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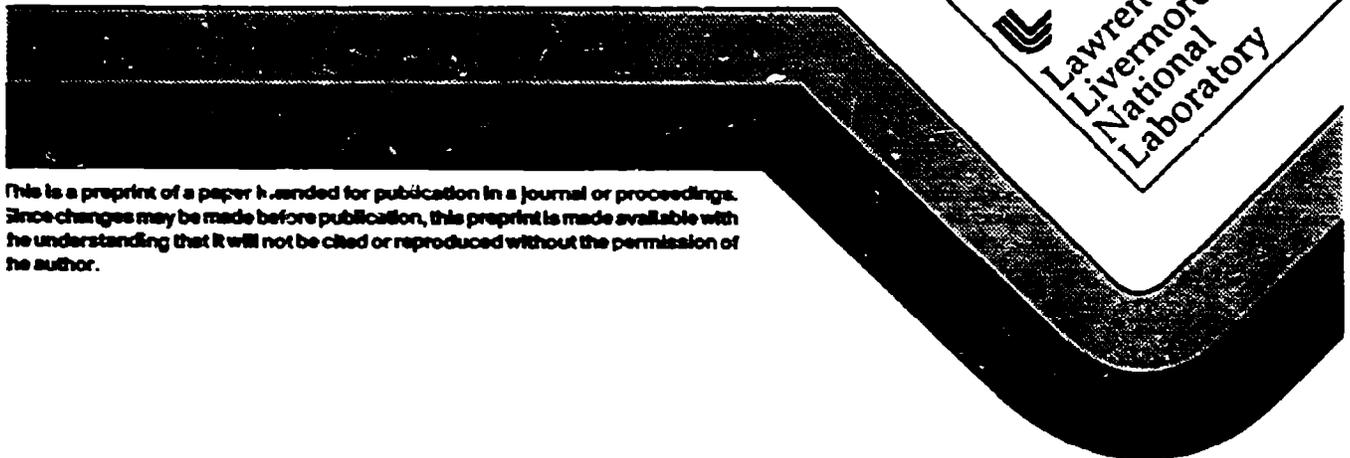
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Electrochemical Planarization for Microelectronic Circuits

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ELECTROCHEMICAL PLANARIZATION FOR MICROELECTRONIC CIRCUITS

A Significantly Improved Process

Need for Flatter Surfaces

The need for flatter and smoother surfaces (planarization) in microelectronic circuits increases as the number of metal levels in ultra large scale integrated (ULSI) circuits increases. The flatter—or more planarized—each layer of material is, the more layers that can be made. More layers yield a denser circuit wiring, a higher final product computation speed, and a less expensive final product, due to a lower number of defects.

Electrochemically Flatter Is Easier and Less Expensive

We have developed an electrochemical planarization process. It first involves the uniform blanket metal electroplating over an insulating layer having embedded conductor lines. The next step is to remove the metal very uniformly, leaving behind embedded conductors that have their top surfaces level with the top surfaces of the surrounding insulator layer. This step has conventionally been carried out by a process called chemical-mechanical polishing (CMP). In CMP, the excess electroplated metal, along with the insulating material, is mechanically polished away (aided by simultaneous chemical etching) until the embedded conductors remain.

At LLNL, we have developed a significantly improved process and apparatus using electropolishing to smoothen and remove the metal layer very uniformly across the surface of the sample. A sample coated with copper is placed in a viscous acid bath, rotated, and an electric current is applied between the sample (positive connection) and the counter electrode (negative connection). Copper is removed from the surface of the sample in an "electropolishing mode," which smoothen the surface. The polishing results from a microscopic preferential removal of metal from more exposed areas. On a macroscopic basis, the material is removed uniformly. When finished, the surface copper becomes mirror smooth.

Applications

- ◆ Planarization of electronic circuits at ULSI level
- ◆ Planarization of electronic circuits at the packaging level
- ◆ Uniform metal thinning and planarization on other substrates such as optical components (mirrors, thin windows), metal samples for scanning electron or scanning transmission electron microscopy
- ◆ Uniform, selective removal of coatings on semiconductors or other substrates.
- ◆ Low-cost optical mirrors on nonsmooth substrates

Our Process Details

We have developed an electrochemical planarization process that fills vias and trenches with metal (without voids) and subsequently planarizes the surface. We make use of plasma-enhanced chemical vapor deposition (PECVD) of SiO₂ for the dielectric layers (although polyimide also works satisfactorily) and electroplated copper for the metalization. Our electroplating tools produce low-resistance (<1st $\mu\text{ohm-cm}$) conductors and are low in cost and maintenance compared to vacuum metalization equipment. Blanket electroplating completely fills the trenches and vias and partially planarizes the surface. Electropolishing further planarizes the surface down to a thin (1000-5000 Å) metal layer. Finally, either an ion-milling or a wet-etch process removes the remaining metal. The process can be repeated as necessary for multilevel metalization.

Advantages Over Existing Products

- More accurate endpoint determination
 - a) Visually by eye
 - b) By measuring the amount of charge passed through the sample
 - c) Colorimetrically by detector

- Easily adaptable to robotic handling
- Easily adaptable to assembly line type manufacturing
- Better uniformity of metal polishing removal
- Virtually infinite selectivity of metal over insulator removal
- Less expensive capital costs
- Electropolisher machine weight is about one-eighth of conventional polishing machines

Open for Collaboration

The Laboratory is seeking an organization interested in collaborating on further improvements for this and related technologies.

Previous Technology Transfer

We transferred our electropolishing technology and a new machine to IBM, which is investigating

the use of the machine and electropolishing process for planarization. Transferring this technology to industry earned us the prestigious 1992 Excellence in Technology Transfer Award from the Federal Laboratory Consortium, which recognizes distinguished work of significant value to U.S. industries. 

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Electroplated



10µm



Electropolished



Planarization of different width conductors

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