Polyimides in Hybrid Circuit Processing

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The use of polyimides in the manufacture of hybrid circuits is increasing. These organic compounds are suited to thick and thin film applications because of their ability to be patterned, and desirable mechanical, chemical, thermal and electrical properties. Specifically, polyimides are used as dielectric and planarization materials in multilayer hybrid circuits, and for passivation layers and alpha particle barriers.

The advantages

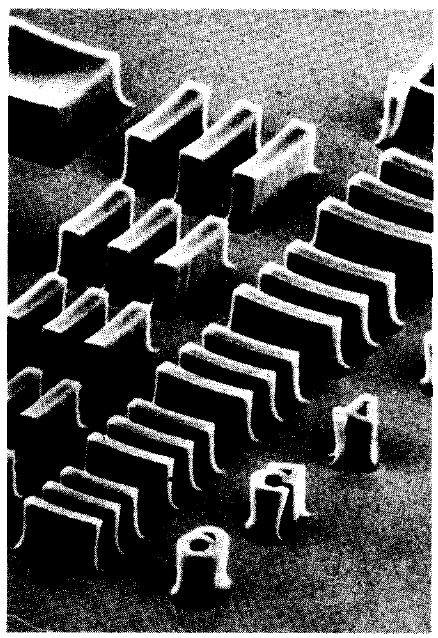
Compared to conventional inorganic dielectric and passivating thin films, which are deposited by chemical or physical vapor deposition (CVD or PVD), polyimides are generally less costly, easier to use and provide more process flexibility.

- Common photoresist processing equipment is suitable for polyimides. This provides a significant savings over the capital required for CVD or PVD processing.
- A polyimide film can accept a subsequently sputter-deposited or plated thin film without damage to the polyimide film. Vertical or tapered walls (Fig. 1) can be obtained enabling control of subtractive, additive or semiadditive thin film hybrid circuit manufacturing techniques. And the processing of polyimides is done at 300°C to 400°C, which is lower than typical 800°C CVD requirements.
- Recently introduced, ready to use, prefiltered photosensitive formulations have simplified polyimide processing. Processing steps and handling techniques are equivalent to those commonly used for photoresists (Fig. 2); a photoresist technologist can convert to polyimides easily, without extensive research. In addition, polyimide processing does not require dangerous gases or chemicals.

Dielectric and planarization

As an interlayer dielectric, a polyimide can be used to form a crossover structure or to build full multilayer structures with via holes.

In microwave hybrid circuit applications, for example, polyimides are used



1. Perpendicular walls, looking as if they were ion etched, have been obtained through wet development of a negative acting photosensitive polyimide. *(Patterns shown in Probimide from CIBA-Geigy.)*

to form a dielectric bridge ("crossover") onto which structures which act as wire bonds are deposited. The crossover provides excellent repeatability in deposited "wire" length and location, which is required in circuits operating at millimeter wavelengths. The polyimide process is advantageous because it provides low inductance bridges with the consistent impedance attainable via linewidth thickness control. Polyimides are useful for these applications at the high frequencies used because they exhibit a low loss tangent (0.0030) and low dielectric constant when fully cured.

Also, polyimides have consistent electrical characteristics, good thickness repeatability (±0.2%) and are "self planarizing" even when working with four layers (a difficult accomplishment with more than two layers of silicon dioxide). Etching of polyimides, without capital intensive techniques, is easily controlled to obtain linewidths down to 1.5 μm and high aspect ratios (Fig. 1).

Comparing the coefficient of expansion between metals and polyimides with the conventional use of metals and inorganic dielectrics, polymers typically are better able to cope with thermal stress without cracking or loss of adhesion.

Polyimides have proved also to be useful when used for the planarization of high-speed digital interconnects. Planarization helps control impedances and the location of conductors in three-dimensional structures.

The natural flow of polyimides helps planarizing because of its viscous nature. This method is inherently simpler for planarizing circuits than biased sputtering of quartz.

Passivation and barriers

Polyimides can also be used to passivate resistive thin films on hybrid circuits; the chemical and thermal stability of polyimides protects corrosion-sensitive films. A layer of polyimide, defined with photolithography, provides an inexpensive passivation and yields resistors with long-term chemical stability and reliability. Furthermore with a polyimide passivation, nichrome can be used as the resistive material; better circuit characteristics can be obtained with nichrome resistors than with tantalum nitride resistors. Polyimides are compatible with the stabilization bake used in resistor fabrication processing, and therefore, allow the fabrication of superior resistors, a feat difficult to equal with other techniques.

Polyimides are also used for alpha protection in hybrid packages containing arrays of sensitive memory devices. This application is similar to semiconductor packaging alpha particle protection.

Future directions

The developers of polyimides for the microelectronics industry have indicated that further improvements are on the way. These will likely include sensitized material or dry development in a plasma similar to some of the newer experimental photoresists.

Polyimides are also playing a role in the development of interconnect concepts for modular wafer integration (a form of hybrid circuitry). Here the material can provide a wafer-integration-like increase in speed performance and miniaturization of computer digital circuitry. □

2. Similar to photoresists, polyimides can be processed with wet or dry etching techniques. The recent introduction of photosensitive polyimides has reduced the number of process steps required.