silicon on insulation technology affords the capability of multi-level devices, with each part of the circuit appearing on its own island. This permits high device densities. Also, the dielectric properties of the insulation make the devices faster than devices made in bulk silicon.

In summary, Basic Energy Sciences research on laser annealing opened a new frontier of science in the manufacture of semiconductors. It contributed directly to solving one immediate problem, giving rise to rapid thermal annealing. More broadly, it provided fundamental knowledge of rapid melting and solidification phenomena, leading to other successful applications. Outgrowths of this research now occupy established positions in commercial production. Others point toward further technical advances necessary for maintaining competitive positions in this important and fast growing industry.

SUPERIOR CERAMICS

From time to time in basic research, a new insight so clearly points the way toward potentially superior products that dozens of commercial and industrial firms rush to capitalize on it. Such was the case with Basic Energy Sciences research on the processing of ceramic materials. The insight not only helped to explain why conventionally formed ceramic materials failed to live up to performance expectations, but also outlined specific methods by which such shortcomings might be mitigated or overcome.

The underlying theory, modeling and small-scale experimentation which gave rise to this insight, stemmed from Basic Energy Sciences research at the Ceramics Processing Research Laboratory of the Massachusetts Institute of Technology. The accomplishment revitalized interest in this ancient material and thrust its promise toward the forefront of a host of modern applications.

For five thousand years and more, ceramic materials have been made from a mixture of clay and finely ground minerals, such as silica (forms of silicon dioxide, SiO_2) and feldspar (forms of aluminum silicates). When wet, these ingredients can be shaped or pressed into a mold of almost any desired configuration. After drying and firing under intense heat, the ingredients fuse together in a process called sintering. The resultant product is extremely hard, forming a dense but slightly porous solid.

Materials scientists long recognized that the physical properties of ceramics offered unique opportunities for materials design. Although generally perceived as brittle, some ceramics can be made to resist fracture. Others have useful electromagnetic properties. Many ceramics remain hard and functional at temperatures well above those that cause alternative materials to melt.

In practice, however, the fulfillment of this larger promise of ceramic materials had proven elusive. There were a number of serious shortcomings in the performance of the final products, stemming from the way they were manufactured.

In conventional methods of manufacture, ceramics are made from finely ground powders. Greatly magnified pictures of the powder particles showed that they were unevenly sized and highly irregular, appearing like broken stones from a crushing process. At the microscopic level, these shapes, in turn, led to irregular-sized pores, which could not be removed entirely during the firing and fusing process.

The resultant mass contained jagged grains and voids. This flawed microstructure gave rise to a number of undesirable properties: low strength or toughness; weak resistance to mechanical, thermal, and electrical shock; a tendency to crack and break under stress; and inconsistent electromagnetic properties.

Previously, ceramics developers had tried to overcome these problems by using different "recipes," that is, by mixing different ingredients together, changing the firing temperatures, or exerting high pressures during firing. All of these prior attempts were relatively ineffective. They failed to produce the ceramic materials required for today's high technology applications. The basic approach was largely trial-and-error. Knowledge of the underlying processes occurring at the microscopic level was limited.

Rather than alter the recipe, Basic Energy Sciences researchers took a more fundamental approach. They noted that theoretical models of ceramics often predicted strength and other properties superior to that which was found in reality. They knew that the models "idealized" the ceramic particles as densely packed, single-sized spheres.