shorter and the development and design phase is often longer than the life cycle of the pertinent products.

- The interdependencies between industrial production systems and product-oriented services are increasing. This means that complex products can only be sold competitively at the international market if industrial product systems are coupled with efficient product-oriented services.

- The increasing interindustrial interdependencies in advanced industrial systems will have important effects on the industrial organizational structures. Depending on the type of products, this will lead both to processes of concentration and of deconcentration.

The economic and social impacts of the technological process in "strategic industries" in the industrialized countries cannot yet sufficiently be estimated. The effect of new technologies on economical growth and employment may be different in the three leading industrial areas, namely the USA, Western Europe and Japan. It has been estimated /3/ that in the USA only 13% of the 105 Million employees are working in "high-tech" industries, which are only 14 Million employees. The main increases in employment have been reached in recent times in the areas of low-wages services whereas the number of "high-tech"-employees has only changed very little. For the Federal Republic of Germany similar relations seem to be valid. It may be assumed that only [illegible] Million employees out of the total of 26 Million employees are working in the high technology area. On the other hand in Japan where the so-called new technologies have the broadest effect, a very low unemployment rate is observed. However, this must also be seen in connection with other factors like the characteristic industrial organizations and the social structures of Japanese companies.

These brief considerations indicate that the connections between materials technologies, industrial structures and economy are by no means simple and need thorough analyses which consider the influences of numerous technological, economical and social factors. In a simplistic view three fundamental changes are to be observed:

- For basic materials industries, growth of output in pounds is not a desirable main criterium any more.

- A steady but accelerated trend towards adding more know-how in the use of materials and their properties

- Last but not least the demand by people for better quality for life will be the main driving force in industry's activities. This term "quality of life" comprises not only environmental protec' on but in general providing new and more sophisticated products and services.

In addition to these more global remarks, the trends in materials technology in the main western trade blocks, namely USA, Japan and the European Communities, are briefly reviewed.

2.1 United States of America

The trends and opportunities in materials research in the USA were reviewed in 1984 by the Materials Research Advisory Committee cf the US National Science Foundation. Several overall trends in the field are noted, including (i) expansion of the frontiers of extreme physical conditions (temperature, pressure, materials purity etc.); (ii) the increasing sophistication and power of theory to confront the complexity of real materials; (iii) the careful study of model systems which isolate for study certain fundamental or technologically important problems; (iv) a shift toward the study of complex materials and systems; (v) increased sophistication in the methods of materials preparation; (vi) fuller characterization of materials on the atomic scale which ultimately determines the macroscopic properties of primary interest; (vii) an increased focus on understanding and controlling the processes used to make materials, and the tailoring of specific properties either for practical applications of fundamental study. Finally, three critical institutional needs are noted; (i) access to modern synthesis, characterization and computational tools that already exist but are not readily available due to their high cost; (ii) nurturing of appropriate institutional arrangements which take into account the broad interdisciplinary nature of materials research; (iii) the development of institutional and financial mechanisms to foster greater collaboration between universities and private industry.

Materials R & D in the USA is performed at universities, private companies and Government agencies. It is supported by National programmes (like the "National Materials and Minerals Program Plan" of April 1982) and considerably large budgets. For example, the US Federal Agencies DOD (Department of Defene), DOE (Department of Energy), NASA (National Aeronautic and Space Administration), NSF (National Science Foundation), NBS (National Bureau of Standards), BOM (Bureau of Mines) had in 1983 a budget of nearly 200 Million US $ for funding in six key materials areas:

- Composites
- Ceramics
- Rapid solidification
- Polymers (crystal)
- Polymers (synthetic)
- Polymers (membranes)

2.2 Japan

Systematic strategies for materials R & C in recent years brought Japan in a key position in certain material-related industrial sectors. In this sense Japan controls "strategic technologies" as indicated by the following positions:

- world's largest producer of high performance ceramics for the electronics industry and engines

- world's second largest producer of titanium (same level as USA)

- world's second largest producer of components for information technologies

- world's second largest producer for carbon fibers.

As a part of major research and development projects on new metal material implemented by the Japanese Government, the R & D Project on Basic Technology for New Industries is promoted by the Agency of Industrial Science and Technology of the Ministry of International Trade and Industry (MITI). The R & D areas include the following projects:

- Fine ceramics (1981-1990; 13 · 109 yen)
  Development of structural materials having the characteristics of high strength, high corrosion resistance, high precision and durability in a high temperature environment.

- Polymer membranes (1981-1990; $10 \cdot 10^9$ yen)
  Development of highly efficient liquid separation membranes and gas/air separation membranes which will make it possible to perform separation, concentration, and purification of substances which require a large amount of energy and do not permit easy processing according to conventional separation processes.

- Conductive polymers (1981-1990; $5 \cdot 10^9$ yen)
  Development of electric conductive polymer materials which have high electric conductivity, permit easy processing into electrical and electronic part materials with functions not available in conventional metal materials.

- High performance plastics (1981-1990; $6 \cdot 10^9$ yen)
  Development of polymer materials with high crystalline characteristics and with the modulus of elasticity in bending being 100 GPa or over.

- Advanced alloys (1981-1988; $8 \cdot 10^9$ yen)
  Development of superhigh heat resistant alloys, heat resistant and highly durable alloys, and lightweight highly durable alloys with emphasis respectively on heat resistance, durability and lightweight.

- Advanced composites (1981-1988; 11 · 10^9 yen)
  Development of plastic composite materials, fiber reinforced plastics (FRP), and metal composite materials, fiber reinforced metals (FRM), as structural materials which are light in weight and high in strength and durability.

- Photo-active materials (1985 - ...)
  Development of materials which will make it possible to utilize the changes of molecular structures due to light (change of absorption ratio and reflection) for recording and other purposes.

Although some new materials, including fine ceramics-based and carbon fiber-based composite materials and engineering plastics, have already been put into commercial use, the majority of new materials are expected to be introduced into full-scale commercial application in the late 1980's through the year 2000.

According to a report on the future outlook (in the year 2000) of new materials, announced by Industrial Structure Research Committee of the Ministry of International Trade and Industry in March 1984 /4/, the total new materials market is predicted to reach about 5.4 trillion yen (approximately US$ 22.8 billion) at 1981 prices. The largest market will be the fine ceramics market at 1.9 trillion yen, followed by new metal materials and specialty polymer materials, each amounting to 1.5 trillion yen, followed by advanced composite materials of 0.4 trillion yen. Also, according to this prediction, large scale integrated circuits (LSI) are expected to consume a majority of fine ceramics and new metal materials, while lightweight structural materials are expected to consume a majority of the specialty polymer materials and advanced composite materials market.

The market of electrical function materials, mainly for use in large-scale integrated circuit (LSI) materials, is estimated to reach 2.5 trillion yen, the optical function materials market, centering around optical fiber materials, amounting to 0.6 trillion yen, and the thermal function materials market focusing on thermal resistant structural materials, amounting to 0.5 trillion yen.

2.3 European Community (EEC)

In the EEC there are increasing attempts to create a "technology community" with the help of common research and technology programmes.

In 1982 on behalf of the Commission of the European Communities, EEC, a study was carried out to determine the future materials research requirements within the EEC /5/. The study included opinions from trade associations, scientific and technological societies in all main branches of industry and materials technology:

- automotive industry
- construction industry
- vessel construction
- mining
- chemicals industry
- electrical industry
- plastics industry
- aeronautics industry
- machine and plant construction
- metals industry
- paper and board industry
- welding technology
- steel fabrication
- structural steelwork
- textile industry.

In this study, the main areas of industry-related R & D efforts in materials were identified as compiled in Tables 3, 4 with respect to
- materials category
- materials properties.

On the basis of this study, the EEC programme BRITE (Basic Research in Industrial Technology for Europe) has been launched in 1985 with a budget of about 180 million US $ over a period of 4 years.

In addition, the programme EURAM (European Research in Advanced Materials) will start in 1987 with a budget of about 80 million 80 million US $ over a period of 4 years. The main research areas and materials classes to be studied in the frame of EURAM are compiled in Table 5.

3. Materials technologies in developing countries

3.0 General considerations

Although, many of the advances in new materials generally occur in the industrialized countries which have large research and development programs in new materials and a ready market for application, the results of the advances will reach the developing countries through changes in the pattern of new material trade and changes in usage of materials in their economies. In addition developing countries may develop their own new materials and uses, e.g. composites, suitable to their resource and domains. However, the diversity of conditions in developing countries and the endowment of raw materials will require different approaches to be evolved by each country. The question "which material technology is most appropriate" cannot be answered through comprehensive catalogues or criteria in a general manner. Instead this question has to be considered and answered individually in any single case. It appears that the following questions must be answered before and during planning basic materials industries /3/:

- Where is the natural resource located?
- By what method can it be extracted?
- How and where will it be processed?
- What are the impacts on natural environment?
- What are the energy implications?
- What will it cost?

- What is its commercial value at current and likely future prices?
- What are the export possibilities?
- What impact on imports can be expected?
- What social-economic effects are to be anticipated?

In order to describe in detail the potentials of advanced materials for developing countries, a Bulletin on "Advanced Materials and Development" will be published early in 1988 by the United Nations Centre for Science and Technology for Development in cooperation with BAM, the Federal German Institute for Materials Research and Testing /6/. The following sections are original quotations from the Summary of this ATAS Bulletin.

3.1 Implications of materials technologies for development

- "World economic forecasts for the consumption of metals over the next few decades indicate relatively modest but nevertheless positive rates for metals such as iron, copper, tin and lead. These rates will vary between 1 and 3 percent. On the other hand, consumption of metals such as aluminum, chromium and nickel, as well as those used in the manufacture of special steels, is likely to increase at rates above 3 or 4 percent, particularly in the case of certain metals which are widely used in areas of high technology, such as columbium, titanium and gallium, where the rates will be in excess of 5 percent.

- The industrialization of developing countries will further support the consumption of traditional materials, although the spread of new technologies will probably reduce the extent of these benefits in comparison with the benefits gained by the industrialized countries at similar stages of development. This will depend on the ease with which technology is transferred.

- Through research the use of new materials has spread into areas which are different from those for which they were originally intended, since their greater efficiency makes up for their higher price.

- There exist manufacturing techniques for products of primary importance to developing countries, which are heavily dependent on human resources readily available in developing countries. The skills to deal with composites can be quickly adopted and accelerated by appropriate instruction. Some of the skilled labour force required could be imported in the initial phases mainly for quality control at all stages of production.

- There is a need to balance the use of natural products and their synthetic equivalent products and materials because, on the one hand, natural products support developing countries' economies, but on the other hand, the advancing economies require increasingly sophisticated materials with high knowledge content and specialized efficiency.

- The experience in recent years has shown that besides the development of new materials there is increasing progress in recycling. This has implications on the use of resources. New strategies will be required for design of all kinds of technical products. The structure of the materials mix in these products should be such that they can be easiliy separated after the termination of use into the different materials classes of the pertinent components".

3.2 Capacity building

- "The structure of the manufacturing industry has changed as a result of the marriage of advances in materials and processes with developments in production engineering based on computer-aided design, computer-aided manufacturing, flexible manufacturing systems, etc. The marriage of these two large streams of knowledge has opened vast opportunities.

Products which were formerly made by mass production techniques entailing large capital costs, can now be produced in short diversified production runs. In this way advanced manufacturing technology has provided the springboard to bring forward the general acceptance of advanced materials, and has allowed small and medium sized enterprises to enter markets formerly dominated by multinational enterprises.

- The absence of technological assessments done with local expertise is one of the major reasons that developing local resources for local needs has not taken place. Many decision to establish manufacturing industries in developing countries were based on feasibility studies that use inadequate data. This has contributed to their weak basis and led to their negative effects on the changing and environmental circumstances and general overall national development trends.

- When defining a list of priorities for research and development, high on the list must also figure the economic (commercial) control of research ideas. Among the research staff their must be economists and/or technical research with adequate understanding of economic principles; and it is their task to assess economics of research and of technical development. Efforts should be proportioned to local economic possibilities, that is to say, that each country should choose the proper "technological niches" to avoid early failures. Economies of scale are not always valid, particularly when "specialties" are under consideration.

- The most feasible approach for industrializing countries to improve materials-related technologies is to establish neutral and capable institutions for materials testing and quality control. It may, therefore, be necessary to build up the existing infrastructure in teaching and research institutions, in terms of national central facilities, for the testing of materials. In testing and maintaining standards, care must be taken to ensure that these institutions do not become instruments of delay".

3.3 Policy options

- "The most practical strategy for materials technology development is to "make some and buy some". Individual national resources, capabilities and priorities can lead to widely varying choices about the mix of the two options.

- Industry - university collaboration can help the universities define basic research agendas for solving fundamental problems, and, in the process, help the universities train and educate materials scientists and engineers with the type of background and skills industry most urgently requires.

- Financing methods should be tied to contractual, coordinated and long-term research and development programmes.

- Different forms of co-operation such as shared use of installations and instruments should be used to keep the costs within bounds.

- Policies require a "critical mass" in order to be effective. This concept appears at several levels. First, many laboratories have neither size nor material resources necessary to undertake effective research and development in new materials. Secondly, the national research and development potential is often limited. Third, the restricted size of potential markets has implications for technological development and, hence, for research and development.

- Materials centres can emerge from national and international efforts to promote co-operation between disciplines and between laboratories.

- Education and training programmes need to be reconsidered in terms of the requirements for materials science researchers and engineers with multidisciplinary backgrounds.

- The establishment of a variety of novel approaches to measurement and performance evaluation is required concurrently with, or even in advance of, the appearance of these materials in commercial technology. The achievement of traditional long bases of experience before the need for standards arises is therefore not possible for advanced materials. Furthermore, advanced technology and materials on which it depends are increasingly international. A new, broadly based, international effort is thus essential to assure that the prerequisite measurement base is in place as the development of new standards becomes necessary.

- The minimum conditions, including, at least, facilities for materials testing and quality control, must be established in each country in order to ensure that the optimal number of educated nationals contribute to development efforts.

- Connection to existing information and data bases must take place on terms and in an environment that simultaneously ensures a respect for and cultivation of the local knowledge-base".

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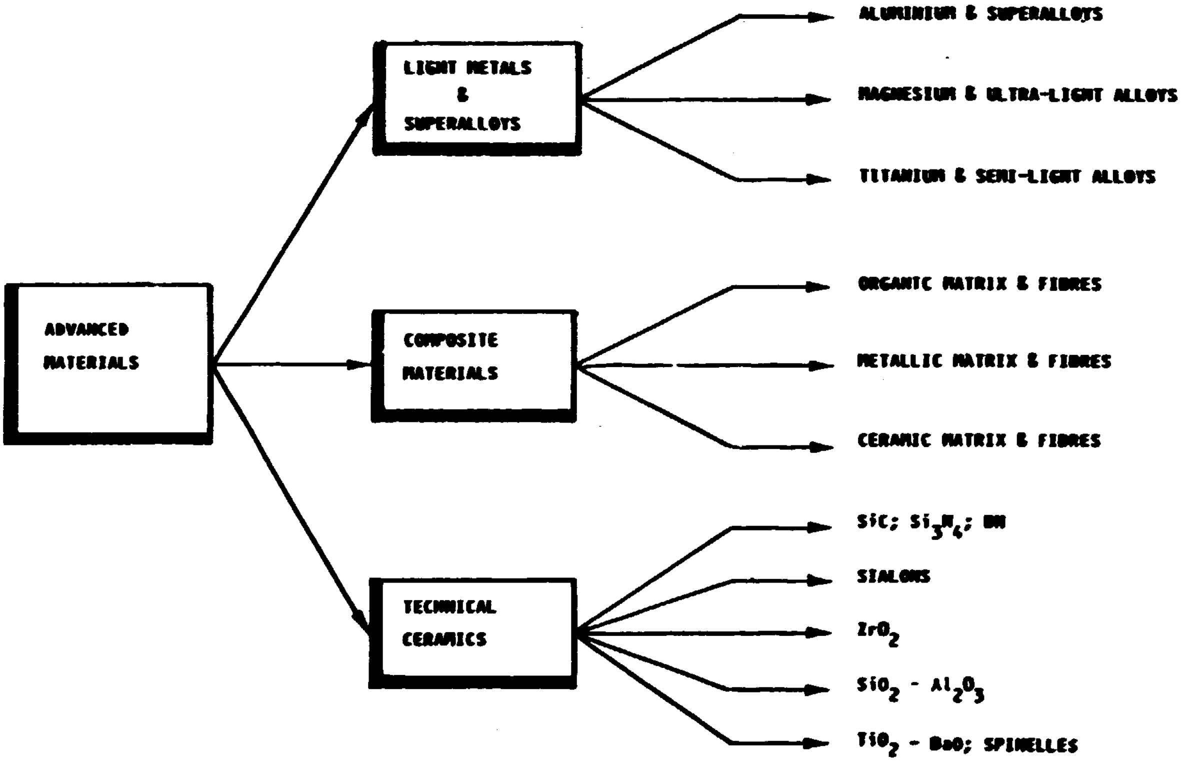

Table 5: Topics of the programme on European Research in Advanced Materials (EURAM)

PRODUCTS	1983 sales	% average annual volume growth 1983-1990
	In FF billions	In %
New steel products	294	2,3
Technical plastics	120	7,3
New non ferrous products ..	64	3,4
Composites (all grades) ...	54	8,2
Ceramics	29	17,4
New glass products	19	10,4
All new materials	580	5,5

Table 1: World market outlook by materials product category (Ref /2/)

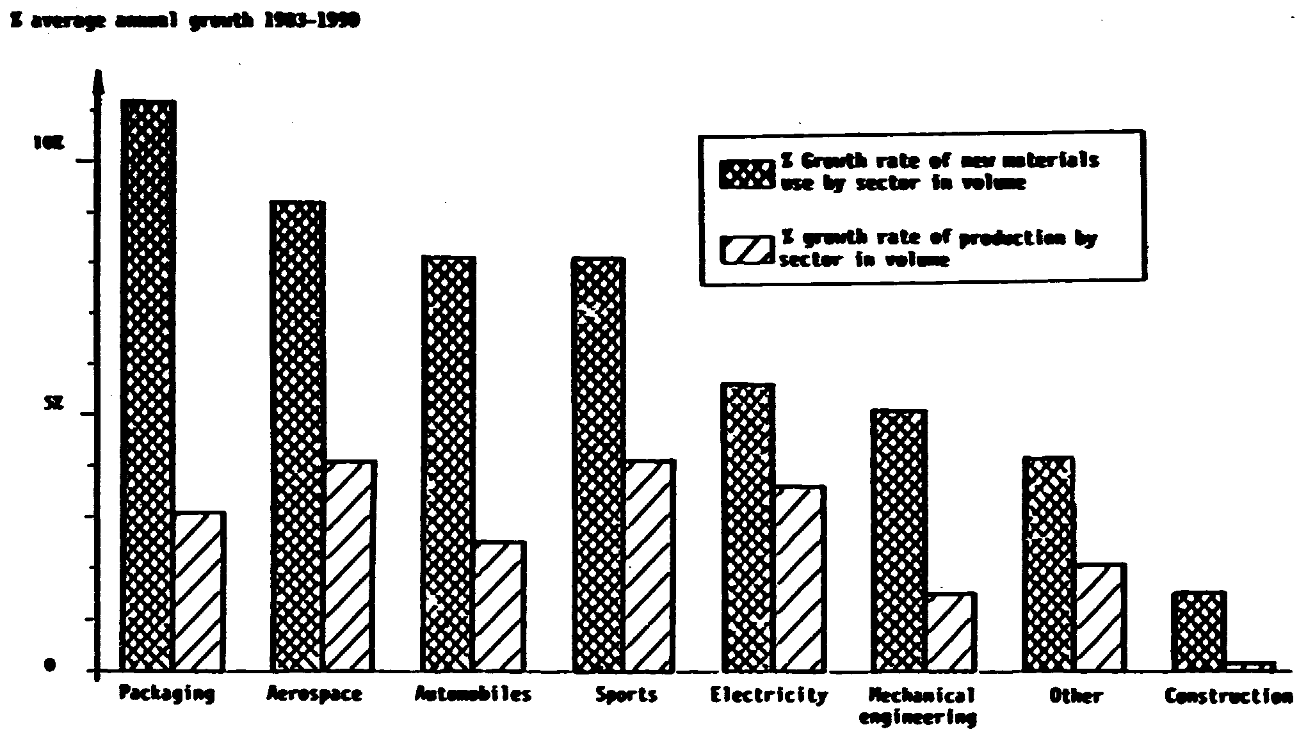

Table 2: Growth of new materials' use by sector in Europe (Ref /2/)

Material category	Proportion of research suggestions
• Composite materials	58 %
• Metals and alloys	51 %
• Ceramics, inorganic materials	46 %
• Organic materials	32 %
• Energy and information-relevant materials	14 %
• Renewable materials	7 %
• Biomedical materials	5 %

Table 3: Material categories relevant to future industrial developments in the EEC (Ref /5/)

Material properties	Proportion of research suggestions
• Corrosion behaviour	40 %
• Wear and tribological properties	28 %
• Thermal behaviour	28 %
• Strength	26 %
• Durability (chem. biol. environmental)	22 %
• Fatigue	17 %
• Fracture mechanics	15 %
• Long-term stability, creep	11 %
• Surface properties	7 %

Table 4: Material properties relevant to future industrial developments in the EEC (Ref /5/)

INTRODUCTION OF ADVANCED MATERIALS TECHNOLOGY TO DEVELOPING COUNTRIES

by K.M. Zwilsky

INTRODUCTION

Materials science and engineering (MS&E) plays a large supporting role in the development of national economies. Materials technologies are enabling technologies that translate progress in materials research into new products and services. MS&E affects virtually all industrial sectors of an economy, and new materials and processes are often the controlling factors in the development of new technologies. MS&E is unique in cutting across industrial development in a way that few other technologies do (computers perhaps being another example).

The USA has long been a leader in basic research in many areas of MS&E, yet other countries have been more effective in taking the results of some of this work and applying it to the marketplace. Technology transfer is a very complex subject both in the sense of moving from a discovery in the laboratory to commercial activity within a given country, and also in the sense of transferring knowledge and technology from country to country. In the USA for example, a debate has been in progress for several years on how the country can regain a competitive position in certain industries perceived to have been lost to other industrialized nations.

Many books have been written on technology transfer, and a good summary can be obtained in a recent work by Stewart and Nihei entitled Technology Transfer and Human Factors.* Although it is beyond the scope of this paper to examine technology transfer in detail, a few excerpts from the book may be of interest to provide a context for transferring materials technology between countries. Citing other work (Dahlman and Westphal, 1983), the authors describe three levels of technology transfer: (1) the capability required to operate a technology--for example, to run and maintain a plant; (2) investment capability--that required to create new productive capacity; and (3) innovation capability--the ability to modify and improve methods and products. These, they state, require different types and levels of skills and different supporting institutions. Only when all three capabilities have been transferred has the receiving nation acquired a permanent mastery of the technology. The authors emphasize the importance of human resource development that must be fostered to complement technology transfer. They state, "Workers may have to be literate and numerate; technical and professional employees may need an engineering background; managerial employees may need substantial general education plus exposure to a variety of management-specific topics."

A final quote from the book, this one on technology transfer mechanisms, is the following: "The mechanisms for technology transfer are as varied as the agents (for transfer). This variation depends in part on the type of technology. Is it proprietary or not? Is it highly sophisticated or not? It depends in part upon the agent undertaking technology

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*References included at the end.

transfer. Is it a firm, a government agency, non-profit, or university? The firm has the capability of using the technology at a new site for productive purposes, whereas the government agency or foundation or university may not be producers. Hence, the firm has options for technology transfer (such as direct investment in a subsidiary) that are not open to other agents."

Although we cannot go into a more detailed discussion of technology transfer here, it is clear that it is country-specific in the extreme. What works in one country may work better in another or may not work at all in a third country. A thorough knowledge of the institutions and interactions among institutions is necessary for a technology transfer effort, and any comments made have to be subject to a country-by-country evaluation.

MATERIALS TECHNOLOGY TRANSFER INFRASTRUCTURE: RECEIVING COUNTRY

The success of technology transfer programs depends first and foremost on the enthusiasm of the receiving country. The motivations for acquiring materials science and engineering knowledge most likely will be based on future economic benefits that would accrue to the country. Increasing materials technology must contribute to the country's industrial base and involve materials considerations that range from cement and concrete, wood, and other building materials to advanced engineered materials including plastics, ceramics, and composites. In general, emphasis on materials technology in a given country should be related to development of a product line that emphasizes a natural advantage of that country, be it in raw materials, labor costs, or others, or to the specific fulfillment of a direct need such as building materials or road construction materials.

Every sector in a given country--government, industry, academe--has an important role to play in the technology transfer process. Most government policies are likely to be short-range; however, planning for the pay-off of technology demands strategies that are long-range. It is important that government encourage the transfer of any materials technology through its policies affecting research and development in government laboratories and universities as well as policies that are favorable to industry in terms of patent, financing, taxing, and import and export regulations. In other words, government must create the climate, set the goals, and provide the funds under which technology transfer can be brought to fruition.

The role of industry is, of course, to manufacture and market products for sale to domestic and perhaps foreign markets. The sophistication of industry, its research and development posture, and its interactions with government in the regulatory, research, and training arena all play a role in the successful transfer of new materials technology.

The role of the university, not surprisingly, is to educate the materials engineers and scientists needed to carry out the program. The education process should be geared toward meeting the needs of industry by close working relationships between the university and industry.

The preceding paragraphs outline the most basic building blocks of the infrastructure that must exist for the transfer of materials technology as well as any other technology. Facilities and human resources are the required ingredients, no matter what mechanisms are set up to provide them.

One of the important new elements in building the infrastructure in receiving countries is the role of metallurgical or materials oriented professional societies. Probably no initiative will be more fruitful in the future than to provide a technical meeting ground for industrial, government, and university technologists. Formation of technical societies in individual countries should be encouraged, and their role should be strengthened if they already exist.

A number of American technical societies are embarking on collaboration with other countries. ASM INTERNATIONAL for example, a society for engineered materials, has in the past few years increased its efforts to become truly international and has members in over 100 individual countries--both developed and developing. In a number of cases, local societies offer joint memberships with ASM INTERNATIONAL. The Society produces handbooks (including a well-known metals handbook series now being supplemented by handbooks in composites, plastics, and electronic materials), home study courses, in-plant courses, video courses, computer software for materials selection, magazines, and abstract services. The educational information is arranged in a way that permits a technical person who is not necessarily a skilled educator to familiarize himself with the material and to teach it to others. A few members of the Society in any given country can thus have a great impact on teaching subjects that vary from the fundamentals of metallurgy to plastics, ceramics, and advanced composites. Such courses could be taught in-plant, through university extensions, or at special sites arranged for by the local society. Courses for various skill levels are available, depending on whether the purpose is to train engineers or technicians.

Other materials societies in the USA also encourage interaction with other countries. These include the American Ceramic Society, the Materials Research Society, The Metallurgical Society, the Society of Manufacturing Engineers, and the American Society for Testing and Materials. Another mechanism for introducing educational materials to a receiving country would be to rely on recently retired technologists from industrialized countries who may be willing to volunteer their time to teach such courses, provided their travel expenses could be defrayed.

MATERIALS TECHNOLOGY TRANSFER INFRASTRUCTURE: SENDING COUNTRY

The same sectors for technology transfer--government, industry, academe--operate in the industrialized countries, supplemented by some additional organizations such as foundations and perhaps trade associations. Governmental agencies in the developed countries may provide funding for technology transfer to developing nations for socioeconomic, geopolitical, or humanitarian reasons. Industrial interest is generally motivated by transfer of technology to build new markets, although some industries have trade associations interested in working with like-minded organizations in developing countries to exchange information on data and standards. In general, charitable foundations may be looked upon as providing some funding in areas of their specialty, especially those foundations that have a specific interest in developing countries. Universities are often interested in exchange programs with other countries as well as in educating students from developing countries. Moreover, individual investigators often welcome collaborative work with like-minded colleagues in far-away places. A potential role for professional societies in the developing countries was outlined in the previous section.

TECHNOLOGY TRANSFER MECHANISMS

Following are some specific examples of mechanisms set up for collaboration and technology transfer. It must be emphasized that these examples are drawn from many places and need to be very carefully evaluated to see whether they fit other specific circumstances.

Multi-Participant Research Program--Funded

A common research program participated in by a number of countries can be a powerful stimulus to technology transfer. One example is the Research Grants Program of the U.S. National Research Council's Board on Science and Technology for International Development (BOSTID). Funding is provided by the U.S. Agency for International Development. The program is guided by a Committee on Research Grants, which selects research areas and approves the grants. Proposals are solicited in certain areas for which an announcement of detailed objectives and research priorities is prepared. These objectives and priorities are the product of an initial organizational meeting of expert scientists from developing countries, international organizations, and U.S. institutions. The institutions receiving the grants will contribute to the research by providing partial support of the research staff, laboratory and/or field testing facilities, and administrative services. Thus a number of developing countries contribute to the research in a specific area of direct interest to them. One interesting feature of these grant programs is that scientists from the USA and other industrialized countries may participate in grant-supported research through collaboration with the grant recipients, but they may not receive grants themselves. Periodic meetings of grant recipients and others working in the field are held to encourage communication and cooperation among institutions working within a particular research area. Optional collaborative mechanisms may include periodic visits of scientists to grantee institutions and short-term training of investigators from grantee countries in the USA. The following research areas have been selected for grant awards: grain amaranth, tropical trees, biological nitrogen fixation, mosquito vector field studies, rapid epidemiologic assessment, and diagnosis and epidemiology of acute respiratory infections in children. Although none of these areas relates to MS&E, there is good reason to believe that materials-related programs would lend themselves to such a mechanism of shared research and technology transfer.

Multi-Participant Research Program--Not Funded

There is no reason that a program similar to that described above could not function without direct investment or grant funding, although the latter undoubtedly is an inducement to participation. A program could be organized around a common purpose, such as the development of a new ceramic composite or a fundamental investigation of advanced polymers or fibers (or, in fact, any other topic of interest). Depending on circumstances, an international organization such as UNIDO could notify scientific governmental organizations or, alternatively, scientific organizations directly and invite them to help outline the objectives of a program. Interested parties of both developing and developed countries could be brought together for detailed discussions of subjects of common interest.

Perhaps the best way to start would be to establish a Coordinating Committee for Engineered Materials and invite interested countries to send delegates to a meeting of such a committee. The modus operandi then might involve specific countries or groups of countries proposing a project of interest to them to which all of the countries that belong to the Coordinating Committee and that have an interest in the subject may subscribe. Each project would set its own objectives, and each participating country would finance its contributions.

Similar to the BOSTID program described earlier participants would come together on a regular basis to exchange ideas and report progress. Individuals from the developed nations that participate would be available to travel to the developing nations for brief periods of lectures and demonstrations; individuals from the developing nations would travel for brief periods of time to participating organizations in the developed countries for training and familiarization with equipment and techniques.

A similar mechanism is in place at the International Energy Agency (IEA) where small groups of countries subscribe to specific programs or projects in energy conservation or development in such varied areas as clean coal, nuclear safety, fusion energy, and industrial energy conservation.

By no means do the potential areas for cooperation have to be limited to advanced materials. The manufacture and use of cement and concrete, for instance, is a subject that is coming to the fore in the developed nations, where infrastructure built during the past several decades is rapidly deteriorating. Research and development interests in these areas could well run parallel with those of the developing countries, where much infrastructure needs to be put into place.

It is not only concrete, however, that could be important; other products, such as wood, that are widely available are of great interest to the construction industry in many countries. In the area of engineered ceramics, common development aimed at improving reproducibility and reliability of cutting tools, for instance, could lead to early applications in those countries desiring to establish a machine-tool industry. The areas to be looked at range from production of reproducible, high-quality, inexpensive raw materials through all of the production steps to the finished products; standards, specifications, and nondestructive examination also need to be considered in such a review.

Centers of Excellence

The question of whether a materials- related center of excellence is beneficial depends on the circumstances involved. The center concept can be most beneficial if it provides a mechanism for several parts of the technical infrastructure to come together, so that center activities amount to more than the sum of its parts. In some countries, for example, science and technology are widely separated in different types of institutions, and combining some of their components in a common endeavor can be beneficial. If, in addition, industrial input is factored into the work, the research and development will have a natural outlet in industrial manufacturing. In addition, the training of students and research scientists can often be combined in such an endeavor.

The USA has had three major efforts in center development in the past four decades, and each one has been successful in its own way. The 1950s primarily saw the establishment of major centers (now known as National Laboratories) related to nuclear development and high-energy physics. They were established by what was then called the Atomic Energy Commission and now belong to the Department of Energy. These centers were to a large degree built around major facilities--nuclear reactors, accelerators, synchrotron light sources, etc. With them have come major efforts in MS&E in the use of these facilities for fundamental research and in the development of materials for defense systems, civilian power reactors, and energy systems of many different types. In the past few years, these national laboratories have increasingly become multipurpose, and increasingly they now work closer with industry in applied research. The principal point, however, is that the centers were usually built around large and expensive devices that only the federal government could afford, since the projects undertaken were too large and too expensive to be built by industry or universities.

The second group of centers, called the Materials Research Laboratories, was established in the early 1960s in response to the recognition that MS&E was becoming an interdisciplinary subject drawing on chemistry, physics, metallurgy, ceramics, and engineering as well as the belief that the development of many advanced technologies were hampered by the lack of advanced materials. For a recent history of the origin and progress of these centers see papers by Sproull and Schwartz in Advancing Materials Research, 1987. These laboratories, about a dozen in number, were established at major universities by the Advanced Research Projects Agency of the U.S. Department of Defense, and they brought together different disciplines in an interdisciplinary facility. Their purpose can perhaps best be summarized by quoting from the government contracts within the universities that established the centers (after Schwartz):

> The contractor shall establish an interdisciplinary materials research program and shall furnish the necessary personnel and facilities for the conduct of research in the science of materials with the objective of furthering the understanding of the factors which influence the properties of materials and the fundamental relationships which exist between composition and structure and the behavior of materials.

The reasons for the success of these laboratories were summarized by Sproull, and a few are abstracted here from his paper:

> The important features at each university were, first, that an umbrella contract provided for continuity of support and for the ability to buy large quanta of equipment and facilities. Second, a

local director committed a substantial fraction of his career to making the program succeed. He would use the longevity of support to extract concessions from the university and departmental administrations. Third, the contract provided, in most cases, reimbursement over 10 years for the new construction required to do modern experimentation on materials. Fourth, the longevity of the contract induced the university to allocate the project scarce and prime space in the middle of the campus, thereby establishing the maximum informal connections among disciplines. Fifth, central experimental facilities (such as those for electron microscopy or crystal growth) could have state-of-the-art equipment, even if it was very expensive, and they served as a mixing ground for students and faculty from several disciplines. Sixth, an executive committee composed of people with power and influence in the individual disciplines but oriented toward the success of the program helped the director over the rough spots with department chairmen, people who often were overly protective of their own turf. Seventh, a contract was not given to an institution unless it had a strong disciplinary base on which to build. Eighth, individual grants and contracts with federal agencies continued; most well-established principal investigators received the majority of their support from some other agency and might enjoy help from the program only in the central facilities or the building space.

It is important to note that these premises on which the laboratories were based appear to be equally valid today for establishing such laboratories in any part of the world where a country wishes to expand its activities in MS&E.

The most recent US experience in the development of centers are the Engineering Research Centers (ERCs) established by the National Science Foundation beginning in 1985. (See Kash et al, The Engineering Research Centers: Leaders in Change.) These centers were formed as the vanguard of a new approach to meeting the serious challenges to U.S. industrial competitiveness. They are located at universities and bring together the capabilities and resources of government, universities, and industry. As cross-disciplinery engineering centers they work on problems that are of technological importance to industry, as contrasted with the work of the Materials Research Laboratories described earlier, which specialize in the generation of scientific knowledge. Nam P. Suh, an official of the National Science Foundation, described the ERCs as follows (from The Engineering Research Centers: Leaders in Change):

> At NSF we expect that the cross-disciplinary research conducted at the ERCs will, over the long term, trigger the development of new technologies by industry. We also expect that the unique educational experience provided both graduate and undergraduate students at these Centers will better prepare them to practice engineering after graduation. Consequently, we see the Centers helping industry with the task of meeting foreign competition through both research and education."

The centers are formed around specific technological areas, and the titles indicate the specificity of the objective of each center: Systems Research, Intelligent Manufacturing Systems, Robotic Systems in Microelectronics, Composites Manufacturing Science and Engineering, Telecommunications Research, Biotechnology Process Engineering, Advanced Combustion, Engineering Design, Compound Semiconductor Microelectronics, Advanced Technology for Large Structural Systems, and Net Shape Manufacturing. It is planned that several additional centers will be formed in subsequent years.

In 1986 a colloquium held at the National Research Council reviewed the progress of eleven ERCs. A number of characteristics or approaches that led to successful partnerships and facilitated necessary cultural changes were identified. These included (from The Engineering Research Centers: Leaders in Change).

- The "presence of champions," or strong advocates within the participating organizations.

- A strong and diverse research program, defined in terms of demonstrable cases with bounded milestones and with clear long-range implications and importance.

- Frequent and extensive contact between industrial and center personnel.

- Strong commitment to the center on the part of the university.

- Participation by the funding organizations in setting the centers' overall goals and appraising the research programs' objectives and progress.

- Effective mechanisms for transferring technology.

- Production of highly capable engineers who have a strong sense of industries' objectives and working environments.

These are considered useful guidelines although they are not absolute rules, nor is the list complete. A central theme of the symposium was that the ERC's represent an experiment that is in an evolutionary state.

SUMMARY

Technology transfer is difficult to achieve even under the best of conditions. Basically, it is everyone's business, whether in government, industry, or universities. Certainly a climate must be created that fosters consciousness and translates into concrete efforts. Goals must be clearly enunciated, resources provided, people trained, and outlets for the work furnished. Mechanisms for doing these are important, and some have been described here. One point made earlier should be reiterated--that of the "presence of champions" for a particular idea. People and people-to-people contacts are important, and the beneficial effects of enthusiasm and commitment on the part of a few "champions" cannot be overestimated.

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CURRENT REVOLUTION IN NEW MATERIALS: OPPORTUNITIES FOR THE DEVELOPING WORLD

by P. Rohatgi

1. Introduction

The activity in materials technology is age old starting from the use of agricultural materials, stone, bronze, iron, clays and ceramics. However, most of the developing countries have missed out on the scientific and the industrial revolution of the last 300 years to varying degrees, including the revolution in materials technology. This has resulted in th~ lack of availability of materials per capita in developing countries both in quality as well as in quantity, as compared to the availability of materials in the advanced countries. The developed world is undergoing yet another revolution in materials an example of which is high temperature superconducting materials. It is imperative that the developing world is adequately prepared to exploit the opportunities opened up by these new materials. The overall question is of building capability in the developing world to exploit the opportunities from the new revolution in materials while warding off the threats from the same revolution. Capacity building in materials will involve multidimensional activity including building capacity for technology forecasting, technology assessment, formulating materials policy, education, training, research, development, manufacturing, testing and standardization.

Different developing countries are in different stages of materials cycle and presently represent a spectrum of capabilities to deal with the new materials revolution. In view of this, uniform prescriptions cannot be given for all developing countries. In this paper only broad directions are discussed, and imperatives for individual countries will have to be derived through normative exercises.

The current average availability of manufactured materials[6-19] and energy[20] per capita in the developing world is often one hundred times less than the advanced countries (Tables I, II). In addition the present costs of materials in relation to incomes in developing countries are very high, and this results in further inequitable distributions of even these small quantities of materials. Much of the modern manufactured materials are in the possession of the rich elite in these countries leaving the poor even more impoverished in terms of availability of materials. The abundant supply of materials, and the services produced using materials, such as food, drinking water, housing, energy, health and clothing could go a long way in reducing human misery in the developing world, and even in poorer sections of populations in advanced countries.

The equitable and abundant availability of materials at low costs affordable by the people of developing countries can eliminate international conflicts, national and local conflicts. For developing countries, and even for the poorer sections in advanced countries, the linkage between materials and the basic human needs as mentioned above are more important than the linkages between materials and weapon systems, materials and faster aircrafts, and materials and other secondary desires.

The materials field is undergoing a revolution with the emergence of advanced materials engineered without the restraints of thermodynamic equilibrium to meet specific needs; these materials can now be tailored to meet the property or performance targets. While the science pushed basic advances in materials science appear to be common to the whole world, the directions in which materials science and technology should be driven to meet the needs of development for the third world countries, and the poor in advanced countries, points to additional imperatives which will be the focus of this paper. Monitoring and forecasting developments in materials science and technology and taking preparatory steps like identifying and establishing centers of excellent are some of the imperatives of the day.

2. Challenges for Materials Technology for Development

The existing data on the per capita GDP in different countries of the world shows a linear log-log relationship[(6)] with the per capita availability of different materials including steel, copper, aluminum, cement, zinc and tin in these countries. This indicates that the process of development reflected as well as it can be by rapidly increasing per capita GDP in different countries, will inevitably require production of, and availability of ten to a hundred times additional quantities of materials in many of these countries, as compared to production levels today. Most of the developing countries are at a stage where the unit inputs of materials and energy to produce an additional unit of GDP are likely to continue to increase for several years. Any reductions in requirements of materials per capita due to miniaturization and substitution by lighter weight high strength materials and parts consolidation, would more than likely be offset by increasing requirements of materials due to rapidly increasing populations, and the increasing materialism and consumerism in most of these countries. The challenge for materials technology for development, for at least the next fifty years will be to increase the availability of materials required for housing, water, food, energy and health care, by as much as ten to a hundred times in many of the developing countries without pressures on resources, energy requirements, environment and employment. The populations in most of these countries would have more than doubled in fifty years and by that time these countries would be trying to reach the standards available in the advanced countries today (Table I). Even the basic advances in materials science which could enable the materials technology of the future to meet this challenge should be derived in a normative way, and be accelerated in time by increased inputs compared to basic advances required for new materials for new weapon systems. The paradigm for materials technology for development should lead to basic need based materials[21] (Table III) which are smaller, lighter, longer lasting, low cost, low energy and recyclable based on abundant and renewable resources which can be locally processed using simple and employment generating nonpolluting technologies.

Many of the knowledge driven advances in materials science including rapidly solidified structures, macro molecular materials[22] plasma sprayed and vapor deposited materials, mechanically alloyed materials, materials which have three-dimensional structure architecture at nano, micro and macro scales, materials with controlled interfaces made from super ultrafine powders where the bulk properties do not remain valid, and surface processed materials should be deliberately steered in directions to meet these developmental needs of materials.

3. Issues and Options for Developing Countries

3.1 Housing

Housing remains[16-19] one of the most important problems of development due to lack of availability of materials, and this is an area where miniaturization cannot be applied beyond a certain point. One of the major challenges is reduction in the cost of materials for housing and increase in the performance of construction materials, particularly those based on local renewable or abundant resources. The high priorities here will include a greater attention to materials science and technology of alumino silicates, earth, stone, laterite and clay based products which can be readily made everywhere. There is need to improve the performance of bricks from common clay and develop biomass or solar energy sources to fire them, or to develop low temperature binders and sintering agents. The other area is application of modern materials science and technology to renewable resources, particularly locally available plant based resources; some examples of these resources for materials of construction include bamboo, Impoemea carnea, fibers from plants like coconut, sisal, banana, sunhemp, grasses, and large agricultural wastes like paddy straw, and wheat straw.

A shortage of cement and its high price are great barriers in increasing the supply of housing in developing countries. It is necessary that greater attention be paid to using rice husk ash, fly ash and mineral waste type materials to increase the volume of cement and bringing down the cost of new high tech cements like zero defect cement, rapid setting cement, chemically bonded cement, fiber reinforced cement, the price of which is presently beyond the reach of the poor. Millions of people in the developing world use plant based materials like coconut thatch for roofing, which do not provide adequate protection from nature and require replacement every year. Inputs of modern materials science and technology are required to increase the life and performance of these plant based materials for housing and to make them more resistant to elements of nature and fire.

3.2 Bio-Processing of Materials

A certain amount of advanced research in genetic engineering would be in order to possibly increase the strength of wood and fibers available from fast growing trees, in addition to the present focus on increasing the yield; the development of plants which can get nitrogen from air will reduce considerable pressure of manufacturing fertilizers from minerals in developing countries.

Biological routes to production and preservation[14,23] of materials requires greater attention in the context of development. Some of the areas that require research include microbiological process to extract metals from ores and ocean nodules, and to remove sulfur and silica from minerals like coal and bauxite. Newer methods of microbial degradation can be used to extract fibers and ultra fine ceramic powders at low energy costs from agricultural products and wastes.

The problem of moisture absorption in these natural fibers needs to be solved by techniques such as acetylation. Greater attention needs to be paid to make silicon carbide whisker type high performance materials from other agricultural resources in addition to rice husk with reduced inputs of energy. Modern microbiological techniques to extract fibers and ultra fine powders of silica and other minerals from rice husk and other similar plant based materials to make advanced ceramics, and silicon for solar cells should have a high priority. Attention should be given to possible controlled production of high strength ceramic fibers for advanced composites by pyrolisis of natural fibers. There are opportunities of producing polymeric materials from large quantities of agriculture resources and agricultural wastes. For instance an agricultural waste like cashew nut shell liquid can be converted to very high performance polymers for composites.

3.3 Strategic Materials

Many developing countries do not have resources for strategic metals like nickel, cobalt, tungsten and chromium and it is necessary to synthesize high performance materials with abundant elements like aluminum, silicon, oxygen, nitrogen, and carbon. The synthesis of structural ceramics like silicon carbide and silicon nitride, and composites like aluminum-silicon carbide and aluminum-graphite can eliminate the need of special metals which are in short supply in many countries. Greater emphasis is needed on these kinds of ceramics and composites particularly to decrease their costs of productions and increase their performance especially in regard to toughness. In view of use of coarse ceramics, the developing world is still very much in the stone age compared to the metals age in advanced countries, and it should leap frog into the world of advanced ceramics and composites without necessarily going through the cycle of high performance alloys which will eventually be replaced anyway.

3.4 Utilities

The need to develop inexpensive membranes and filters of ceramics, composites and polymers to purify and desalinate water is an important requirement of developing world and this deserves attention of modern materials science and technology.

In the context of development, the advances in understanding the structure and processing of newly emerging materials need to be applied to materials required for food production, transport and storage. Development of lighter, stronger and more durable and inexpensive clothing material, recyclable paper and other materials required for increasing literacy in the developing world are important imperatives of materials technology for development. The demand for new inert and bioactive materials for transplants and health care will be much greater in highly populated developing world. It is necessary that costs of these materials comes down by orders of magnitude to be accessible to the poor. Some of the health care materials of the future will be smart structures in the form of composites with embedded sensors, actuators, microprocessors, and their costs need to be reduced.

3.5 Recycling

In the context of development, advances in materials science and technology related to recyclable materials,[21] and materials that do not degrade or can be maintained by inputs of human labor are extremely important. This is necessary since the availability of resources of materials and energy are going to be major constraints; regeneration of new material by recycling take much less material and energy than extracting it from its source. Design of alloys and components which lend themselves to recycling and multifunctional uses and which can be used in a series of cascading progressively downgraded applications is necessary. Increased understanding of surfaces and interfaces from a basic atomic and electronic view point, is necessary to generate surfaces which resist corrosion, oxidation, wear and fatigue, and extend the life of materials.

3.6 Energy

Materials for energy generation[20] and transmission, and materials which can be made using decreasing amounts of energy remain major imperatives for development. In view of this, ceramics and composites leading to higher efficiencies in energy conversion systems, higher performance, lower cost materials for solar energy and for fusion energy are important for development. New optoelectronic materials for transmitting energy and information will relieve the constraints in these critical areas. Technologies for direct reduction of iron and aluminum, or technologies which can make use of solar and biomass energies (e.g. plant based reductants and fuel) are very important. It is obvious that production of these primary materials will increasingly shift to developing world to take advantage of mineral resources, low labor costs and present absence of pollution problems and regulations. The science and technology to produce these conventional materials with low energy inputs, in small plants with low capital high labor inputs are important imperatives for development. Materials with high temperature superconducting properties which have been discovered recently could have large implications the developing world.

3.7 Materials Processing

Materials processing needs to be driven in directions of near net shaped components and low energy consuming processes which can generate employment needed in the developing world. Computer-aided design and simulation should be used to reduce redundant factors of safety in order that smaller quantities of materials will suffice. However automation and robotization should be used only selectively where absolutely necessary to obtain quality and reliability. The information input that goes into materials processing should be as high as possible but the actual process should be as simple a technology as possible which can be maintained in the most primitive developing environments. Materials in the context of development should be made as far as possible using local resources,[16-19] local manpower, and simple technologies which can be maintained and established in the developing world without vast inputs of capital. It will be worth while to upgrade the large numbers of traditional materials and processes which have been used in the developing world for ages by inputs of modern materials science and technology. A new trend in materials technology, namely parts consolidation, leading to fewer parts resulting from single step molding of complex shapes could be very important.

The economy of several developing countries is very heavily linked[21] to the export of a given mineral. For instance economies of several countries in Africa are based upon the export of copper. In view of the development of glass communication cables it is necessary that materials science and technology is directed to find new uses of resources like copper otherwise the economies of these countries will collapse and a global advance in materials science will be locally counter productive in terms of development.

4. Conclusions

In summary, materials scenarios in the developing world, and in the poorer sections of advanced countries, are typified by very poor availability of materials per capita both in quantity and quality. In the context of development, materials which relate to basic human needs like food, housing, clothing, energy, water are more important than materials which relate to advanced weapon systems, faster airplanes and other secondary desires. While some of the knowledge driven advances in rapidly solidified materials, plasma and vapor deposited materials, surface processed and interface tailored metals, ceramics and composites and nano-structured materials[22] will indirectly contribute to development, they need to be selectively steered to accelerate the availability of materials for development. Materials technology leading to development in terms of availability of increasing quantities and qualities of materials per capita will require smaller, lighter, stronger, longer lasting recyclable materials made from local renewable and abundant resources using high information simple processes requiring low energy, preferably in the form of solar and biomass, low capital but high labor content. Materials based on plant based products and abundant resources like clays, stones, rocks, aluminum, silicon and oxygen should receive increasing attention along with biological processes to process and preserve materials. Materials for solar energy and fusion energy should receive high priority along with materials for food production and storage, and cloth and paper, and materials for purification of water, and health care.

5. Recommendations

The important question is as to what should the developing world do in view of the new materials revolution signaled by the arrival of materials like high temperature superconductors and optical fibers for telecommunication. Without adequate timely response from the developing world, the benefits of these new materials will again flow primarily to developed world further increasing the gap in the quality and quantity of materials available per capita in developing and developed worlds.

The first and the foremost response of the developing world should be to establish mechanisms to monitor the most significant developments (for instance high temperature superconducting materials) at the earliest possible stages. These emerging developments can be monitored through mechanisms of formal technology forecasting, followed by technology assessments from the viewpoint of individual countries to arrive at the priorities amongst several signals. The technology assessments would be followed by action plans to derive maximum benefits from a particular new development to the country or region in question. One of the responses could be setting up centers of excellence in developing countries, and this has been discussed at some length here.

Mechanisms for monitoring of advanced signals of the future materials technologies in terms of monitoring of scientific papers, patents, and company reports will have to be established in institutions doing teaching, research and development or production of materials in developing countries. Their activity will require world class scientists trained to pick up advanced signals of future materials technologies from scientific literature.

In view of the recent advances in modern materials setting up centers of excellence could prepare developing countries to benefit from the new opportunities that are opening up. In the advanced countries, for example the United States, several centers of excellence in materials science have been set up in the last ten years. Among the developing countries, India has some experience in setting up centers of excellence in universities in the area of materials. These have been set up in the form of materials research laboratories in universities which already have strong programs in materials. In addition to these materials research laboratories, engineering research centers have been funded, for instance centers for composites materials and ceramics have been established. It will be difficult for developing countries to establish a large number of centers because they are quite expensive requiring considerable equipment. It is necessary to pick up a few good academic teaching departments and build excellence in research and development around these departments. This will be the least expensive way to grow such centers in developing countries.

In view of certain recent trends it will appropriate to develop centers on composite materials, ceramics including new high temperature superconducting ceramic materials. These centers should have scientists of world class training, and they should be equipped with modern materials science equipment. The scientists in the developing countries from these centers should periodically visit the most advanced centers in the developed world to bring back the knowledge that is yet to be published. In addition, scientists from developed countries should visit these centers and train and upgrade the information base of the scientists in developing countries. It will be worth while for the developing countries to look at the performance of the centers for excellence in materials in advanced countries especially the United States, and in developing countries like India. In some cases it may be useful for several developing countries to get together and put up one common center of excellence to reduce the cost to each. A parallel example in agriculture is the International Rice Research Institute. Here was an example of a commodity of interest to several developing countries and a single institute of international stature serves a large part of the developing world. For instance, in materials, several developing countries could get together to set up centers of excellence in solar energy materials, room temperature superconductivity, fiber optic materials for telecommunications, advanced composites and ceramics.

In the area of materials, one type of center for excellence could concentrate on synthesis and preparation of a large number of advanced materials. These facilities could include fabrication from solid, liquid and vapor states. Another type of center for excellence could be on the characterization of these materials including the characterization of atomic arrangements, chemical composition and properties both at microscopic and macroscopic levels. These two types of centers for synthesis and characterization could be jointly set up by several developing countries in the form of international institutes.

While setting up of these centers for excellence, it must be realized that these centers will at the most develop an information base in the developing countries. They will not necessarily lead to an increase in the production and the consumption of these advanced materials. The production and use of these advanced materials would require setting up of manufacturing facilities either with the know how generated in these centers or through transfer of technology in terms of plant machinery and know how from the developing world.

The centers for excellence of materials in developing countries could be a basis for promotion of cooperation in research and development. For instance in the area of high temperature superconductivity it will not be proper for the centers of excellence in developing countries to duplicate what has already happened in the developed world or for instance to spend time in understanding the basic structure of these high temperature superconductivity materials. It will be most useful to concentrate in the processing aspects of these high temperature superconductors in the manufacturing facilities that are available in the developing countries. Cooperative research agreements can be established where the flow of basic and non-proprietary information takes place very quickly from developed countries to centers of excellence in the developing countries. The developing country scientists and technologists should try to then develop the technology to produce and characterize these materials in the manufacturing environment in these countries. It is in this location specific role that the centers of excellence in developing countries differ from those in developed countries.

There are large resources of materials which are location specific in several developing countries and have not received much attention in the developed world. Some examples would be materials based on local plant based materials, for instance the coconut tree based resources. Since know-how on these materials will not be generated in the developed world they would be ideally suited for centers of excellence. Likewise, there are certain mineral resources, for instance copper, which are important for the economies of several developing countries. These materials could be substituted by some of the new emerging materials and can devastate the economies of some developing countries. Optical fibers and high temperature superconductors both pose a threat to the markets of copper. Centers of excellence to counter such threats in materials would also be in order.

The organizational structure of a center of excellence should be such that it has a greater impact then equal investments made through the conventional approaches without the centers. Higher investments in centers would deprive certain institutions outside the centers and repercussions of these should be taken care of in advance. As mentioned earlier, one form of centers of excellence in materials technology can consist of state-of-the-art facilities for the characterization of materials, for instance including facilities for electron microscopy with capabilities of directly observing atoms in materials. Such a facility is expensive, and only concentrated resources of a center allow the acquisition and maintenance of such facilities. However, to be most effective, such a facility should be accessible to materials scientists physically present outside the center. A center for materials technology should, therefore, primarily act as a mechanism for large-scale team effort in a given area, instead of merely physically concentrating people and equipment in a given location. A center for excellence in Materials Policy should be conceived, in addition to centers for physical research in specific materials or processes, or preparation and characterization of materials. Such centers should include participation of planners, economists and forecasters.

TABLE I

Per Capita Consumption of Metals in Selected Countries
(Average Values for 1967-69)

No.	Country	Per Capita (GDP US$)	Per Capita Consumption (kg) Aluminum	Copper	Lead	Zinc	Tin	Crude Steel
1.	Argentina	853	1.16	1.73	1.610	1.102	0.076	91.0
2.	Australia	2503	8.047	5.39	8.636	0.331	0.331	468.5
3.	Austria	1604	9.10	4.465	3.151	3.306	__	283.5
4.	Belgium-Lux	2174	16.52	11.465	5.028	13.361	0.283	401.0
5.	Brazil*	326	0.90	0.512	0.301	0.482	0.024	51.0
6.	Canada	3234	10.02	10.354	2.959	4.979	0.215	469.0
7.	Chile	609	__	2.40	__	__	__	71.0
8.	Denmark	2620	1.40	__	3.836	2.020	__	346.0
9.	Finland	1861	2.62	6.00	__	1.312	__	281.0
10.	France	2556	6.37	5.193	3.613	4.292	0.209	359.5
11.	Greece	856	1.54	__	__	0.640	__	95.5
12.	India	88	0.23	0.083	0.090	0.151	0.008	12.0
13.	Italy	1430	4.17	3.339	2.542	2.928	0.117	323.5
14.	Japan	1413	6.41	6.579	1.750	5.181	1.224	501.0
15.	Mexico*	557	0.53	0.969	1.451	0.312	0.034	73.5
16.	New Zealand	1938	__	__	__	2.469	__	267.5
17.	Netherlands	1968	12.67	2.729	4.039	2.703	0.351	341.5
18.	Norway	2398	12.89	3.710	__	5.351	__	375.5
19.	Portugal	543	__	0.922	__	0.526	__	65.5
20.	South Africa	738	1.44	1.549	1.746	2.350	0.085	187.0
21.	Spain	833	3.11	2.476	1.979	1.890	0.052	187.5
22.	Sweden	3311	8.10	10.924	6.898	4.388	__	603.0
23.	Switzerland	2719	11.70	6.109	3.595	4.398	0.142	349.5
24.	Turkey	382	0.37	__	__	0.188	0.027	25.0
25.	UK	1926	6.83	9.646	4.990	4.959	0.315	404.5
26.	USA	4300	17.25	8.950	5.431	5.900	0.288	560.5
27.	West Germany	2275	8.84	9.761	4.719	5.883	0.193	523.5

*Average of 1967 and 1968 figures

TABLE II

Per Capita Consumption of Metals by Regions

Extrapolated Values 2000 AD

Region	Per Capita Consumption Steel	Aluminum	Copper	Zinc
Western Europe	710	20.24	10.50	6.83
Japan	1450	45.86	21.40	13.19
Other developed countries	680	22.32	11.98	8.58
USSR	850	17.47	7.84	3.92
Eastern Europe	610	13.87	5.41	5.92
Africa	20	0.24	0.16	0.07
India-Low growth	26	0.51	0.20	0.32
High growth	51	0.98	0.44	0.70
Asia	30	0.50	0.22	0.31
Latin America	100	1.72	0.91	0.95
China	60	0.79	0.63	0.54
USA	890	52.25	14.63	9.41
World	240	7.27	3.06	2.09

Source: Lahiri, A. Conservation of Mineral Resources in Commerce, Annual Number, 1976, 47-49.

TABLE III

Some Important Targets for Materials Technology for Development

- Genetic engineering for plants to get nitrogen directly from air.
- Genetic engineering for plants with stronger timber and fibers which can be pyrolized to form high performance fibers and carbon-carbon composites.
- Microbial processes to extract metals from ores and ocean nodules, and to remove sulphur and silica from coal, bauxite and other minerals.
- Microbial processes to extract fibers and ultrafine ceramic particles from agricultural products and wastes.
- Solar photovoltaic materials with increasing efficiencies and decreasing costs; solar furnaces for processing materials.
- Materials for fusion energy.
- Membranes made for polymers, ceramics and composites with decreasing costs and increasing performances for purification of water.
- Improved and inexpensive materials for housing from abundant and renewable resources like sand, clay, rock, stones, laterites, plant based materials.
- Composites and ceramics with improved performances based on abundant elements like Al, Si, C, N and plant materials.
- Direct Reduction of iron and aluminum using low energy processes, using solar and biomass energy.
- Recyclable materials with cascading downgraded application with longer life and resistance to corrosion, oxidation, wear and fatigue.
- Rapidly solidified materials for reducing energy losses.
- Surface and interface processed materials with tailored structures and properties to meet specific needs.
- High performance nano-structured materials, nonequilibrium and metastable structures.
- Room temperature superconductors.
- Insitu polymer composites.
- Tough ceramics.
- Net shaped materials fabrication.
- Parts consolidation through single step molding of complex shapes.

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NEW MATERIALS ASSIMILATION

by J. Müller

INTRODUCTION

The last 15 years can be characterized as period of general drive of new technologies and materials. This is also valid for ceramic materials. Their development is fueled first of all by changing and more demanding requirements coming from the end-use sectors. New technologies are being introduced which utilize high temperatures, pressures and aggressive environments which is refelected in the demand for reliable equipment, service life and quality of used products.

New ceramic materials are based on high-purity raw materials of controlled properties. Therefore the technical ceramics is using more and more synthetic materials. However the new ceramic systems are essentially based on industrial minerals which are expected to play an important role. The synthetic processes are very expensive giving incentives for researches into processes to win specialty raw materials in a cheaper way.

The advanced ceramic materials manufacture is a much diverse industry consisting of many specialized segments of different technical requirements and different growth predictions. This results into possibilities for small-scale producers and into uncertainity on the side of raw materials suppliers.

The development and introduction of new technologies affects also traditional established ceramic industries which face the problem of changing markets. However the ceramic tradition is not enough for being successful in the production of new ceramics since their production requires thoroughly new sophisticated quality control techniques and equipment.

Consequently, an evolution in introducing new technologies and materials in developing countries will probably be more successful than the implementation of large turn-key projects. International co-operation with developed countries to use their know-how and expertise as well as co-operation among developing countries themselves can bring results in the development of infrastructure necessary for successful implementation of more sophisticated technologies. Such a co-operation can benefit from a co-ordination support of UNIDO. Principally, raw material analyses, training of technicians, necessary technical and business information, consultancy and other necessary assistance can be organized and provided on international basis.

THE QUESTION OF RAW MATERIALS

It has been assessed that the amount of natural resources consumed after World War II equals to the amount of raw materials and energy used since the start of history up to 1945. However in the 1970's the pattern of constant growth of raw material consumption rapidly changed.

Rates of Growth of Natural Resource Consumption

Product	Period	
	1966 - 1973	1973 - 1980
crude oil	70%	7%
industrial minerals	29%	16%
metallic minerals	54%	7%

Source: IM, Febr. 1987

The reason of this conspicuous development are various

- replacement of metals by plastics, ceramics and composites
- better utilization of used materials
- environmental pressures
- recycling

The development also shows an interesting aspect of growing share of industrial minerals in the overall extraction activity.

The relative share of industrial minerals grows also in coincidence with industrialization. The more developed is a country, the higher is the share of industrial minerals in that country's extraction activity.

As for the future demands for non-metallics there are some indications of important developments:

- the crude oil shortage is expected to return in 1990's. That will stimulate drilling activities and the demand for bentonites and barytes.
- it is expected that the use of low grade coal to generate electric energy will increase; desulphurization processes will be applied consuming limestones and gypsum
- the demand for plastics will go up, especially for new grades which will use mineral fillers as functional components; it will result into the demand for processed kaolins, e. g. of defined properties
- the importance of zeolites is growing, they can be produced synthetically from kaolins and perlites.
- the growing consumption of paper generates the demand for mineral fillers
- the developments in advanced ceramics will lead to the increased demand for smaller quantities of very pure minerals extracted from industrial minerals such as monazite, kaolin, silica, talc, wollastonite, bauxite etc.

TWO MODELS

The new technological developments have an impact on almost all countries. The changing pattern of raw material consumption affects mainly less developed economies which are active in extraction of natural resources. The developing countries with established traditional ceramics are faced with changing markets, especiallly in the case of refractories. Further, because the sophisticated technologies and materials promise profitable ventures, there certainly will be a looking for co-operation with developing countries in order to employ comparative advantages, e. g. cheap labour force. And last but not least there will be effective local demand for new materials that will economically substitute for traditional materials, e.g. new building materials, light-weight composites, building materials composed of non-metallics and biomass etc.

From the above necessitates that developing countries will try to assimilate new materials and new technologies. There are 5 basic strategies how to acquire a new technology:

- internal research
- purchase of new technology
- joint venture with a proprietor of required technology
- venture capital to get access to new technologies
- acquisition of a firm owing the new technology

Each strategy has its advantages and disadvantages.

Without discussing them into detail let us look at two cases described by J. B. Wachtman Jr. and M. G. Mc Laren in "Advances in Materials Technology", Monitor, UNIDO:

The first study deals with the transfer of refractory technology to a country in Eastern South Asia. There were many raw materials available for refractory use in this country, but the existing industry was extremely poor and not well managed on a scientific and engineering basis. A manufacturer from the United States surveyed the needs throughout the world for possible technology transfer and after a round of negotiations, an agreement was signed in 1973. This company had 30 different products as candidates for technology transfer. In order to accomplish this technology transfer, it was necessary to instruct the engineers of that country in the various methods of material characterization and the technology of modern production techniques. By 1974 one product of low technical importance had been transferred and was available on the market. At this point geologists were employed to search the country for additional raw materials and to develop an even better characterization laboratory and beneficiation techniques. During the next ten years, most of the 30 different products were transferred to the developing nation, but all along the way support was required from the licensing company with respect to carrying out laboratory analyses, making technological assessments and slowly equipping a modern laboratory. Initially, the materials were transferred from Eastern South Asia to the United States for evaluation and development in actual pilot plant operations to prove the feasibility of the product. After the feasibility of the materials was determined, the technology was again transferred to Eastern South Asia.

Perhaps the most important thing to understand is that this evolutionary development required only 14 years. This is a relatively short period for the transfer of technology and speaks well of the technical abilities and assistance programmes generated by the licensing corporation.

The second study deals with a country in South America and had an even longer time frame for developing the technology transfer. In 1965, an emerging ceramic industry in this country was totally dependent upon imported raw materials. In fact, 95 per cent of all materials used in their whiteware plants were from overseas. Of course, this was an intolerable position, both from economic and technological standpoints. As in the first study, the geologists from the corporations began a search for available and usable raw materials for their industry. Using outside consultants and licensing arrangements from the United States, technical criteria and characterization techniques were determined and used as specifications for the whiteware industry in that country. Over time the characterization techniques of the materials became part of the everyday existence of the company and resulted in greater utilization of the indigenous materials of the country. In fact, today 95 per cent of all material used in the whiteware industry is indigenous material. When this technology was transferred, it was certainly considered by that developing country as high technology. Once the basis of a good ceramic industry was developed, the next levels of high technology ceramics were installed. These were in the areas of spark-plugs, ferrites, special glasses etc. An evolutionary base had matured to the point where the higher technologies could be transferred. It should be pointed out again that this effort started in 1965 and that only now can one see the emergence of some truly high-technology products in that developing country.

INTEGRATED APPROACH TO INDUSTRIAL MINERALS

As example of complexity and sophistication of the question of the utilization of raw materials can serve the case of advanced ceramics. Industrial minerals have been used for the production of high-technology ceramics for at least 45 years. The most important raw materials for the steatite and mullite ceramics have been clays. But recent advanced ceramics families had to change into larger utilization of synthetic materials. One of the reasons was the impossibility of ensuring the constant chemical composition which has crucial consequence since some ceramic systems can be considerably changed by 0.1% additives.

However the synthetic materials can be considerably more expensive than their natural pendants which is an incentive for efforts put into research of cheap materials for advanced ceramics. The following table demonstrates why.

Assessment of critical price levels - trigger prices

cost of produced component (USD/pound)	ceramic component	weight of ceramic component in engin (pound)
40 or less	spark-plugs combustion chambers bearings of turbo-chargers	1/4 - 2/3
25 - 20	cutting tools, specialty parts, turbocharger houses	2/3 - 2
15 - 10	cylinders, pistons parts of heat ex-changers	10 - 20

source: ACR Westwood

J. Rubin and J. Negrych describe another case demonstrating the sophistication of the raw material problem. The electronic ceramics are based on Al_2O_3 which has usually residual α- radioactivity. This α- radiation can destroy the memory of integrated circuits. They followed the alumina sources and succeeded in finding bauxite that yielded aluminium relatively free of α- radiation.

The above amply demonstrates the necessity of the integrated and interdisciplinary approach to the question of industrial mineral utilization. This integrated approach should be based on a teamwork of several disciplines which are in mutual interrelation - geologist-mining engineer-mineral upgrading engineer--chemist-ceramic engineer-market researcher.

The UNIDO-Czechoslovakia Joint Programme provides the assistance in integrated utilization of non-metallics that follows this interdisciplinary pattern.

The following are the components of our approach:

a) Non-metallic mineral inventories providing as much as possible information on important local raw materials

b) Complex utilization of a deposit, e. g. non-traditional utilization of raw materials such as bentonites for soil rehabilitation and environmental protection which can enable to excavate larger quantities or lower grade parts and to economize the excavation

c) Looking for local materials to substitute for imported body components or to introduce materials conserving energy and improving some final properties

d) Information on advanced up-grading techniques, technical information on different ceramic technologies on requests from developing countries

The UNIDO-Czechoslovakia Joint Programme provides some of the above assistance free of charge:

- basic, preliminary characterization of small raw material samples
- technical information and technological publications
- it covers financially the cost incurred in Czechoslovakia during technical workshops
- it covers cost of stay in Czechoslovakia for short-term study tours

CAPACITIES IN DEVELOPING COUNTRIES FOR CO-OPERATION

The Joint Programme in Pilsen has been in contact with several established bodies in developing countries co-operating with them in the characterization of indigenous raw materials, in researching ceramic, glass and building materials technologies. The objectives of the below listed organizations are more or less identical. It is the development of ceramic industries and efficient utilization of natural resources.

Algeria - ENOF, Enterprise Nationale des Produits Miniers Non-Ferreux et des Substances Utiles - Belfort

Brasil	- FTI Industrial Technology Foundation, Río de Janeiro
China, P. R.	- Chinese Non-metallic Mineral Development Centre, Suzhou
Egypt	- Central Metallurgical Research and Development Centre, Cairo
Guyana	- Institute of Applied Science and Technology, Georgetown
India	- Central Glass and Ceramic Research Institute, Calcutta
Indonesia	- Centre for Advancement of Small Business, Bandung
Sri Lanka	- Ceramic Research and Development Centre, Piliyandala

Some details provided by the Centres are attached.

CONCLUSION

New developments in technologies and materials have various impacts on international trade and national economies.

The problem of introduction of new materials into established infrastructures in developing countries is a very complex one. International co-operation of developing countries among themselves under a support and guidance of UNIDO could bring good results.

Such a network guided by UNIDO could help develop in an evolutionary manner the prerequisites of successful new material introduction projects. Appart from capital for facilities and marketing skills, the prerequisites are laboratory facilities and proper techniques, standards, trained technicians and managers, education facilities, competent labour. The lacking components in particular countries could be substituted for by providing international consultants, raw material characterization and body formulation from abroad, world technical and scientific information and international interdisciplinary teams. Also own research and mutual exchange of information could be co-ordinated within the network.

There are possible scenarios for assimilating new technologies and materials

- integrated approach to natural resources
- joint ventures with established suppliers of new materials because one of the most serious constraints is the marketing capability
- gradual development of established industries under appropriate technical assistance from abroad.

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Appendix

China, People's Republic of

The People's Republic of China is very rich in non-metallic minerals and rocks with extensive reserves of bentonite, kaolin, graphite, talcum, asbestos, gypsum and diatomites ranking the world's leader.

China Non-metallic Minerals Industry Corporation, which has been approved and established by China National Economic Committee, is an economic organization for exploiting and managing non-metallic minerals and products. Among its subsidiaries, there is also the Suzhou Non-metallic Mine Designing Institute which is dealing with up-grading and processing of non-metallic minerals and rocks.

After the liberation, the Chinese non-metallic minerals and rocks industry has developed gradually. However, its development is still slow behind the required level and, therefore, the quality of raw materials and products is not so good and some of high-quality non-metallics are still imported to China, such as washed kaolin and long-fibre asbestos. The main factors which affect the development of the non-metallic industry of China are: a/ the research works.design , technical information services and standardization are not conducted so well;b/ the advanced processing techniques and equipment are less imported from abroad; c/ there is no Centre for such activities established in China; d/ there is a lack of organization which should be responsible for such activities.

The Centre for Up-grading and Processing of Non-metallics will be established in the Suzhou Design Institute of Non-metallic Mines in Suzhou City, which is about only 86 km far from Shanghai, in the Jiangsu province.

The Suzhou Design Institute of Non-metallic Mines was established 25 years ago. 370 officers and workers, of which more than 250 are engineers and advanced technicians and 150 with higher than university education, are responsible for the research of dressing and testing of non-metallics as well as for the design of new mines and processing plants and for the improvements of existing and developing new technologies. The Institute is being expanded with the capital of 8,000,000 Yuans.

The Suzhou Design Institute of Non-metallic Mines is the major one in the People's Republic of China, which is concerned with up-grading, refining, purification, processing and mining of non-metallics.

Source: Draft Project Proposal, UNIDO-CSSR Joint Programme

Institute of Applied Science and Technology

Guyana

The expansion of the Ceramic Programme, which is being requested, is designed to secure the capability of local personnel to formulate and produce pilot plant quantities of ceramic bodies and glazes for tiles, tableware, electrical porcelain, etc., to international specifications. The Ceramic industry has a large potential needing many different technologies, which must be selected according to the market requirements and locally available raw materials. Apart from the body, the glaze is a very important part of many ceramic products.

The quality requirements to the body raw materials differ very much according to the type of ceramic product. Electro-porcelain requires the most purified raw materials, while wall and glazed floor tiles can usually be produced from ordinary clays, kaolins, sands and limestones.

Different types of glazes are required for each product, and also depends upon the maturing temperature. For the suggested ceramics, both fritted and unfritted glazes will be applied. The manufacture of glazes requires special quality raw materials, which will have to be purified. Opaque glazes will in addition require import of zirconia or zirconsilicate in proper fineness. There is no hope that the fritts needed for wall and glazed floor tiles manufacture, could be produced locally in commercial quantities in the near future.

All future development of ceramics will have to be based on technologies with the lowest possible energy requirement.

Training of local technicians abroad as well as several short term consultancies, will be needed in order to implement the various ceramic projects.

Each type of the ceramic products, after laboratory and pilot plant work, conducted locally, should be verified abroad from the point of view of pressing, casting and shaping, drying and firing under industrial conditions. The body will need, in addition to the present tests, determination of the coefficient of thermal expansion and moisture expansion. Depending upon the properties of different bodies, a variety of glazes and decors are needed. Proper quality control is essential.

Because the initial proposal of the IAST requires about 5,000 pieces of tile as overseas reference samples, considerable amounts of body raw material needs to be shipped to the selected subcontractor. The proposal by IAST for the wall tiles technology, nicely describes the plans. However, its implementation will require at least 12 months. Therefore, in order to save time and reduce the cost, it is recommended to reduce the amount of reference samples to about 50 pieces for wall tiles and 5 pieces for sanitary ware, which are enough as reference samples.

Taking all of the foregoing into consideration, it is evident that only one or, a maximum of two, ceramic technologies can be developed within the forthcoming 18 months and to achieve that IAST must concentrate its efforts to them. Proper finance is another condition. Taking into consideration the present pressure to start the manufacture of wall tiles and sanitary ware as soon as possible, these two ceramic technologies can be considered for implementation during the presently requested expansion of the ceramic programme, while porcelain, stoneware and refractories may be developed during the Phase III starting in 1987.

An economic and commercial evaluation of the slip house operation is recommended, as UN support of pilot plant production, for industry on such large scale, in a Research Institute is a most unusual arrangement.

The supplies of clay body from the IAST to the industry will be terminated when the projected wall tile plant has been erected by the Vanceram Company. The slip house for the wall tile factory is projected to be able to produce also clay body for the dinnerware production. The slip house at the IAST wil until then continue experimental production of various types of bodies, such as for wall tiles, floor tiles, sanitary ware, procelain and artistic ceramic products.

Testing of the final products is a very important issue. Some important apparatuses are not available in the Institute at present. There is a need for an autoclave and an apparatus for determination of the coefficient of thermal expansion of ceramic bodies and glazes. It is recommended that these apparatuses be included in the list of equipment.

The establishment of the wall tiles and sanitary ware plant in Guyana is very urgent and, therefore, the output of the expanded project will be completed with pre-feasibility studies for both industries.

Source: Draft Terminal Report, UNIDO-CSSR Joint Programme

India

The ceramic and glass factories are devided into two basic groups - organized sector and unorganized sector - according to the investment costs. The unorganized sector incluaes all enterprises with investment costs lower than Rs 2 million. However, such factories sometimes employ more than 1000 people and their output, quality and quantity-wise can be considered to be from medium scale enterprises. The following table shows the break-down of selected ceramics and their representation in the organized and unorganized sectors:

Type of Ceramics	Annual Production			
	Organized Sector		Unorganized Sector	
	10^3 tons	%	10^3 tons	%
Glazed tiles	60	92	5	8
High Tension Insulators	36	100	0	0
Low Tension Insulators	3	13	20	87
Sanitary Ware	35	78	10	22
Stoneware	40	21	150	79
Tableware	16	24	50	76
Refractories	900	60	600	40
Bricks and roofing tiles	N.A.+/	0	N.A.+/	0

+/N.A. ..... not available

The Central Glass and Ceramic Research Institute, Calcutta was established in 1950 under the Council of Scientific and Industrial Research. The objective of this Institute is the scientific and applied research of national importance in the field of glass, ceramics, refractories, vitreous enamels and mica.

The major activities of the Institute are related to the optimal utilization of the country's resources of related raw materials to the substitution for imported subjects in the field of ceramic and glass materials and to the adopting and updating of imported technologies in the related fields. Aside the basic scientific research, the Institute also extends technical advisory services, such as information extension, consultancy and testing. As far as energy conservation is concerned, the Institute deals with different kiln constructions and with lowering firing temperatures. The Institute has developed and constructed an experimental kiln which will be involved in semi-industrial tests related to the energy management problems. For such duties, the Institute is being equipped with additional equipment which will be completed during 1984.

Source: Draft Project Proposal UNIDO-Czechoalovakia Joint Programme, Pilsen

Indonesia

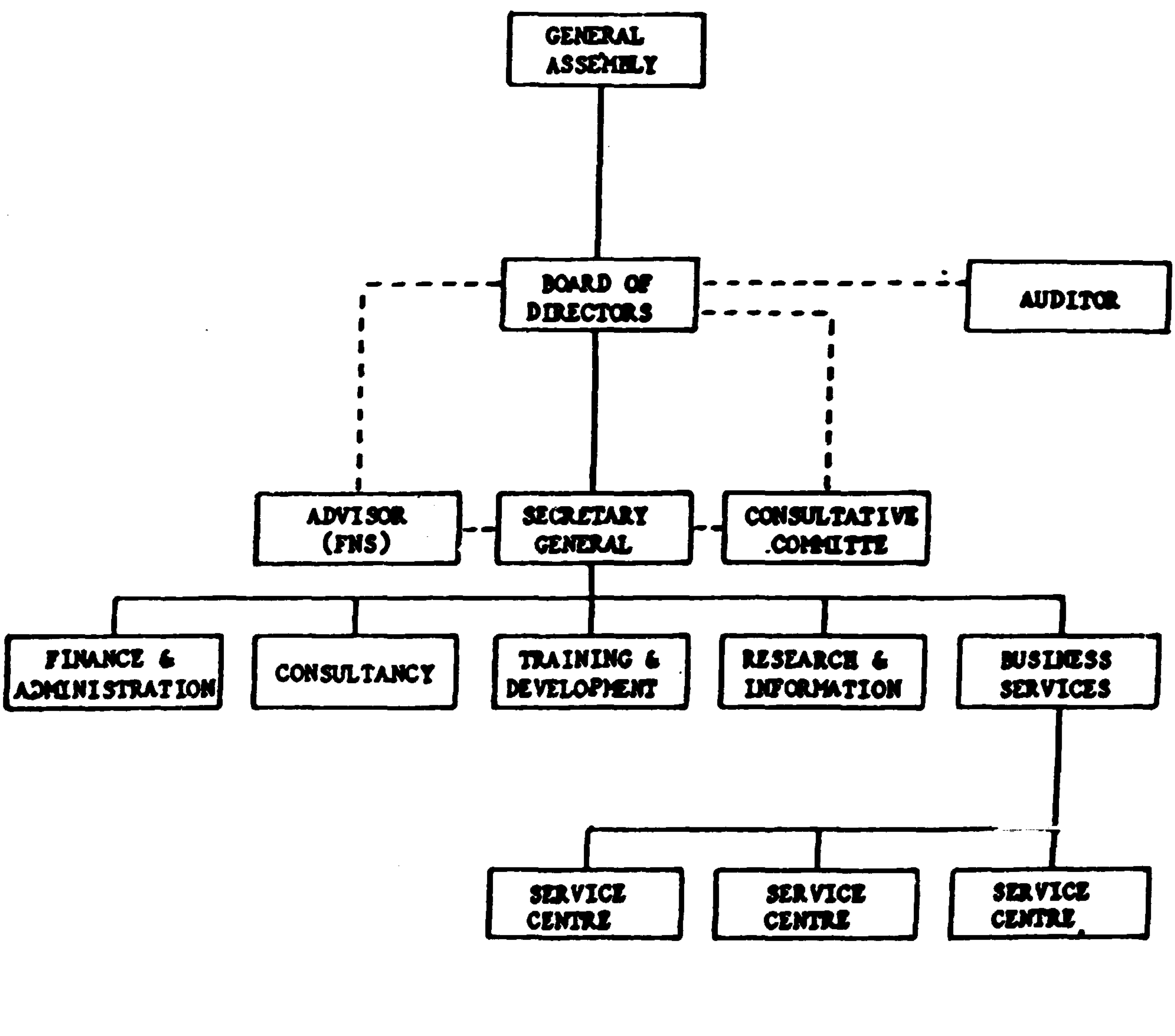
PUSAT PENINGKATAN USAHA KECIL
CENTRE FOR ADVANCEMENT OF SMALL BUSINESS

May 22, 1987

THE ORGANIZATION

PUPUK is an independent non-profit organization founded at the end of 1986 by the West Java Chamber of Commerce and Industry (KADIN JABAR) in cooperation with the Friedrich-Naumann-Stiftung (FNS).

Organizational structure :



THE PROJECT STRATEGIES

- Providing consultancy services
- Providing technical and management training programs
- Introducing new products and production techniques
- Expanding market outlets
- Providing relevant information, advice and services to small enterpreneurs in the project region
- Establishing cooperation between all relevant public and private institutions
- To offer business services

BASIC PROGRAMS

- Promoting selfhelp efforts, cooperative spirit and solidarity within small business and involved persons
- Longterm (on the job) training program for craftsmen in Plered and Pasir Jambu covering technical, skill and managerial aspects
- Seminars and workshops about problems of small-scale and craft industry development in West Java
- Stable and economic supply of suitable and processed raw material inputs as well as common facilities for ceramic and blacksmith craftsmen
- Development of new designs/prototypes and improvement of product quality
- Marketing programs, exhibitions, leaflets, catalogues as well as organizing new marketing systems
- Assistance in obtaining credit facilities for the craftsmen, preparing feasibility studies and cost calculations

PROGRAMS OF RESEARCH & INFORMATION DIVISION (1987-1988)

* Development of sectoral industries (blacksmith, ceramics & building materials):
  - Studies of marketing and raw materials (trade network and its impacts)
  - Cost analysis
  - Setting-up development indicators and its monitoring
  - Data acquisition, data processing and analysis of development
  - Obtaining feedback from other parties regarding internal studies and methods of development
  - Opportunity research and feasibility studies
  - Translation of foreign manuals and publications
  - Studies of production and quality control system
  - National sectoral studies

  NOTE: - Existing industrial centres under development: ceramics (Plered, Purwakarta), and blacksmith (Pasir Jambu, Bandung)
  - Proposed sector to be developed: building materials (red-bricks, roofing-tiles, sand-based products)

* Setting-up national information network on small business:
  - Seminars/discussions on information system and services for small business
  - Data acquisition of relevant informations from other institutions
  - Information exchanges
  - Development of small-business library
  - Computerization of the division
  - Information services for small businessmen

* Others:
  - Publication of manuals and studies
  - Electronic data processing services
  - Industrial policy studies
  - Studies of the impact of current industrial and economic policies on small business development

CERAMIC RESEARCH AND DEVELOPMENT CENTRE IN PILIYANDALA

The Ceramic Research and Development Centre was established in 1984 as a joint venture of the United Nations Industrial Development Organization and the Ceylon Ceramic Corporation. This Centre is the principal national institution which conducts the research and development works in the ceramic and non-metallics problems not only for the C.C.C. but also for other customers.

The main objectives of the Ceramic Research and Development Centre are:

1/ Research, development and testing of non-metallic raw materials, ceramic and clay building materials

2/ Consultancy services for ceramic and non-metallic industries and raw materials and feasibility studies' preparation

3/ Up-grading and refining processes for ceramic and non-metallic raw materials, technological development of different ceramic bodies, stains and glazes

4/ Energy management in the ceramic industry

5/ In close co-operation with the Geological Survey Department, the Ceramic Research and Development Centre is responsible for the technological evaluation of non-metallics of Sri Lanka.

The Centre is devided into 12 laboratories and sections:

1. X-ray Thermal Analysis
2. Electron and Optical Microscopy
3. Material Testing
4. Chemical Laboratory
5. Design Development
6. Pilot Plant for Ceramics
7. Kilns
8. Energy Management, jointly with the C.C.C.

9. Sample Preparation
10. Workshop
11. Stores
12. Administration

The Ceramic Research and Development Centre has the total number of 20 personnel of which 15 are highly educated research officers. Some of the research officers were trained abroad, the others are programme to be trained during 1987 and 1988.

Since its establishment, the Ceramic Research and Development Centre has been assisted 12-times by UNIDO experts in the total duration of 61 m/m.

During 1986, the Centre made a good progress in its achievements. It provided a lot of consultancies, research and testing works for public as well as private industries.

Source: Draft Terminal Report, UNIDO-Czechoslovakia Joint Programme, Pilsen

BRAZIL'S NATIONAL POLICY ON NEW MATERIALS

by R. C. Villas-Bôas

CONTENTS

1. ABSTRACT

This paper presents an overview of the reasonings behind New Materials developments, exposes the brazilian national policy on New Materials analysing the sectorial panorama on:

ºNew Metal Alloys

ºAdvanced Ceramics

ºQuartz and Silicon

ºEngineering Polymers

ºComposites

In each of these sectors, the role played by local industries, research centers and universities as producers, R+D developers and education conductors are described.

The general guidelines of each of the aforementioned sectors are discussed regarding humam resources, R+D infrastructure, reliability and quality assurance, pilot plant and industrial promotion units. Identification of immediate R+D opportunities are tempted.

Matrices of the financing expectations of the research activities, training and education, planning and assessment studies are presented, by financing source as well as by individual sector.

Finally, several constraints for the use of New Materials in Third World countries are discussed.

2. Introduction

Within the last two decades worldwide developments in materials technology have been producing new metal alloys,fine ceramics products, engineering polymers, as well as hybrid material composites that are replacing the more traditional metal products at a remarkable rate.

New Materials can be viewed as substances,or combination of these, known or developed from the incorporation of first principles to the preparation, fabrication and utilization of new or old applications , however always presenting new criteria in their build-up . There is an implicit or explicit utilization of innovative project, manufacture and utilization reasonings towards quality and reliability of use .

Figure 1 shows a comparison between the production of raw steel , sintetic polymer and non-ferrous metals in the United States, from 1955 to 1980, and may be utilized to draw attention for the rate of industrial efforts linked to these materials .

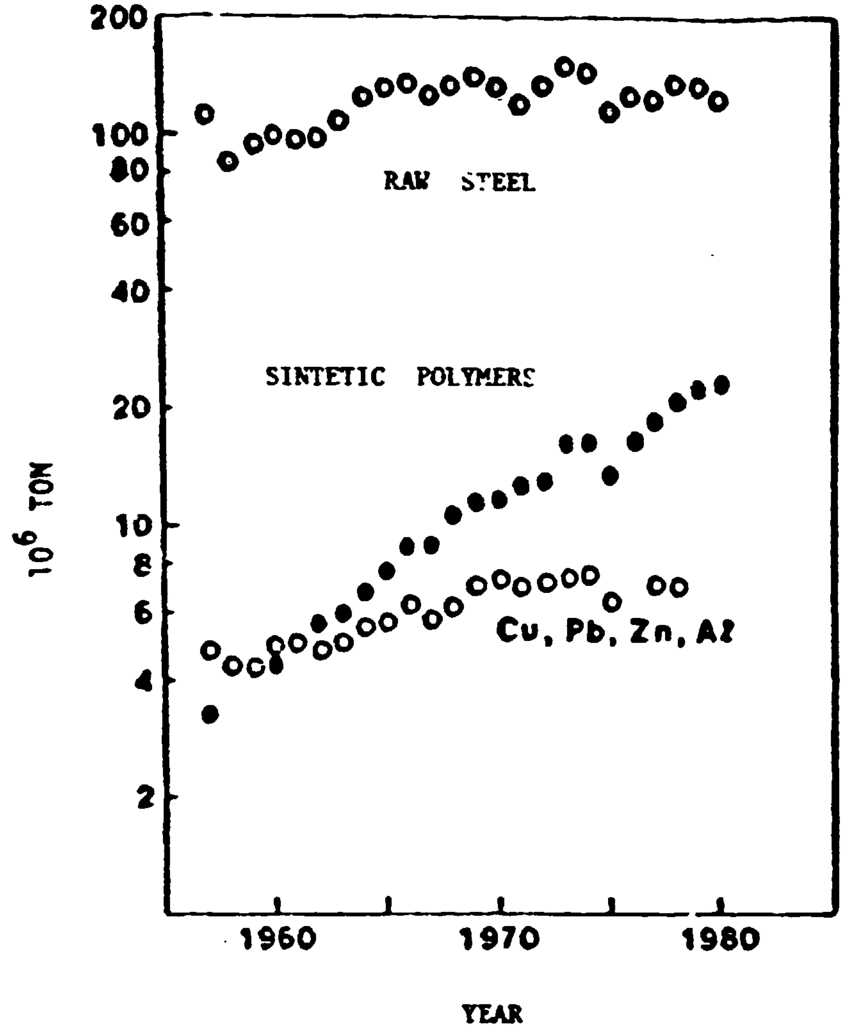


Figure 1. - Raw steel, non-ferrous and sintetic polymers production in the United States.

Source: Materials and Society, vol.8,no.2,1984

New materials development efforts are primarily tailored to :

A) promote substitution towards a more rigorous specification materials application.

B) promote substitution of vulnerable or critical ores or metals.

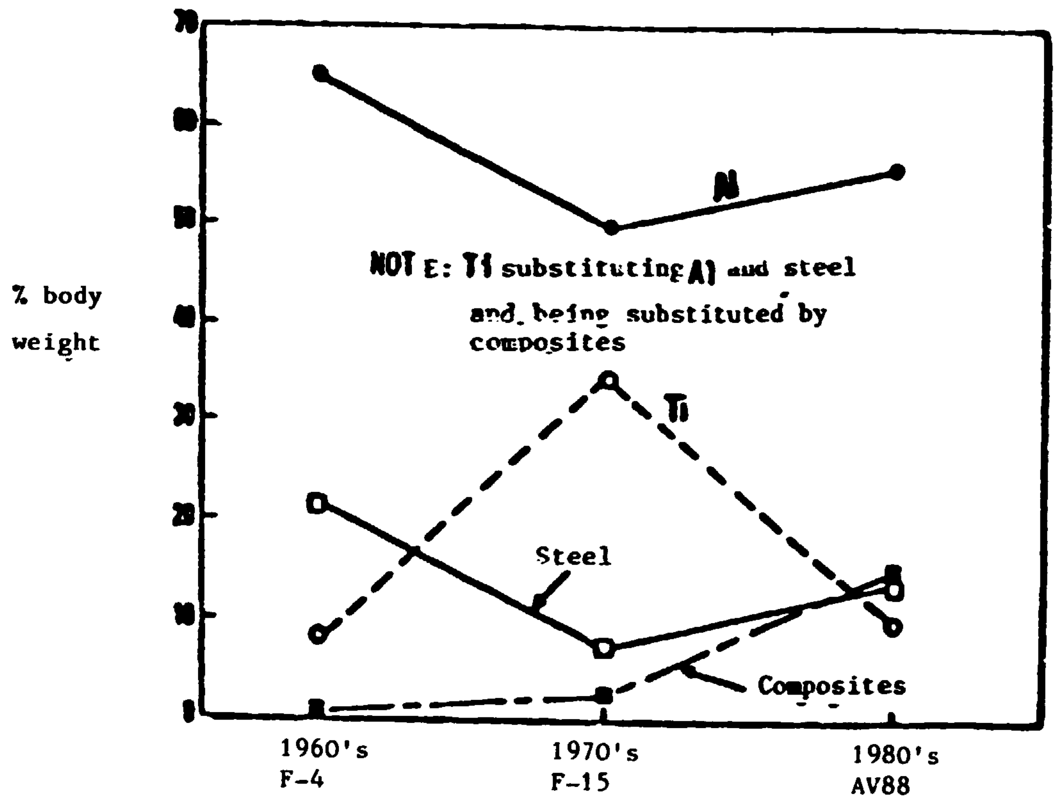


Figure 2.- Structural Materials in Military Aircrafts
Source: Materials and Society, vol.8, no2, 1984

Figures 1 and 2 illustrate the substitution of materials that occured in a short time span .

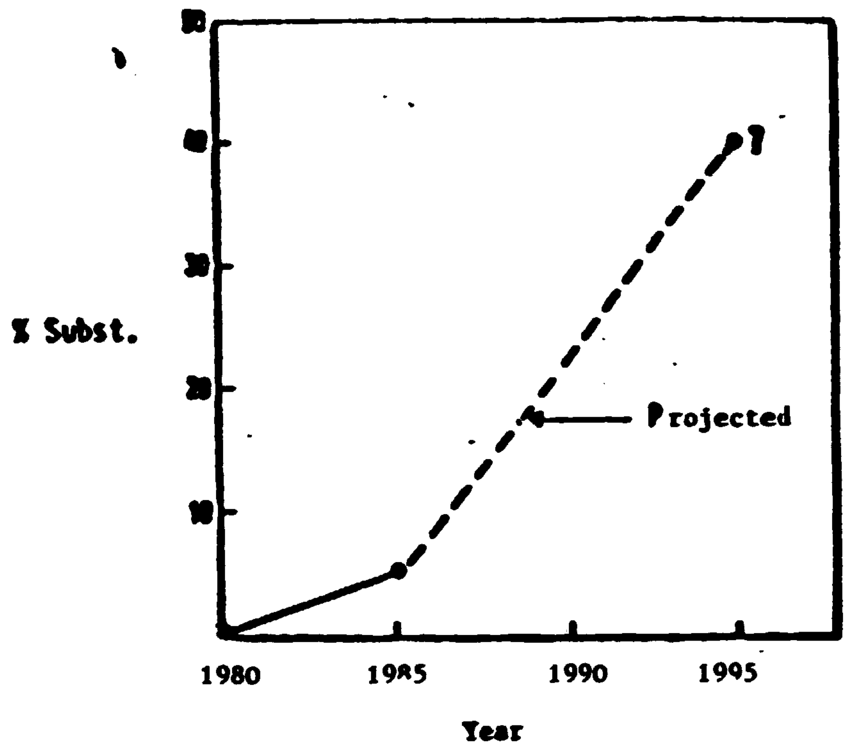


Figure 3.- Substitution of Copper by Optical Fibres in telecommunication systems.

Source: Materials and Society, Vol.8, No. 2, 1984

As for promoting substitution towards a more stringent material specification,either for a novel or old application,several research and industrial facilities are engaged all over the world in market searching and opening of opportunities related to the high technology fields,such as aeronautics,informatics,micro-electronics, etc...

As for promoting substitution of vulnerable or critical ores and/or metals, government efforts of the industrialized countries are envisaging to change the profile of dependability of the central economies from traditional sources of supply.

In both cases the underdeveloped economies do tend to suffer. In the first case due to the fact that either it has to rely its industrial basis on ,so considered, "second hand" materials or to import process or product technology to match with such new development -since its R+D infrastructure in the materials area lags far behind that of the industrialized countries-. In the second case, the situation is such that,very often, a metal or ore that is being substitute is a good export item of a industrializing country.

Hence the problems that face the developing countries to at least partially match such a situation are not of a trivia nature: they have to secure a position that is vital to their balance of payment in foreign currency, from the exporting commodities, and, also to prepare themselves to deal with the introduction of new materials in their own domestic economies.

Thus, such new materials developments, viewed as an amelioration of the raw materials crises of the industrialized countries, may cause a deepening economical crises for the third world.

3. New Materials in Brasil

It is clear that such third world countries that intend to maintain or even improve a given position of competition in the world market must closely follow whatever is happening in relationship to the novel materials basis that is under way around the industrialized world.

Those advanced third world countries that posses a reasonable sophisticated industrial infrastructure have already an expressive part of their domestic industry severely affected from options and estrategies defined within the industrialized countries economies. It is not a small lot of already substituted materials that madesup the day-to-day activities in the advanced third world economies.

From the Brazilian perspective three are the main points to justify a national policy towards new materials:

- There are in the country very important world ore reserves of estrategic minerals:
  - o Quartz (95%)
  - o Niobium (96%)
  - o Titanium
  - o Berilium
  - o Rare earths, and others.

Since these raw materials are of fundamental importance for several Hi-tech applications, there is a danger to import the artifacts having the materials made up of these estrategic minerals if no policy towards new materials developmen is not implemented.

- There exists a scientific and technological capability within the country that may be considered a good seed for such R+D effort. Although a considerable increase in number of researchers is envisaged, the already existing professionals are qualified to undertake the initial steps towards the creation of new materials technology.

- The national market is internationally quoted as one of the most promissing markets for hi-tech products and artifacts. In fact, the country does have indigeneous industries that use and even develop new material products.

3.0 New Metal Alloys

Metal materials have been the most prominent target for non-metallic new material substitutes. However, due the inherent sinergisms of their properties and peculiar characteristics, metals and their alloys are maintaining their competition on a vast gamut applications.

Due to its ore resersves, Brasil has to undertake its own path towards being an industrial and technological center for the development of new metal alloys. Such new metal alloys are being employed in the electronics, aeroespacial, oil extraction, chemical and petrochemicals, automobil, steel making, nuclear and biomedical activities.

At the traditional metal industry level, crude steel predominates the Brazilian metal production.

Secondary refinig and laddle metallurgy processes, widespread among the country producers, allow the production of steels holding a high degree of cleaniness for stringent applications.

Figure 4 shows the main existing laddle processes in the Brazilian steel industry.

PROCESS	HEAT/SIZE (t)	COMPANY
POWDER INJECTION	85/100	COSIPA
	80/180	USIMINAS
	80/100	VIBASA
	25	VILLARES
WIRE INJECTION	200	CSN
	200	CST
RH	85/(180)	USIMINAS
	100	COSIPA
LADLE DEGASSING	42	COSIPA
TAP DEGASSING	110	VIBASA
VACUUM-INGOT TEEMING	110-230	VIBASA
LADLE FURNACE	85	MENDES JUNIOR
	100	CSBM
	(180)	USIMINAS
ASEA-SKF	25	VILLARES
	50	PIRATINI
VAD/VOD	26	ELETROMETAL
VOR	75	ACESITA
AOD	35	ACESITA

Figure 4.- Main laddle metallurgy processes in the Brazilian steel industry
Source: Metalurgia International, Vol.1, No. 1, October 1987

Controlled rolling of high strength low alloy steel (HSLA) is being widely used at the Brazilian steel mills to produce plates for large diameter line pipe and offshore platforms. It is expected the incorporation of the thermomechanical control process (TMCP) in Brazilian plate mills in a near future. Such technique being mostly applied to steels containing microalloy additions such as niobium is well suited to the country.

Continuous annealling, offering a relatively low cost method of producing high strength cold rolled steel, having good formability characteristics, was introduced in Brazil, at CSN, this year.

Figure 5 illustrates the volume and variety of products made by the Brazilian steel industry in 1985.

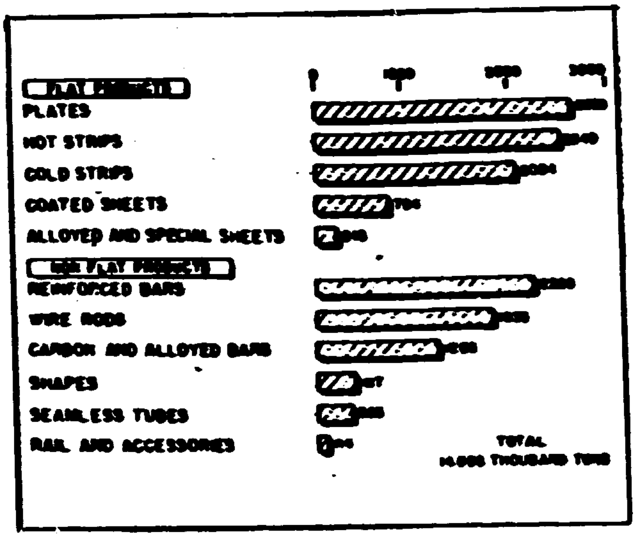


Figure 5.- Volume and variety of products made by the Brazilian steel industry in 1985.
Source: Metalurgia International,vol.1,nol, October 1987

At the new metal alloy materials side, considerable progresses have been made by several Brazilian enterprises:

- o Special steels: Villares, Aparecida, Piratini, Eletrometal and Acesita
- o Special alloys: Eletrometal, Metal Leve
- o Nodulizing iron: Fundiçao Tupy, COFAP

Regarding R+D Facilities:

- o Iron and Steel Making: Usiminas, CSN, Aços Villares all having their own R+D facilities; COSIPA, ACESITA, Piratini, Aparecida and Eletrometal, all have R+D nuclei that together with public research centers and universities facilities develop their own R+D needs.

- Pure metals and special alloys : FTI(Fundaçao de Tecnologia Industrial),CTA(Centro Tecnico da Aeronautica),CETEC(Fundaçao Joao Pinheiro),CVRD(Companhia Vale do Rio Doce),IPEN(Instituto de Pesquisas Nucleares),IPT(Instituto de Pesquisas Tecnologicas) are government and company research centers that develop intensive R+D efforts .CBMM (Companhia Brasileira de Mineraçao e Metalurgia) develops R+D projects dealing with Niobium applications through several research grants with brazilian and foreign universities and research institutions and ,as well, conducts propertary research on more sofisticated Nb products .

Regarding R+D at university facilities, as well as training and education,several metallurgical and materials engineering departments and physics departments are engaged on special steels and new metal alloys :UFRG(Universidade Federal do Rio Grand do Sul),USP(Universidade de Sao Paulo),UFSCar (Universidade Federal de Sao Carlos),UNICAMP(Universidade de Campinas), UFRJ/COPPE(Coordenaçao dos Programas de P´os Graduaçao/Universidade Federal do Rio de Janeiro),IME(Instituto Militar de Engenharia),PUC-RJ(Pontificia Universidade Cat´olica -Rio de Janeiro),UFMG(Universidade Federal de Minas Gerais) .

Figure 6 shows,in a matrix way, the several new metal materials being investigated .

MATERIAL			INDUSTRIAL SECTOR	AEROSPACIAL	NUCLEAR	MILITARY	AUTOMOBIL	STEEL MAKING	CHEM.+PETROCH.	ELECTRO-ELCS.	BIOMEDICS	PETRO-EXTRACT.
CONVENTIONAL	STEELS		special	•	•	•	•	•	•			•
			ultra-high resis. +tenacity	•		•	•	•	•			•
			stainless	•	•	•		•	•	•		
			recovered		•	•	•	•	•			•
			ultra-high purity			•	•	•				
			roll.control. microstructure			•	•	•				
			microalloied			•	•	•	•			•
	ALLOYS		Al	•	•	•	•		•	•		•
			Mg	•	•	•	•					
			Ti	•		•			•		•	•
			Fe	•		•			•		•	
			Sn				•		•	•		•
			Cu							•		
			Ni	•	•				•	•	•	•
			Others							•		
	Superalloys			•	•	•		•	•			•
	Cast Iron					•	•					
STRATEGIC	Zr				•				•			
	Be					•						
	RareEarths				•	•				•		
	Refractories			•		•	•	•	•	•	•	
	Nuclears				•							
	Fiber Reinforced			•		•						
ADV	Superconductors									•		
	Amorphous Met.Alloy				•					•		
	Memory Effect Met.Alloy			•			•			•	•	

Figure 6.- Industrial applications of new metallic materials

Source:"Tendencias e Perspectivas na Área dos Novos Materiais",Associaçao Brasileira de Metais,ABM, Julho,1987 .

The general guidelines on the new metal alloys programme are:

- o <u>Human resources:</u> due to the forecasted increasing demand for R+D activities it is expected an increment in the qualification of human resources as the postgraduates, (*)higher qualifications at the undergraduate and technician levels are needed. Areas related to metallurgical engineering, materials science, solidstate physics and chemistry, as well as quality control systems and technological management are to offer more enrollment.
- o <u>R+D Infrastructure:</u> There exists within the country a primary R+D infrastructure that needs an adequate articulation in terms of managerial capability to maximize the scientific and technological potential developments; as well some identified institutions do need equipment repositions and some others are facing the need for more sophisticated and advanced equipment. Spare parts for the standard as well advanced equipment are still a problem within the country.
- o <u>Immediate opportunities for R-D linked to market needs:</u>
  - oo <u>Special steels:</u> High-technological application stainless steels; high-purity; microalloyed and rolling controlled microestructure
  - oo <u>Special alloys:</u> Aluminium, titanium, magnesium, berilium, copper, barium, galium, litium special alloys and pure metal
  - oo <u>Noble metals:</u> High-purity gold and gold alloys for medical and dentistry applications; pharmaceutical applications and electronic applications.
  - oo <u>Superalloys</u>
  - oo <u>Amorphous Alloys</u>
  - oo <u>Lantanides:</u> High purity oxides;
  - oo <u>Pure metals:</u> Tungsten, talium and zirconium
- o <u>Assurance of quality:</u> Industrial quality; standards and reference metal materials; management of quality control systems.
- o <u>Assembling and production:</u> To secure effective ways and procedures to install and assist at the start-up phase industrial enterprises to produce or implement the outlined guidelines.

3.1 Advanced Ceramics

The fine ceramics world market was estimated to be around a 3 billion dollars figure in 1985. Of these, around 2 billion dollars are estimated to correspond to the figure attached to micro-electronics substrates and 1 billion dollars to ceramic capacitors.

NOTE:(*) ;at the industrial level,besides post-graduates higher qualifications at the undergraduate...

In the next 15 years the foreseen expansion of such market is around 16% to 20% per year, being the ceramic sensors market increasing of the order of 28% per year, the advanced structural ceramics market by 25% per year and the tooling market by 20% annum.

The Brazilian ceramic industry, the traditional, not the advanced, is currently ranking second in the world, after Italy, with a production level around 90 million square meters.

At the advanced ceramic level, the Brazilian market is estimated to be of the order of 300 million dollars, being a substantial share of this market, 80% to 90% held by local industries producing substrates, varistors, insulators, ferrit capacitors and piezoelectric components. The remaining market is on the special refractories, mechanical seals, thread-guides and others.

However, several products are still imported as sensors, ferrites, tubes for sodium lamps, ferrites, catalysers, cutting tools, and some special refractories.

Around twenty industries are producing for this market; half are multinationals and the other half genuinely national.

Of the national companies, two are engaged in the ceramics for electronics, seven in thermo-mechanical and one in optical fiber.

In the production of special ceramic powders Brazil has:

- o Alumina: Metal leve (Pilot plants); UFSCar, IPEN, UNESP (R+D efforts)
- o Zirconia: IPEN (10 t/y pilot plant); UFSCar, UNESP, IPEN (R+D efforts)
- o Titania: TIBRAS (Industrial production of T_1O_2 pigment): CVRD (R+D efforts)
- o Niobio: CBMM (Optical and crystal grade industrial production)
- o Silica: CVRD (R+D efforts and pilot plant for quartz powder)
- o Lanthanides: Nuclemon, CVRS (R+D efforts)

The following are some producers of advanced ceramics products:

- o Optical fibers: ABC-XTAL
- o Isolating parts and heating elements: Carborundum, NGK, BOSH
- o Capacitors: CERTEC, Rohm, Thomson-CSF, Vitramon
- o Sensors: MITEC, ENGECER
- o Substrates: COORS, NGK
- o Special parts of Al_2O_3: COORS, Keramus, Procer
- o PZT: Thornton-INPEC
- o Varistors: VC VAR
- o Thread-guides: CIL and others

Regarding R+D facilities for advanced ceramics, a lot has to be done in terms of acquisition as speciliazed equipment for specific purpose applications. However, some research institutions do posses a good R+D standard:

- o Nuclear Ceramics: CDTN, IPEN
- o Optical Glasses: CETEC
- o Structural Ceramics: CTA, IME, IPEN, UFSCar, COPPE/UFRJ (Film depostion).
- o PZT: IPqM, UFSCar, CETEC
- o Ceramic characterization: COPPE/UFRJ, USP, INT, IPT, USP
- o Powder: IFQSC, UFSCar, IPEN, CETEC
- o Ferrites and Biomedical: INPE
- o Superconductor: CBPF, UFSCar, UNESP, UNICAMP, USP, IPEN

Regarding training and education:Technitians (Senai), undergraduate level in ceramics (UFSCar, UFPb, UFSC), post-graduate (USP, IME,UNESP,UNICAMP).

The general guidelines on the advanced ceramics programme are:

- o Human Resources: expanding opportunities for ceramics will require more scientists, researchers and engineers with wide knowledge and an inter-disciplinary approach in advanced ceramics. Faculty members training programs are envisaged, specially through scholarship grants abroad. Libraries are deficient in advanced ceramics topics and must be given financial support in order to hold a sufficient number of books, magazines and journals related to the field.
- o R+D Infrastructure: Specialized equipment has to be provided as well as substitution of old fashioned ones that are working at their level of fatigue.
- o Immediate Opportunities in R+D:
  - oo Processing Technology: In order to connect processing variables, particle-size distribution, composition, temperature, to the desirable final properties of the advanced ceramic materials. The obtaining of ceramic powder through chemical route, specialy sol-gel techniques, are a need; sintering techniques.
  - oo Advanced Ceramic Products: Isolators, ferroeletrics, piezoelectrics, semiconductors; structural ceramics on Al_2O_3, Z_rO_2, T_iO_2, Sialons, nitrites carbites and their composites.
  - oo Chemically bonded Ceramics: including advanced cement pastes and concretes. These represent an outstanding potential for low-cost, net shape fabrication of ceramic structures.
- o Assurance of Reliability: The reliability of advanced ceramics is the single most important determinant of success in any application. Advances in brittle materials design, process control, non-destructive evaluation, crack propagation processes and life predictions are needed.
- o Quality Assessment: Purity and submicron size control of the sinteric prime substances for ceramic manufacture; physical and chemical control standardization procedures; chemical analysis control, reference materials.
- o Production Facilities: Pilot plant and industrial plants for Z_rO_2, Z_rOC_2; TiO_2. lantaniedes, Al_2O_3,BeO, SiC, Si_3N_4.

3.2 Quartz and Silicon

Several are the industrial application of quartz and silicon, mainly on optics and electronics.

High-quality quartz reserves are located in Brasil, that holds 95% of the world reserves. It is the sole producer of blocs of piezoelectric quartz and the major producer and exporter of quartz pieces.

Cacex, the national exporting authority, establishes exporting prices ranging from 1,2 to 6,0 dollars a kilogram, the average exporting price being of the order of 1,3 dollar a kilo. Therefore, the financial benefits from quartz industrialization are occurring outside national borders.

Of the advanced materials that are made-up of quartz, the country detains own technology for cultivated quartz production (Cetec) and oscillators. ABC-XTAL industrial plant does produce cultivated quartz, although utilizing Motorola's technology, corresponding to near 1% of the world market.

Brasil does not hold technology for fused quartz production, importing products as diffusion tubes, optical glasses, etc....

ABC-XTAL manufactures optical fibers using CPqD-Telebras developed technology.

As for silicon, Brasil is one of the major world producers of metallurgical grade silicon, being almost all the production using quartz!

For the production of one kilo of metallurgical grade silicon, around 2,8 kilos of quartz are needed.

The country does not produce electronic grade as well as solar grade silicon, importing its needs on the form of final products. There is a factory called Heliodinamica that imports polycristaline electronic grade silicon and produces monocristaline plaques and solar cells.

Research and development are being carried out at Cetec and IPT research centers and at UNICAMP, USP, and IME university facilities.

The general guidelines on the quartz and silicon sector are:

- o Human Resources: To promote training and education compatible to the needs of this sector.
- o R+D Infrastructure: To provide for specialized equipment for those R+D institutions and universities.
- o Immediate Opportunities for R-D
  - oo Technological Domain: High purity quartz powder, fused quartz, electronic and solar grade silicon.
- o Quality Assurance: Industrial quality control systems to assess product reliability

- Production Units: To promote the installing of industrial units on high-purity powder quartz, cultivated quartz, oscillators, fused quartz, electronic and solar grade silicon.

3.3 Engineering Polymers

There exists some difficulties to identify a strategic positioning of the industry and research institutions in this area of engineering plastics in Brazil.

The trends in the research sector is very much conditioned by the stage of development of the nation's petrochemical industry. Thus, there is a search for identification of the worldwide tendency of such engineering plastic materials and how do they fit within the country's reality.

The actual meanings of such enormous generation of polymeric advanced materials worldwide do not seem to produce echoes on the national business enterprises, limited as they are to the still very weak market demand of such materials.

Notwithstanding, due to the great degree of internationalization of the internal Brazilian economy it is safe to admit, in a near future, a significant increase in demand for such advanced polymers; and when such a stage will be reached the expectations are that great difficulties are to be faced by the Brazilian petrochemical industries, since they are, in fact, already having problems in obtaining foreign technologies, due to the fact that the international market is extremely catalyzed do not enhancing technical dissemination.

Two are the main advanced polymer application: the reinforced ones, having excellent structural problems, adherency, the conducting and photo-active polymers; the second group may be called as "social application polymers", as the membranes (water purification, pollution control, dialysis) and bio-compatible materials (medical purposes).

The main R+D centers are: INPE, INCOR, CTA and CENPES; at the university level, UFRJ (IMA, biophysics and COPPE), UFSCar, UNICAMP.

The general guidelines for the advanced polymer programme are:

- Human Resources: Training and education at all levels is badly needed;
- R+D Infrastructure: Need to enlarge and equip the existing R+D centers and universities. It is foreseen that with the installing of petroquisa R+D facilities at the UFRJ campus, and subsequent operation, will act as a catalyzer for major actions regarding advanced polymer research and training.
- Immediate Opportunities for R+D
  - oo Membrane processes and production
  - oo Bio-compatible materials
  - oo Reinforced plastics

- oo High-cristalinity polymers
- oo Homogeneous polimetric alloys
- oo Photosensitive materials
- oo Special adhesives
- oo Engineering plastics
- oo Polymers from alternative sources

- o Reliability: Process and product reliability systems and procedures are to be emphasized;
- o Production Units: To promote special polymer industrial units.

3.4 Composites

Composites are hybrid advanced materials composed of inorganic and organic substances having properties superior to those of the constituents alone. They are any combination of particles, whiskers or fibers in a common matrix.

Figure 7 illustrates the way composite materials may be formed.

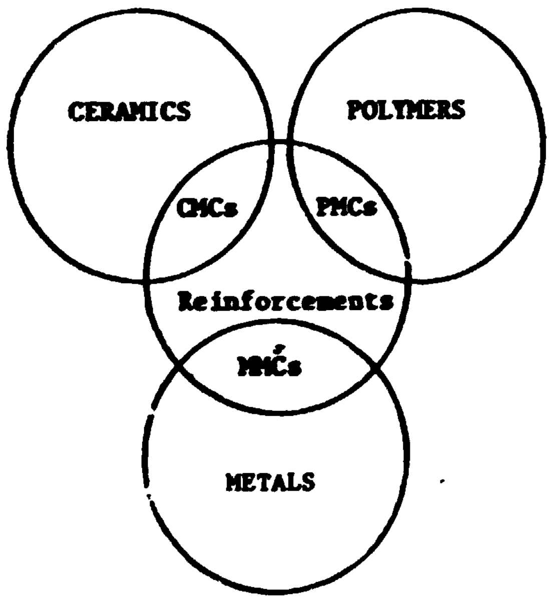


Figure 7..- The Way Composites Materials are formed.

Source:Office ot Technology Assessment

In Brasil composites were introduced by the aeronautical industry for structural purposes (pressure vessels, floors, rocket tubings, etc...). They consist of fiber and matrix combinations which yield superior strength and stiffness as well corrosion and fatigue resistance being relatively expensive and typically containing a large percentage of high performance continuous fibers (such as high-strength glass, graphite, aramid, or any other organic fiber).

They are fabricated by a laborious process called "lay-up", typically involving placement of sequential layers of polymer-impregnated fiber tapes on a mold surface, followed by heating under pressure to cure the lay-up into an integrated structure. Automation is beginning to speed-up this process, but production rates are too slow to allow for a significant accomplishment.

Market opportunities are appearing outside the aeronautical and defense uses, as for the demand on glass fiber reinforced polyester resin . However, less than 2% of such materials may be classed as advanced and are used in the sporting goods and industrial equipment industries.

It is expected that within a decade, composite unibody frames could be introduced in limited production; as well, medical implants, storage and transportation of corrosive chemicals, weapons and military vehicle are considered to be near term markets.

Embraer produces structural composites for its aeronautical industry.

As for R+D facilities, CTA, IME and INPE are those working in advanced composites research. At university level, UNICAMP.

The general guidelines for the advanced composites programme are:

- o <u>Human Resources:</u> Training and education efforts at all levels, due to the very embryonic nature of the national capability in the area.
- o <u>R-D Infrastructure:</u> Still very modest and insufficient for long term programmes; needs to be installed and equipped.
- o <u>Immediate Opportunities in R+D</u>
  - oo <u>Processing Methodology:</u> Development of new, low-cost fabrication methods are critical for advanced composites, as well how process variables do affect final properties.
  - oo <u>Mica reinforced polymeric composites:</u> Mica flocs as an alternative to glass fibers.
  - oo <u>Boron, Carbon and Aramid Fibers</u>
  - oo <u>Inorganic Matrix Composites:</u> Aluminium

- oo **Biomaterials:** Apatite as reinforcing agent for poliethilene matrix of ultra-high density (Orthodentical purposes) and PHB (Fracture Fixation).
- oo **Delamination Control:** As the single most important mode of damage propagation; as well interphase control techniques in order to assess its influence on composite behaviours.
- oo **Chemical Infusion:** To incorporate new properties to the matrix (conducting pclymers, lenzes and biomaterials)
- o **Testing Methods:** need for standardized testing methods and procedures to avoid, or hinder, variability in reported property values.
- o **Industrial Units:** to promote adequate erection of industrial plants on needed advanced composite materials.

4. Financing

In order to have a start on the afore exposed policy the figures shown in Figure 8 are in effect.

VALUES IN MILLION CRUZADOS

FISCAL YEAR	1987					1988				
Sources / Areas	MCT	FINEP	CNPq	SEI	TOTAL	MCT	FINEP	CNPq	SEI	TOTAL
Planning & Studies	10	5	-	-	15	15	5	-	-	20
Training & Education	6	10	192	3	220	40	15	394	3	452
R-D Infra-structure	74	30	-	-	71	130	50	-	-	180
R-D Projects	48	420	18	5	513	210	86[illegible]	3[illegible]	5	1.[illegible]
Reliability & Quality Assur.	12	5	-	-	19	25	20	-	-	45
Productive units Assistance	-	30	-	30	60	-	50	-	30	80
TOTAL	150	500	210	38	898	420	1000	430	38	1888

MCT= Ministry of Science and Technology

FINEP= Loan and Financing State Enterprise

CNPq= National Research Council

SEI= Secretary of State for Informatics

Values in 10^6 Cz$

Cz$1 = US$ ______________

Figure 8 .- Budget for the new materials programme

Source: "O desafio dos novos materiais", Colecao Brasil ciencia, No. 2, MCT, 1987

As for sectorial application, figure 9 shows the values in million of cruzados; the same observations holding for figures 8 and 9.

VALUES IN MILLION CRUZADOS

FISCAL YEAR	1987						1988					
Area / Source	NMM	AC	QS	EP	C	TOTAL	NMM	AC	QS	EP	C	TOTAL
MCT	46	44	15	30	15	150	122	98	73	92	35	420
FINEP	164	62	118	35	121	500	330	68	102	71	429	1000
CNPq	74,6	36,5	30,4	45,5	23	210	141,2	80	61,8	93	54	430
SEI	ND	ND	ND	ND	ND	38	ND	ND	ND	ND	ND	38
TOTAL						898						1888

NMM= New Metalic Materials

AC= Advanced Ceramics

QS= Quartz and Silicon

EP= Engineering Polymers

C= Composites

ND= not defined

Figure 9. - Area distribution of financial values

Source: "O desafio dos novos materiais", Coleçao Brasil Ciencia, No. 2, MCT, 1987

5. Constraints for the Use of New Materials

Several are the constraints imposed on a national policy regarding the development of efforts in advanced materials technology.

Besides those of a more strategic position exposed at the introduction chapter of this paper, others are:

5.1 Training and Education: The now-a-day demand for scientists, researchers and engineers well trained in advanced materials technology and utilization is lacking far most behind any supply. This holds true for the industrialized world, and in a most promiment way in the third world countries. It is recognized that education may show the most effective approach towards accelerating the development and utilization of new materials. Undergraduate courses are to be offered in a systematic basis to engineering, physics, and chemistry bacherlos; post-graduate courses aiming to create the research and development capabilities on new materials are a must; special emphasis is to be put on faculty members training programmes.

5.2 Interdisciplinary Approach: The combined efforts of specialists from several fields of knowledge play a decisive role in project, manufacture and utilization of new materials. Sinercism,so common in nature, but seldom appreciated in scientific thinking, is the key role to understand and interpret new material designs. No distinctive ways to carry out a given project on the product and the material from which it is made is allowed in new materials developments. Such an approach however, although needed for advanced materials proper designs, is very much against the third world countries capabilities, due to their lack of qualified personnel.

5.3 Integrated Design

Advanced materials development and utilization claims for an extensive database on materials properties and capabilities in producing sophisticated software for computer modelling and simulation analysis, aiming to know how the properties of the microscopic constituents, acting in a given sinergetic environment, determine the overall behaviour of the desired product.

This constraint, again, acts against third world countries, due to their lack in qualified personnel and computing tools.

5.4 Systems Approach to Costs

One of the characteristics of advanced materials is their hight cost and it is unlikely that such a characteristic is going to change in a near to medium term foreseeable future.

The "system costs" approach, including primary materials manufacturing, utilization properties and life cycle of the product, tries to diminish the cost disadvantage of the new materials; the idea being the cost decrease from US$300 per pound to less than US$20 per pound (that actually occurred to the standard high strength carbon fiber), repeating and decreasing further to the US$5 per pound range to compete satisfactorily with common metalic products (that actually is far from happening).

Two very important costs in favor of the economicity of some advanced materials, as composites, ceramics and engineering polymers, are the energy and labor costs.

5.5 Attitude toward R+D

Research and development activities are officially spoken of being very necessary and of utmost importance in almost any government official and businessman speech all over the world.

In the industrialized countries R+D is an integrated part of the running enterprise and is the responsible for maintaining the competivity of a given company and or for improving a given country's supremacy. Even in these countries R+D expenditures are heavily financed by the government.

In the third world countries, however, R+D expenditures either from government or from local industry are extremely poor, thus widening the distance from the central economies. Why is this so? Answers to this question are normally given in terms of social economical priorities: Transportation, basic health, production, etc....

Such answers do show a remarkable lack of real meaning and understanding of the role of science and technology. They are not an end per se, they are the way to overcome and reach the ultimate goals imposed by the country!

In any country and specially those of the third world a coupling of resources is a must: there are not enough facilities to be utilized for R+D purposes; there are not enough conventional and specialized equipment to deal with; and there is credibility from the industry (and government) towards local R+D groups!

What to do then? Firstly, government has to view R+D programmes not as perfunctory actions to which some illuminated people dedicate themselves for their own satisfaction; secondly, local industrial business, eager to go around and bring any "expert" they can find available, has to promote R+D projects that fit their own needs; thirdly, R+D personnel has to understand that they are not divine inspired and need to sweat in order to have credibility.

Therefore, from a national standpoint, a consortium of actions and activities, coupling available scientific capabilities with engineering skills, laboratory and scale-up facilities, as well testing operations, is to be carried out if any chance of success is to be assured.

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