Materials Sciences

Materials Sciences research aims at increasing understanding of materials properties and related phenomena. This understanding contributes to development of new or substitute materials, to tailoring materials to meet defined needs, and to predicting materials problems and service life.

LASER ANNEALING

There was an intense flash of laser light. It lasted less than fifty one-billionths of a second. Basic Energy Sciences researchers had melted the surface of a silicon crystal. They noted its almost instantaneous cooling and resolidification. Upon closer inspection they observed near-perfect crystal regrowth.

Their subsequent investigation of the phenomenon and, more broadly, of the laser as a means to manipulate the atomic structure of silicon crystals, opened a new frontier of science in the manufacture of semiconductors—the basic components of computers.

Knowledge stemming from this research revolutionized semiconductor manufacturing. It gave rise to a widely adopted annealing process, known as rapid thermal annealing. It laid the scientific foundation for the development of photochemical processing. It also contributed to the emergence of the so-called "silicon on insulator" technology. The latter technologies are both leading contenders for making the next generation of computer chips.

The basic technology, called laser annealing, exploited the laser's unique capability to deliver an intense concentration of energy in the form of light with blinding speed and surgical precision. Initially explored as a solution to a problem involving the repair of damaged semiconductor surfaces, the technology eventually proved to be much more than simply an annealing process.

The researchers found that the laser, when "tuned" and timed properly, could deposit a precisely measured amount of energy into the first 300 or so atomic layers of a material's surface. This rapid energy deposition, in combination with natural processes of cooling (heat conduction and radiation), provided a means by which the crystalline lattice structure of a material's surface and near-surface layers could be modified and adapted to serve specific design objectives.

In the presence of a thin film coating or envelope of reactive gases, for example, the melting process can be made to absorb "impurities" and induce certain electrical properties. Likewise, foreign atoms can be "implanted" through bombardments into a material's surface layers, and laser annealing can "activate" desired properties by repairing the bombardment damage.

Further, selected atoms can be "packed" into key positions of a material's surface structure in proportions that far exceed those of equilibrium chemistry, giving rise to new classes of man-made materials. Precision timing also makes laser annealing a powerful research tool, akin to a "stop action" camera, for studying atomic details of crystal growth and rapid solidification.

Pursuing these possibilities, Basic Energy Sciences researchers provided much of the fundamental knowledge and early understanding about laser annealing and its attendant phenomena, culminating in dozens of articles published in major scientific journals, including *Applied Physics Letters*, *Journal of Applied Physics*, *Physical Review Letters*, *Physical Review*, and *Science*. Out of these findings grew numerous and varied applications of importance to commercial manufacturers of electronic devices.

In the 1970's, for example, one of the principal means for manufacturing semiconductors involved the "doping" of crystalline silicon with so-called "impurity" atoms of phosphorous. This was accomplished by "implanting" positively charged