cial look at sialon and fiber-reinforced ceramics, and manufacturing technologies for these.

The Industrial Base Technology Development Project, which includes research in ceramic materials, began in 1981 and will continue for 10 years. The materials covered in the research and development of "fine ceramics" (as they are designated in Japan to differentiate them from ordinary potteries) are silicon nitride, sialons, silicon carbides, boron nitride, several oxide ceramics, and zirconia. The requisites for the above materials are the capability to fabricate complex sintered parts of corrosion resistance, wear resistance, high strength, high dimensional accuracy, and material reliability. Japanese demonstrations:

Hitachi has already built a complete passenger car powered by a silicon carbide-insulated diesel and has run it through 50 hours of road tests. This material consists of SiC powder with special aluminum sintering additives and maintains its high strength under 1,600°C, 100 kg/mm^2, which is twice as high as the conventional SiC.

- Kyocera has manufactured and marketed silicon nitride glow plugs for light-weight diesel engines in Japan. They have greatly reduced the "waiting time" for diesel engine start-up because of the materials capability for rapid temperature increase.
- Isuzu (Tokyo) is developing a turbocharged Adiabatic Engine with a reported 30% improvement in fuel economy. Production is set for 1990.
- NGK Spark Plug has succeeded in the trial manufacture of an all-ceramic "Dream Engine." All parts except the bearings and piston rings are made of ceramics. The crankshaft, which is most difficult to form, has been reduced to a monoblock ceramic construction. The crank case alone is made of alumina ceramics, and all other parts are made of silicon nitride. The engine has performed very well in its test running for 50 hours.
- The most recent and significant development is Nissan's production of a silicon-nitride turbocharger which has been incorporated into its 300 ZX sports car, considerably improving turbo performance. The advantage of the ceramic turbocharger rotors is the low density of the material used—sintered silicon nitride. The low energy decreases the turbocharger response time by lowering the inertia, through increasing the intake of air. In future cars, engines should simply be made stronger and more thermally efficient without the need for turbochargers.

Judging by the current level of U.S. investment, the Japanese will gain in their lead in advanced engineering ceramics. The U.S. Department of Commerce cited the following as probable reasons: domination of the electronic components business and the supply of advanced ceramic powders, a larger and more organized effort, initial performance-cost characteristics of demonstration products, a long-term commitment to market development, and an outstanding record in developing and implementing superior commercial manufacturing processes and process technologies. There are about 2,000 engineers and 4,000 technicians actively engaged in advanced ceramics technology in Japan. Based on these figures, their annual expenditure is between $300 and $400 million. Using similar reasoning, the Department of Commerce estimates annual U.S. advanced ceramics research and development at about $100 million.

The U.S. government must make long-term commitments to funding, which will, along with better protection of patents and proprietary rights, ensure the continued participation of industry. The Department of Commerce has called for a five-to-ten-year budgetary commitment by government, which would allow American industry, like the Japanese, to engage in long-range planning.

Ceramics can revive the failing auto industry

Despite reductions in auto production, which are due to a shrinking economy, the programs for high-technology structural ceramics in heat engines are continuing in the United States. A breakthrough in ceramic heat engines will bring an economic revival to the industry.

According to *Ward's Automotive Reports* of April this year, General Motors Corp., saddled with a million-car oversupply in recent weeks, has cut its third-quarter vehicle production plans by more than 8%. Nummi Corp., the joint venture between GM and Toyota Motor Corp. in Fremont, California, trimmed its third-quarter projections by almost 60% from a year ago. American Motors Corp. plans to slash output by almost 36.5%, and Volkswagen of America is planning a 21% reduction.

This economic situation is not holding back the research projects that have already begun in the United States for structural ceramics and their application to heat engines.

The Advanced Gas Turbine (AGT) project will be completed this year. This is the government's main demonstration ceramic heat engine. It will be followed up next year with the Advanced Turbine Technology applications project, which will further test the durability of ceramics. The AGT, because of its high thermal and mechanical stresses, is considered by the Department of Energy to be a test bed of structural ceramic technologies. It is hoped, of course, that the success of the AGT in automobiles will make it applicable also to aircraft which presently use turbines made of strategic metals. The second demonstration model is the Adiabatic Diesel Engine, which will continue to be funded next year. The third is the Stirling engine, the MOD II, which will be completed in FY87.