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VLSI Technology Overviews and Trends

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Since 1960, the electronic industry and the integrated circuit market have grown exponentially. We expect that such growth will be sustained through this decade and that by 1990, factory sales of electronics in the United States will reach $400 billion; 20 percent of this will be in integrated circuits. The worldwide electronics market is expected to grow at a similar rate, or about 15 percent annually in electronics sales and over 30 percent annually in integrated circuit sales. In ten years, the electronic industry will rival the automobile, chemical and steel industries in sales volume.

The main impetuses for such phenomenal growth are the intrinsic pervasiveness of electronic products and the continued technological breakthroughs in integrated circuits. We are now at the dawn of the VLSI era. We expect to have ultra-sophisticated VLSI chips built before 1990. These chips will have a one to two orders of magnitude increase in component density (1~10 millions per chip), a two to three orders of magnitude decrease in both unit cost per function and power-delay product, and about a factor of 10 decrease in the minimum feature length (0.25~0.5μm). Because of their advantages in circuit designs, unipolar devices will dominate VLSI and capture a major market share of all semiconductor devices sold.

At every step of the manufacturing process, from crystal growth to device packaging, numerous improvements and refinements will be made. VLSI processing will become more automated, resulting in tighter control of all processing parameters. The process temperatures will continue to decrease from approximately 1,000°C to possibly 600°C or lower.

In the foreseeable future, no other semiconductor will seriously challenge the preeminent position of silicon in VLSI applications. Silicon crystal diameters will continue to increase, but at a slower rate than in recent years. Crystals with diameters larger than 200 mm can now be grown with no special difficulties. However, the gain in productivity becomes marginal for crystals with diameters larger than 150 mm. Low temperature epitaxy process and silicon-on-insulator substrates may become important for VLSI circuits.

As wafers become larger, hot-wall tube reactors will be used extensively for film deposition. Low-pressure chemical vapor deposition (CVD) and plasma-assisted CVD may start to replace physical deposition methods such as evaporation and sputtering. It is unlikely that aluminum will be replaced as the material used for circuit interconnection. However, other highly conductive films compatible with VLSI processing (such as silicides and intermetallics) and multilevel (three or more) metallization will be used to facilitate interconnection and reduce parasitics.

Anisotropic oxidation will be used in VLSI processing to eliminate "bird's beaks" and to reduce the isolation area. Improvement in the quality of the thin gate oxide is of special importance, because the major reliability problem of VLSI chips will continue to be associated with this oxide. Low-temperature processes will be used to minimize any thermal broadening of implanted doses, and these processes can be coupled with rapid heating techniques, such as those using pulsed laser radiation, to optimize VLSI device characteristics.

VLSI pattern transfer will remain one of the major areas of intensive study in the future. Hybrid lithography will be used to take advantage of the unique features of each lithographic process to maximize throughput and minimize any registration errors. To achieve submicron linewidth control in VLSI, dry etching will become mandatory.

We expect substantial advances in global simulation of process, device, and circuit modeling. Two-dimensional and three-dimensional device and process modelings will be extended to full logic and memory cells incorporating interconnection, parasitics, and isolation regions. Any global simulation program will be user oriented so that process-device-circuit performance can be readily simulated before the device is processed or the circuit is laid out.

Reducing the cost of device testing will require an on-chip, self-testing capability. Transmission electron microscopy will be used extensively for device and process diagnostics. VLSI will also require less expensive packages to be developed. As the component density increases, the power dissipation per unit area will also increase. We expect that special considerations will be given to the thermal design of VLSI packages.

Because of the worldwide efforts in VLSI technology, we believe that most of the developments mentioned here will be realized, probably sooner than we anticipate. Many of the electronic products that will be available in 1990 may not have even been conceived of at the present time.