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New Developments in Materials and Processing Aspects of Silicon Device Technology

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The manufacturers of today's silicon integrated circuits seek constantly to produce higher density device structures having improved performance at a lower overall cost. To achieve these goals, smaller and more controlled structures are being developed and economies of scale for manufacturing are being introduced. The establishment of new processes for fabricating these improved device structures requires better understanding of the process mechanisms, better control of the materials and processes, and improved processing equipment.

The following outlines the main areas of silicon integrated device fabrication and indicates new materials and processing developments associated with each area.

Silicon Materials--The main advancement in the area of silicon materials has been the availability and use of 4-inch (100 mm) diameter silicon wafers. This increased wafer size almost doubles the chip production rate at a moderate wafer cost increase. Few technical problems have been noted.

Oxide Passivation--The addition of a chlorine species to the thermal oxidation ambient has led to improved oxide and device properties. Another improvement in oxidation process control is the use of the hydrogen-oxygen reaction system for cleaner and more reproducible steam oxidation. High pressure oxidation is also under investigation.

CVD Processing--The main improvements in chemical vapor deposition (CVD) processing have been the development of lower cost, higher volume apparatus. These include "hot-wall" techniques for the deposition of polycrystalline silicon and silicon nitride, continuous deposition reactors for silicon oxide, and plasma reactors for the low temperature deposition of silicon nitride.

Diffusion--The incorporation of ion implantation into a majority of new device structures, both bipolar and MOS, makes this technique by far the most significant development in the area of dopant control. Improvements in equipment have made ion implantation cheaper and more versatile, thus extending its economic range of use.

Metallization--The use of aluminum alloys incorporating silicon and copper has permitted the tremendous increase of packing density in integrated circuits without experiencing adverse affects such as electromigration, aluminum spiking, and other metal-related failure mechanisms. Continuing emphasis has been placed on improved metal deposition methods and equipment.

Photomasking--The largest contributing factor for successfully obtaining one million or more components per chip as predicted for 1980 will be the development of satisfactory electron beam or X-ray patterning techniques. This includes the fabrication of masks as well as possible direct wafer exposure processes. In the latter, the development of proper equipment such as projection printing or automatic alignment will be an important factor.

Packaging and Assembly--The primary current activities in areas of packaging and assembly involve achievement of improved reliability but at lower cost, even with more complex devices. Thus, plastics with improved properties are being developed, along with more automated methods of assembly.

These developments in semiconductor materials and processing techniques are being combined with newer device technologies. These include the use of various oxide isolation structures, such as Isoplanar or anodized silicon, and V-groove techniques. All are useful for obtaining higher packing densities and better device performance for both bipolar and MOS circuits.

We can then ask how much further and in what direction will silicon device technology go to achieve increased packing density, improved performance and lower cost. Also, we can ask what other technology advances can be anticipated in the near as well as distant future. It is reasonably certain, for instance, that the use of gaseous processing, e.g. plasma etching, will increase, both from conservation and cost aspects, as well as considerations involving more controlled and smaller device geometries. The answers to these questions will depend in part on the ability of materials and process scientists, in cooperation with device and design engineers, to continue the trend of the past several years in which significant advances in device processing technology have been made.