sage a growth in organic semiconductor technology). What one can reasonably expect, however, is that the elegant work of *Friend* et al. might soon lead to the development of high-performance sensors utilizing relatively cheap and easily processed organic materials.

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Conference Reports

Advanced Materials—R & D Efforts in Germany

A good three years after the German Federal Ministry for Research and Technology (Bundesministerium für Forschung und Technologie, BMFT) initiated its Materials Research Program, the first Materials Research Symposium took place in Hamm/Westphalia on September 12–14, 1988. Approximately 600 scientists and engineers discussed, in plenary lectures and review papers. the current state of knowledge and techniques in materials research. Results obtained up to now in various advanced research and development projects were presented in specialist papers and posters.

Following intensive discussions with many experts, five main themes that appeared to offer a high potential for innovation had been chosen for the Materials Research Program: ceramics, powder metallurgy, metallic materials for high temperatures and specialized applications, new polymers, and composite materials. The idea of the program is to stimulate progress by setting up joint interdisciplinary research projects involving academic research institutes and industrial laboratories, with well-matched complementary work plans carefully drawn up and agreed in advance. The industrial partners contribute with about 50% of the cost of such R & D projects. Federal funding up to a total of DM 1.1 billion is to be made available over the ten-year program. The Materials Research program is being supervised on behalf of the BMFT by the Materials Research Project Group of the KFA (Nuclear Research Center), Jülich.

The DM 940 million that has been committed to the Materials Research Program up to the time of this interim review in Hamm is divided between 265 collaborative projects involving 637 research laboratories; Table 1 summarizes the distribution between topics. Of the funding provided by the BMFT, 34% has gone to academic research institutes and 66% to industrial laboratories.

Table 1. Distribution of presently committed research funds between the five main themes of the Materials Research Program (million DM).

	Ceramics	Powder metallurgy	High temperature metals	Polymers	Composites
Total budget	251	94	176	200	220
BMFT contribution	124	58	99	103	116

Ceramics

This part of the program is aimed mainly at research and development on monolithic ceramics, and also includes ceramic films. It is strongly focussed on high performance structural ceramics (engineering ceramics). At present there are very few applications for which the reliability of complex shaped ceramic engineering components under dynamic load is adequate. It should be possible to greatly improve the reliability of ceramic components by quality control during manufacture, or by structural reinforcement, helped by the expected development of more reliable non-destructive testing methods. The powders used as starting materials for the manufacture of ceramic engineering components can be synthesized by reactions in the solid state, by production from melts, or by precipitation from solutions or from gaseous phases. An example of the

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many developments in progress is that by Elektroschmelzwerk Kempten (ESK) in collaboration with Kühnle, Kopp & Kausch AG (KKK) of Frankenthal and the Technical University of Braunschweig; this team is working on a new process for manufacturing turbocharger rotors from sintered silicon carbide or silicon nitride materials (SSiC, SSN and SRBSN). In particular, with Si_3N_4 rotors it has already been found that the frictional conditions at 1300 K allow peripheral velocities greater than 500 ms^{-1} to be achieved, and in tests with a SSiC rotor an operating life of 10000 km has been obtained. There are good prospects for achieving peripheral velocities of >500 ms^{-1} at 1500 K and a failure probability of less than 0.1%. However, considerable further work will be needed to achieve consistent series production with this level of quality, while also paying adequate attention to economic aspects. With the R & D work that is currently under way, ceramics research in the Federal Republic of Germany has taken a considerable step forward. However, there is likely to be an increasing need in the future for R & D work in the field of functional ceramics (including glass-ceramics and glass) with special physical properties, e.g. as regards electrical, electronic, optical or magnetic behavior.

Powder Metallurgy

Some of the topics in the powder metallurgical part of the Materials Research Program are: the reproducible manufacture of rapidly quenched powders for making alloys that are not accessible by melt metallurgy; the development of new process methods for manufacturing engineering components and semi-finished parts with, for example, spatial variations in their properties (graded structures), or with unusually high strength and toughness; the development of economical methods of production for large mechanical components. As an example, work is in progress at the Technical University of Hamburg-Harburg and at the Max Planck Institute for Metals Research, Stuttgart, in collaboration with several industrial partners, to develop high-strength aluminum alloys made by powder metallurgical techniques; with alloys of the type Al-Zn-Mg-Cu-X it was found that yield stresses as high as 750 MPa and a fatigue strength of 300 MPa could be obtained, thus giving strength properties significantly better than those of the corresponding alloys made by melt metallurgy.

Densification of powders by the direct explosive method offers an attractive means of compacting, especially for the newly developed rapidly quenched types of alloys, or for brittle materials such as ceramics or intermetallic phases. The possibilities for industrial applications of this technology are being investigated in a collaborative project between ESI GmbH, Eschborn, and Rheinmetall GmbH, Düsseldorf. The studies are based on a commendable symbiosis of theoretical calculation and experiment. The very rapid densification process, which is characterized by extremely high pressures and material velocities, was simulated using a computer program for finite element calculations. The parameters thus determined were then used in setting up experiments, and this resulted in the production of samples with 99% densification. Following the successful compaction of spherical samples, it is planned that the next stage of the project will investigate explosive densification of powders consisting of plates and of complex mechanical components such as turbine blades.

Metallic Materials for High Temperatures and Special Applications

Metallic materials continue to occupy a preferred position in high performance engineering applications, and are used in many areas of modern technology. They have high strength and toughness with good thermal conductivity, and can be economically produced and worked. The application of new metallurgical knowledge has led to improved properties with regard to strength, toughness, stability at high temperatures, and corrosion resistance, showing that the scope for continued development of metals made by melt metallurgical techniques is still far from exhausted. One factor that limits the potential applications of metallic materials is the maximum service temperature; excessive temperatures result in deterioration of the mechanical properties and corrosion resistance, and a reduction in creep strength. An example of an approach to these problems is the collaboration between the Ruhr University of Bochum and the VAW, Bonn, which is concerned with R & D work on new types of structures in Al-Li based alloys. The demand in airplane construction for materials that are ever lighter but also stronger has led to the development of Al-Li alloys with reduced density and increased tensile modulus. This allows the construction of aircrafts with significantly reduced structural masses. In these research studies the combination of new materials structures and optimized heat treatments has led to materials whose mechanical properties are superior to those of conventional cast and wrought aluminum alloys.

The overall impression is that the work on materials for high temperatures and special applications covers a wide range of topics, including both the further development of conventional high performance materials and basic studies on the potential uses of more novel materials.

New Polymers

This aspect of the program is concerned both with developing high performance polymers for use as engineering materials and with producing functional polymers with entirely novel physical properties, e.g. electrical, electronic, optical or magnetic properties. High mechanical performance in polymers may involve requirements such as stability even at very high temperatures, or high strength while retaining good processability. Looked at in terms of theoretically attainable values, only a fraction of the potential strength properties of polymers has been used up to now. It is true that the theoretical values cannot be fully realized in practice, but there is nevertheless an enormous potential for development. Possible approaches include specifically synthesizing or otherwise forming a precisely defined molecular architecture. An example of this is a development at the Max Planck Institute for Polymer Research, Mainz, in which flexible side-chains are attached to rigid main-chains with the aim of reducing the melting temperature so as to facilitate down-stream processing, without a significant deterioration in the good mechanical properties.

Remarkable progress has been achieved in the field of functional polymers. For example, BASF in collaboration with Bayreuth University and the Max Planck Institute for Polymer Research, Mainz, has succeeded in producing polymers with intrinsic electrical conductivity similar to that of metals.

In another research project on "polymeric optical fibers", Hoechst AG, Frankfurt, has scored a notable success. Precursors for making a polymeric light-transmitting fiber have been synthesized; these have better high temperature resistance ($T_g > 130°C$) and considerably lower light attenuation (20 dB km^{-1}) than conventional polymeric optical fibers made of polymethylmethacrylate (PMMA: 100 dB km^{-1}). This has been achieved by means of a hydrogen/fluorine and hydrogen/deuterium exchange in esters of acrylic and methacrylic acids. These materials make it possible to transmit signals over a distance of 1500 m without intermediate amplification, whereas the plastic optical fibers used previously have needed booster amplifiers every 100 m.

A large market in the field of short-range information technology (transmission distances under 2 km) is predicted for polymeric optical fibers, as they are more flexible than glass fibers, even with large fiber diameters, and they also offer a wider range of choice in refractive index; also the cost of a system is less owing to easier working of the material and lower manufacturing costs.

Functional polymers are likely to become especially important as a result of future advances in research. Efforts are being made to ensure close cooperation between research partners in the electronics and chemical industries.

Composite Materials

This research topic is concerned with high performance materials in which a polymeric, ceramic or metallic matrix is reinforced by the inclusion of fibers, whiskers or particles. Such materials are used in applications requiring high strength, stiffness and heat resistance with low mass.

An example of development work in this area is a project on composites based on polymer matrices, under the overall control of Volkswagen AG. This is concerned with developing economic production methods using winding and tape-laying techniques for producing motor vehicle components. A typical example is the manufacture of transmission shafts for automobiles. Here the rate of production was increased to such an extent that it is now possible to make these components with an operating cycle of less than 30 s.

Another example that may be mentioned is a joint project by the companies Didier and Kolbenschmidt to develop a composite material with a matrix of ceramic and metal. It has previously been shown that ceramic fiber reinforced metallic materials already come very close to meeting the specifications for use as pistons in automobile engines. The idea being investigated in this project is to combine the advantages of the two materials by building into the piston a fiber gradient. According to this concept the piston has a dense ceramic layer on the combustion face, with a continuous gradation of the ceramic fiber fraction along the length of the piston, from 100% at this face down to zero at the other end. The mechanical characteristics thus obtained show an improvement over those for conventional piston materials which is in some cases as much as 100%. Another very important property of materials used for pistons is the resistance to thermal shock. In this case fiber reinforcement gives an improvement of 300 to 400% in the results of temperature cycling tests.

The idea followed at Hamm of organizing the conference program with a strong interdisciplinary emphasis has proved especially successful, bringing together scientists and engineers from all branches of materials science in wide-ranging and stimulating discussions covering different disciplines. The proceedings of the symposium have been published by the Materials Research Project Group of the KFA Jülich. In addition, an overall evaluation of the results achieved compared with international developments will be published by the BMFT late in 1988.

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