U.S. Electronics Needs New Strategy

The traditional strategy that combines the short-term focus of industrial laboratories with the long-range perspective of universities apparently is not up to the Japanese challenge

FROM 1980 to 1985, the share of the worldwide market held by U.S. manufacturers of semiconductor devices shrank from 64 to 53%, a substantial drop considering that semiconductors are the foundation on which our high-tech society rests. Although the market will continue to grow toward $50 billion by 1990, according to a new National Research Council (NRC) Report titled *Advanced Processing of Electronic Materials in the United States and Japan*, the downward trend in the U.S. share is unlikely to be reversed anytime soon.* The report, released with some hoopla on 4 June, identifies seven key technologies for next-generation integrated and optoelectronic circuits in which the United States already lags Japan, its main competitor.

But the most important implication of the report is that the traditional American research and development strategy that calls for industrial laboratories to concentrate on short-term product development, for government laboratories to confine themselves to mission-oriented projects, and for universities to examine phenomena that may have no immediate applications in either sphere is no longer appropriate for semiconductors.

Taking note of a series of successful multiyear research and development projects undertaken by Japanese companies under guidance of the Ministry of International Trade and Industry, the report concludes that "mechanisms to encourage long-term commitment to research and development in U.S. industry need to be formulated" and that "U.S. industry should be intimately involved with the government laboratories."

In truth, there is nothing novel about these recommendations, but the NRC thought them important enough to emphasize once again by convening a 1-day seminar under the joint chairmanship of Frank Press, president of the National Academy of Sciences, and Robert White, president of the National Academy of Engineering, at its headquarters on the day the report was made public to review the report and explore its policy implications.

The morning session, chaired by Press, began with an overview of the report by John Poate of AT&T Bell Laboratories. The report was intended to survey the comparative status of electronic materials processing technologies in the United States and Japan. To help in assessing the Japanese position, several members of the study panel made a quick 1-week visit last November to seven industry laboratories, one government laboratory, two university laboratories, and one processing equipment manufacturer.

All in all, the report concludes that U.S. manufacturers continue to hold the lead in three important processing technologies (ion implantation, thin-film epitaxy, and film deposition and etching), while they have slipped behind during the last year in a fourth technology, optical lithography. These judgments are partly subjective, based on the perceived quality of work done in the two countries, and partly quantitative, based on sales by manufacturers of processing equipment in the two countries to semiconductor companies. While processing equipment sales are not large in terms of dollars (about equal to the wine cooler market, according to Poate), it is generally considered that leadership in semiconductors and in processing equipment go hand in hand.

The report finds seven emerging technologies where the Japanese are now leading.

There is no comfort to be had because of the overall current U.S. lead in processing equipment sales. An American company pioneered the development of and was the early sales leader for the leading-edge optical lithography systems called wafer steppers, but it has not kept pace. The same reversal could just as quickly occur in the other processing technologies, said Poate. Moreover, as miniaturization proceeds apace and designers look for ways to cram more transistors or other devices on a chip, future generations of semiconductor-based electronic and optical integrated circuits will make more stringent demands on these technologies, and it is here that the danger to U.S. leadership is already evident. The report finds seven emerging technologies that will play varying roles of importance in future electronic and optical devices where the Japanese are now leading:

- microwave plasma processing
- lithographic sources
- electron and ion microbeams
- laser-assisted processing
- compound semiconductor processing
- optoelectronic integrated circuits, and
- three-dimensional device structures.

There is more to making an integrated circuit smaller than just improving the resolution of the lithography process, although this must be the starting point. Processing temperature is a major problem because of atomic diffusion of dopants and thermally induced interactions between materials. When transistors were comparatively "large," a small drift in the position of a dopant during a heating step was not so critical. As the size decreases, the tolerance for such changes drops concomitantly. Hence, there is a major effort to reduce processing temperatures at every stage.

To take just one example, consider microwave plasma processing, which was discussed at the seminar by Bill Appleton of the Oak Ridge National Laboratory. Current plasma processing technologies, such as reactive ion etching, work at radio frequencies. A gas flows through a chamber containing the wafers to be processed. A radio-frequency field ionizes the gas, creating the plasma. Ions from the plasma bombard the wafers, where etching occurs by a combination of physical displacement and chemical reaction. One major difficulty is that the relatively high energy (up to 1 kiloelectron volt) of the ions also damages the wafer surface, which must then be annealed to remove the damage.

Appleton described several projects at Nippon Telegraph and Telephone (NTT) Corporation and the Hitachi Central Research Laboratory based on the use of 2.45-GHz microwaves that generate a plasma by means of electron cyclotron resonance. As it works out, the ions in the plasma have maximum energies up to only about 50 electron volts, making the etching process much more gentle. In addition to etching, Japanese researchers have used this idea to

*Available from The National Materials Advisory Board, 2101 Constitution Avenue, NW, Washington, DC 20418.

epitaxially grow silicon layers on silicon wafers, oxidize silicon surfaces, deposit insulating films on silicon, and deposit metal films on silicon, all at low temperatures as compared to the usual practices. While little or no comparable work on such a process is under way in the United States, the Japanese equipment maker, the Anelda Corporation, has already translated the NTT design into commercial instruments.

In summing up the reasons for the Japanese success in developing new electronic materials processing technologies, Poate pointed to four factors identified in the report. The first is *commitment* as manifested by the willingness of Japanese industry to dedicate both people and money to long-term research and development projects with a 10-year perspective. Oversight and funding from the Ministry of International Trade and Industry also helps.

The second factor is *coupling*, which occurs in two ways. Within a Japanese semiconductor company, there is a close coupling between exploratory research and development and product development. There is also a close interaction between the semiconductor company and the equipment makers. As one person commented from the floor during the seminar, U.S. equipment makers are often prevented by nondisclosure agreements from exploiting what they learn by working with a semiconductor company on a new processing technology.

The third factor is *commerce*. Japan's semiconductor industry comprises at least ten firms that are large enough and farsighted enough to pursue research across a broad range of technologies and to cover product development at every stage from the laboratory to the marketplace. Only two American companies can match this scale of effort. Though not mentioned by name, presumably these are AT&T and IBM, both of whom make chips for internal use only.

Finally, the fourth factor is *creativity*, which, in contrast to their past copy-cat image, the Japanese are demonstrating in their research and development programs for advanced electronic materials processes.

In the afternoon discussion of policy implications, which was chaired by White, no one seriously questioned these findings, although John Armstrong of IBM and others expressed much interest in upgrading university laboratories and getting them to contribute more directly, and Robert Stratton of Texas Instruments pointed out the low status in the United States of the manufacturing engineer as another important factor. All in all, the sentiment was that some way to fill in the gap between short-term development and long-range research has to be found. ■ ARTHUR L. ROBINSON

Anthropologists Suggest Cannibalism Is a Myth

The anthropology literature is full of stories of cannibalism, but increasingly many anthropologists are now saying that unequivocal evidence for this practice is nonexistent

WILLIAM Arens of the State University of New York at Stony Brook says he got interested in cannibalism for the most innocent of reasons. He was teaching an introductory course in anthropology in 1977 when, halfway through the semester, a student asked why he was lecturing "on kinship, politics, and economics instead of more interesting things like witchcraft, fieldwork experiences, and cannibalism."

The student's question, says Arens, "struck a sympathetic chord since I remembered that these were very much like the topics which first attracted me to anthropology." But like nearly all anthropologists, Arens notes, he ended up paying "more attention to the esoteric than the exotic." So he decided to prepare a lecture on cannibalism for his students. He ended up, however, provoking a debate among anthropologists that shows no signs of letting up.

What Arens concluded after investigating countless accounts of cannibalism is that there are no reliable firsthand witnesses to this practice. Even in New Guinea, where cannibalism is presumed to have spread the slow virus disease kuru, there is no good evidence for cannibalism, Arens and others say. This is not to say that no one ever ate human flesh. Survival cannibalism—eating another human being in order to survive a plane crash in the Andes, for example—clearly has occurred. But Arens argues that there is no evidence of ritualistic cannibalism—the routine and systematic eating of human flesh. "If I'm right, anthropologists are engaged not in a lie, not in a hoax, but in a myth. They are retelling what is always assumed to be true," he remarks.

Arens has gathered a sizeable group of supporters and has stimulated anthropologists and archeologists to take a careful look at the cannibalism evidence and to ask why cannibalism was ever attributed to various groups in the first place. The question of whether people are or ever were cannibals, says Erik Trinkaus of the University of New Mexico, "is very much tied into our views of who we are and what we are." Lyle Steadman of Arizona State University remarks, "I think Arens is right on target. But he really threatens a lot of anthropologists." Tim White of the University of California at Berkeley is now traveling around the world, looking at cut marks on hominid fossils that have been attributed to cannibalism, to try and determine their origin. And William Durham of Stanford says that Arens's arguments have made him a lot more skeptical of reports of cannibalism.

But not everyone has decided that cannibalism is a myth. D. Carleton Gajdusek of the National Institute of Neurological and Communicative Diseases and Stroke, who won a Nobel prize for his studies of kuru in New Guinea, says that the evidence of cannibalism in New Guinea is so clear that "it's beneath my dignity to answer the argument. The people who are involved with it or know of it have not deigned to get into the argument." And at least one group reports what it considers extremely strong circumstantial evidence that cannibalism was practiced during the Neolithic era. Led by Paola Villa of the University of Colorado and Claude Bouville and Jean Courtin of the University of Provence, these researchers argue that a group of Neolithic cave dwellers in France most likely were cannibals.

When he began to investigate reports of cannibalism, Arens immediately learned that groups never say that they themselves are or even recently were cannibals. It is always their enemies or strangers or other more primitive groups of people who are said to eat human flesh. When people do refer to themselves as cannibals, it is only far back in the most distant past—a way of showing how civilized they have become. Thus the Chinese said the Koreans were cannibals and the Koreans in turn said the Chinese were cannibals. Africans charged that Europeans were cannibals and Europeans said the Africans were. In fact, anthropologists themselves have been mistaken for cannibals. John Middleton of Yale University reported in 1970 that when he worked among the Lubgara of Uganda, the tribe had to redefine him, in Arens's words, "as one of those rare Europeans who did not eat African babies." Arens notes that "I soon learned