Chapter 2

Introduction: Microelectronics Technology and R&D

THE IMPACT OF MICROELECTRONICS AND EVOLUTION OF THE INDUSTRY

Microelectronics technology has dramatically improved the capabilities of computers and communications systems, while also fueling the growth of completely new applications, such as personal computers. Growing extremely fast and providing increasingly powerful and inexpensive tools to manipulate electronic signals, microelectronics has become the cornerstone of information technologies. It is central to such areas as:

- computers, from powerful supercomputers, through business computers, to inexpensive personal computers;
- communications systems, including switching stations and satellite communications;
- consumer products, such as electronic watches, video games, and pocket calculators;
- control systems for industrial applications, automobiles, and home appliances; and
- military systems for national defense.

Microelectronics has become a vital part of U.S. commerce and defense. In both sectors, maintaining a technological edge over the rest of the world is the only way to ensure security—whether military or economic. U.S. companies claimed approximately $14 billion of the $26-billion world market for microelectronics in 1984. I The development of increasingly sophisticated weapons systems means that virtually every aspect of current military technology depends on microelectronics.

1"The Japanese Semiconductor Market and S1 A's301 Petition," presentation by George Scalise for the Semiconductor Industry Association, July 24, 1985.

The dramatic growth of the technology has prompted observers to describe it as the microelectronics revolution. To date, the miniaturization of circuitry, which leads to products that perform faster and better, has been chiefly responsible for this revolution. Shrinking the electronic devices has yielded lower cost, expanded performance, and higher reliability. By any measure—cost for a given function, complexity of circuits, performance—integrated circuit (IC) technology has progressed at a tremendous rate since its inception. In 1964, Gordon E. Moore predicted that the number of components on a chip would continue to double annually, as it had since the beginning of that decade. Twenty years later, technology has not departed significantly from Moore's law. Experts predict a slowing of the trend over the next 10 to 20 years.

At the same time, IC design will begin to alter the way that system engineers use ICs. New capabilities provided by design software, silicon foundries, and the networks that link them allow the end user much greater flexibility in designing chips for a specific application. This trend, coupled with changes in fabrication technology, will affect the industry.

Many other factors, more immediate than the scientific and engineering changes, affect the structure of the American microelectronics industry, especially merchant firms. These include international competition, capital requirements, capital cost, and shifting markets. U.S. microelectronics companies currently face debilitating competition from Japanese sources, and other Asian countries (e.g., Korea) are also preparing to enter the market. At the same time, the industry is growing stead-

ily more capital-intensive, since every technological advance demands more complex equipment and production facilities. The high cost of capital exacerbates this problem. Finally, although many of the markets for uses of microelectronic products are growing, some of them grow explosively and then plummet as rapidly, as did the video games market. These shifts cause instability in the industry.

Together, these technological, international, and economic trends and forces are altering the microelectronics industry. The changes mark the beginning of the maturing of the industry and may signal the beginning of the end of an era of apparently limitless growth.

THE NATURE OF RESEARCH AND DEVELOPMENT IN MICROELECTRONICS

Since microelectronics has expanded swiftly and will continue to do so, research and development (R&D) activities play an extremely crucial role in its progress. As the technology and the industry mature, however, the reasons for supporting R&D may shift. For example, the approaching "post-shrink" era (beyond the limits of miniaturization for silicon integrated circuits) may demand renewed vigor in basic research to find a successor to silicon ICs.

To suit the needs of those who use the products based on microelectronic devices, R&D efforts in microelectronics are aimed at making circuits that:

- cost less,
- operate at higher speeds (higher frequencies),
- require less power and generate less heat,
- are more reliable and last longer, and
- carry out specific functions.

These goals are prioritized in different ways depending on the end use. For example, low cost is typically the chief concern for chips to be sold in high volume, but high speed may be the dominant requirement in making components for supercomputers, and concerns about power consumption may dominate for ICs intended for use in satellites.

For the microelectronics manufacturer, in the short term, these requirements translate into:[2]

- making ICs with smaller component devices (i.e., smaller transistors, resistors, capacitors, interconnections) and packing these devices closer together on the chip;
- using larger wafers so that more chips can be made on a single wafer;
- using new processes and new equipment in chip fabrication;
- packaging chips in increasingly sophisticated ways;
- designing increasingly complex circuits; and
- designing circuits that are tailored to specific applications.

Scientists and engineers involved in longer term R&D are trying to anticipate technological needs beyond the current generation of products. Their concerns center on topics such as:

- new materials for microelectronics (e.g., gallium arsenide);
- new devices to replace or augment transistors (e.g., quantum-effect devices);
- new equipment to fabricate these materials and devices;
- integrating optical and electronic circuitry; and
- advanced design tools.

[2] *App. A: Current Microelectronics Technology* provides some general background information on integrated circuit technology, and *App. B: Glossary of Terms gives* definitions for technical terms.