Overview

New structural materials technologies will be a determining factor in the global competitiveness of U.S. manufacturing industries in the 1990s and beyond. Today, for instance, materials account for as much as 30 to 50 percent of the costs of most manufactured products. New materials that can reduce overall production costs and improve performance can provide a competitive edge in many products, including aircraft, automobiles, industrial machinery, and sporting goods.

Remarkable advances in structural materials technologies have been made in the past 25 years. New materials such as ceramics and composites offer superior properties (e.g., high-temperature strength, high stiffness, and light weight) compared with traditional metals such as steel and aluminum. What is more, the materials themselves can be designed to have the properties required by a given application. Use of such designed materials, which are often called "advanced," can lead to higher fuel efficiencies, lower assembly costs, and longer service life for many manufactured products.

Although the United States has achieved a strong position in advanced materials technologies, largely as a result of military programs, it is by no means certain that the United States will lead the world in the commercialization of these materials. The technologies are still in their infancy, and cost-effective use of advanced materials and fabrication processes is yet to be demonstrated in large-scale commercial applications. Potential end users in the United States have adopted a "wait and see" attitude, pending the solution of remaining technical and economic problems. However, through well-coordinated government-industry efforts, several countries, notably Japan, have initiated more aggressive programs to commercialize their evolving materials technologies. These programs have succeeded in bringing advanced material products to the market years in advance of comparable U.S. products. Concern about the U.S. competitive position has led Congress to seek a coherent national program to ensure that the United States will be able to capitalize on the opportunities offered by advanced materials.

Advanced materials can be classified as metals, ceramics, polymers, or composites, which generally consist of fibers of one material held together by a matrix of a second material. Composites are designed so that the fibers provide strength, stiffness, and fracture toughness, and the matrix binds the fibers together in the proper orientation. This assessment focuses on three promising categories of structural materials: ceramics (including ceramic matrix composites), polymer matrix composites, and metal matrix composites. The principal purpose is to describe the major opportunities for use of ceramics and composites, and to identify steps that the Federal Government could take to accelerate the commercialization of advanced materials technologies in the United States.

THE U.S. ADVANCED MATERIALS ENVIRONMENT

The current value of components produced from advanced structural ceramics and composites in the United States is less than $2 billion per year. However, by the year 2000, U.S. production is expected to grow to nearly $20 billion. This estimate includes only the value of the materials and structures; it does not include the value of the finished products (e.g., aircraft and automobiles), whose performance, and therefore competitive posture, is improved by use of the materials. When the overall value of these products is taken into account, use of advanced structural materials is likely to have a dramatic impact on gross national product, balance of trade, and employment.

Military demand for high performance materials in the United States has already created a

thriving community of advanced materials suppliers. These suppliers are also seeking commercial applications for their materials. At present, though, advanced materials developed for military applications are expensive, and fabrication processes are poorly suited for mass production.

Potential U.S. commercial end users believe that major use of these materials will not be profitable within the next 5 years, the typical planning horizon of most firms. In many cases, 10 to 20 years will be required to solve remaining technical problems and to develop rapid, low-cost manufacturing methods. Investment risks are especially high for commercial end users because the costs of scaling up laboratory processes for production are enormous, and the rapid pace of technology evolution could make these processes obsolete. Hence, there is very little commercial "market pull" on advanced materials technologies in the United States.

In contrast to the market pull orientation of firms in the United States, end users in foreign competitor nations, notably in Japan, are pursuing a "technology push" approach, in which near-term profits are sacrificed in favor of gaining the production experience necessary to secure a share of the large future markets. This aggressive approach will probably give these firms a significant advantage in exploiting global markets as they develop. OTA finds that manufacturing experience over time with advanced materials will be a prerequisite for competing in those markets; U.S. companies should not expect to be able to step in and produce competitive advanced materials products after the manufacturing problems have been solved by others.

THE ROLE OF THE FEDERAL GOVERNMENT

The Federal Government directly affects the development of advanced materials through funding of basic research, technology demonstration programs, and military and aerospace procurement of advanced materials and structures. The U.S. Government currently spends about $167 million per year for R&D on structural ceramics and composites, more than any other nation.

Counting only basic and early applied research, the Department of Defense (DoD) sponsors about 60 percent ($98 million) of this total. In the case of the military, the government itself is the customer for materials technology and hardware. Advanced materials are truly enabling technologies for many military systems such as the National Aerospace Plane, Stealth aircraft, and missiles; they can also enhance the mission capability of a host of less exotic systems such as tanks, ships, submarines, and ground vehicles. Transfer of DoD-funded materials technology to the commercial sector, however, is discouraged by two major factors. First, the high cost of military materials and fabrication processes limits their acceptance in the commercial sector. Second, to deny these advanced materials to the U.S.'s adversaries, the government imposes restrictions on the export of the materials and on access to related technical data.

About 40 percent ($69 million) of Federal spending for structural ceramics and composites R&D is nonmilitary in nature, including most of that funded by the Department of Energy, the National Aeronautics and Space Administration, the National Science Foundation, the National Bureau of Standards, and the Bureau of Mines. These agencies generally do not act as procurers of hardware. Rather, they sponsor materials research ranging from basic science to technology demonstration programs, according to their various mission objectives. Where appropriate, they openly seek to transfer materials technology to the private sector.

FOUR KEY POLICY OBJECTIVES

OTA's analysis suggests four key Federal policy objectives that could accelerate the commercialization of advanced materials technologies. Options for implementing these objectives range

from those that have a broad scope, and affect many technologies, to those that specifically affeet advanced materials technologies.

1. Encourage potential end users to make long-term capital investments in advanced materials.

Greater investment in advanced materials by potential end users would help to generate more commercial market pull on these materials in the United States. The climate for investment in long-term, high-risk technologies such as advanced materials could be improved by Federal Government implemention of a variety of policy options designed to make more patient investment capital available. These would include providing tax incentives for long-term capital investment, reducing taxes on personal savings, and changing tort law to make product liability proportional to proven negligence. .

2. Facilitate government/university/industry collaboration in R&D for low-cost materials fabrication.

The high cost of advanced materials development and the small near-term markets are forcing companies to seek collaborative R&D arrangements to spread the risks and raise the large amounts of capital required. Three major reservoirs of materials expertise are available to U.S. companies: 1) universities, 2) Federal laboratories, and 3) small high-technology firms. Among industry/university and industry/Federal laboratory collaborative centers in advanced materials, OTA finds that industry generally participates to gain access to new ideas and trained graduate students and industry considers the scale-up costs too high and the payofffs too uncertain to justify commercialization of collaborative research results. The government could encourage the commercialization step by establishing collaborative centers in which government and industry would share the costs of downstream materials fabrication technology development. Another option would be to provide incentives for large companies to work with those small, high technology firms that have advanced materials fabrication expertise, but lack the capital to explore its commercial potential.

3. Facilitate more effective commercial exploitation of military R&D investments where possible.

In the next 5 to 10 years, military demand for advanced materials is likely to grow at a faster pace than commercial demand, so that military policies and requirements will strongly influence the agenda for advanced materials development in the United States. It is evident that government restrictions on advanced materials and associated technical data in the interests of national security can cause conflict with U.S.-based firms seeking unrestricted access to markets and information. Furthermore, these conflicts are likely to become more severe as commercial applications grow and as the companies involved become more multinational.

Ultimately, both national security and a competitive manufacturing base will depend on a strong domestic advanced materials capability. Therefore, a major goal of U.S. policy should be to strike an appropriate balance between military and commercial interests+ Among the options that could be considered are: updating export control lists so that they are applied only to technologies that provide important military advantage to the United States and that are not available to our adversaries from other sources; greater support for military programs aimed at developing low-cost materials fabrication processes that could be adapted for commercial use; and clarification &military domestic sourcing policies for advanced materials.

4. Build a strong advanced materials technology infrastructure.

Through acquisitions, joint ventures, and licensing agreements, materials technology is flowing rapidly among firms and across national borders. Critical advances continue to come from abroad, and the flow of materials technology into the United States may already be as important as that flowing out. It essential that an adequate technology infrastructure place for rapidly capitalizing on research results, whether they originate in the United States or abroad. Policy options for building up this infrastructure include: increasing funding for research on reliable, low-

cost manufacturing methods; gathering and disseminating information on foreign and domestic research efforts; accelerating development of materials testing standards and materials property databases for designers; and increasing support for multidisciplinary materials engineering programs in universities and for retraining of engineers in the field who are unfamiliar with the new materials.

TWO VIEWS OF ADVANCED MATERIALS POLICIES

Congress and the Administration have adopted conflicting views of policymaking with regard to advanced materials. The crux of the conflict is whether the Federal Government should adopt a national plan for advanced materials technology development, or whether goals and priorities should be established in a decentralized fashion according to the different missions of the principal funding agencies.

According to the congressional view, national goals and priorities should be established above the agency level, and agency spending on materials programs should be made consistent with them. This view is expressed in the National Critical Materials Act of 1984, in which Congress established the National Critical Materials Council (NCMC) in the Executive Office of the President. The NCMC is charged with the responsibility of working with the principal funding agencies and the Office of Management and Budget to define national priorities for materials R&D and to coordinate the various agency efforts.

In the Administration's view, priorities for advanced materials R&D cannot be separated from the functional requirements of the structures in which they are used. Because different agencies have different requirements for materials, determination of R&D priorities is best made at the agency level. Strategic advanced materials planning is seen as putting the government in a position of "picking winners"—a role that is best left to the private sector. According to this view, the Office of Science and Technology Policy's Committee on Materials (COMAT), and other interagency committees, which meet to exchange information about ongoing advanced materials projects and budgets, are adequate for avoiding excessive duplication and waste. The NCMC is considered redundant with these committees.

OTA finds that it is more difficult to define national policy goals for advanced materials than for more traditional critical materials. To succeed in its task, the NCMC will need to establish a more precise definition of the goals that would motivate such a national materials policy, as well as to develop high-level Administration commitment to the concept of such a policy.

Pending the resolution of these differences, there are three further functions that the NCMC could perform. First, it could serve as a point of contact for monitoring industry concerns and recommendations regarding joint industry/government initiatives. Second, it could gather information on domestic and foreign materials R&D efforts and disseminate it to industry. Third, it could act as a broker for resolving conflicts between military and commercial agency goals for advanced materials.

ADVANCED MATERIALS POLICIES IN A BROADER CONTEXT

In many respects, the competitive challenges facing advanced materials are a microcosm of the challenges facing the U.S. manufacturing sector as a whole. Therefore, advanced materials policy cannot be viewed as a wholly separate issue. Policy options such as tax incentives for long-term capital investments or revision of export controls could also serve to stimulate a broad range of other technologies. Such policy options cannot be adequately addressed at the agency level or in interagency committees; they clearly must be initiated in the highest councils of government. Advanced materials policies therefore, can most effectively be treated as one facet of a high-level, high-priority policy of strengthening the Nation's entire industrial and manufacturing base.