

## Tutorial 75 - - June 2007

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### Unique Polished Polyimide Substrate

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A unique polished polyimide substrate for electronic packaging applications combines the advantages of a low dielectric constant flexible substrate with the flatness, smoothness and fine patterning capability of a wafer. It has excellent dimensional stability, very low water absorption, and high-temperature stability.

The substrate is made of pure, unfilled polyimide insulator with a mirror surface finish. The fabrication process yields a semi-crystalline polyimide boule or "ingot", which is sliced and polished to yield bulk disks with an average surface roughness of 3 - 5 nanometers. Wafer dimensions are similar to silicon wafers, 2", 3", 4", 6" and 8" diameter and standard thickness 0.5 mm. Thinner and thicker wafers are also available. Figure 1 shows a finished wafer.

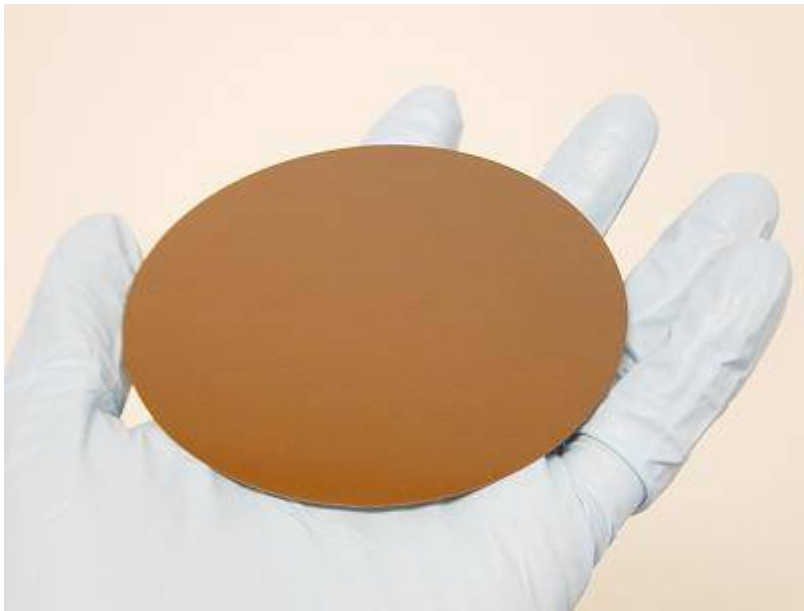


Figure 1. Polyimide substrate.

Processing with thin film technology creates circuits with micron size features. Cladding with sputtered chromium and titanium films followed by electroplating with gold showed excellent adhesion and no contamination of vacuum equipment. The films were patterned to create 2 $\mu$ m lines and spaces.

Densely packed vias can provide several thousand vertical electrical connections per square

inch. Laser ablation creates 40 $\mu$ m diameter via holes on 100 $\mu$ m pitch. The high aspect ratio vias can be metallized using electroless plating. The vias can also be etched using deep reactive ion etching (DRIE), and filled by electroplating.

The thermoset polyimide material is very temperature resistant, retaining most of its mechanical, physical and thermal properties and dimensional stability at high temperature. It can operate continuously at 300°C in air and upwards of 500°C in inert environments or for shorter durations. It retains its shape after pyrolyzing at 1000° C.

Dimensional variations were less than 0.04% after cycling from 23°C to 260°C for two days. 30 minutes at 500°C in air showed no dimensional changes. The coefficient of thermal expansion is constant over a wide temperature range.

The polyimide has a moisture absorption rate of 0.24% at 100% RH after 24 hours immersion, less than 1/10th the water absorption rate of Kapton. A higher grade of the polyimide absorbs only 0.08% over the same period, 1/30th that of Kapton. The polyimide has very good hermeticity, replacing ceramics in some hermetic applications. It has also replaced metals in some mechanical applications because it does not require lubrication.

### Packaging Applications

The packaging advantages of the polyimide substrate are its flexibility and thinness, which minimize the stresses in ultra-thin films. (Figure 2) It can be easily micro-machined with laser and by dry etching. Handling and processing is similar to silicon wafers. The polyimide wafer is compatible with wafer level and chip scale packaging (WL-CSP) and can withstand BCB curing temperature.

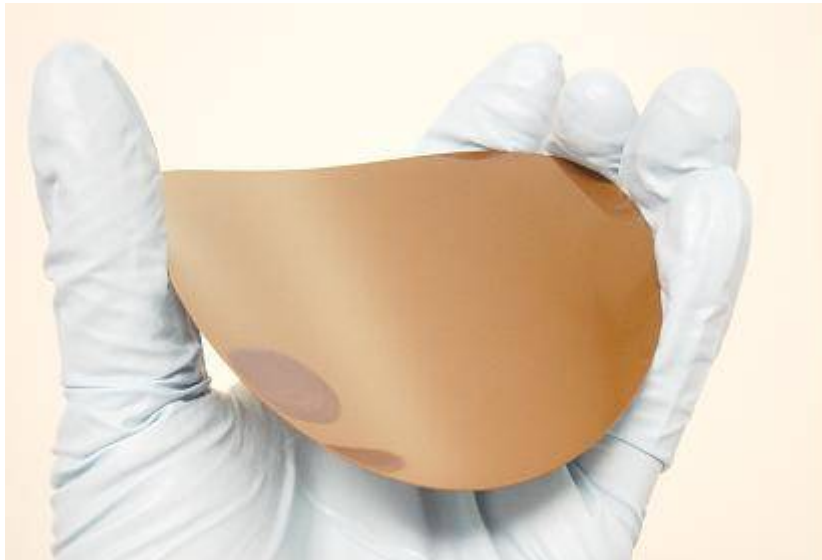


Figure 2. Polyimide substrate flexibility.

Applications include:

- Packaging silicon layers and multi-chip modules (MCMs) in high-density high-speed interconnects.
- Stacking several layers of metallized polyimide wafers provides high-density 3-D interconnects. The multi-layer stack preserves the smoothness and planarity in every layer.
- Interconnecting with low dielectric constant, high speed, high connection density substrates for 3-D System-in-Package and Package-on-Package applications.
- Bonding to silicon and glass wafers by adhesiveless fusion bonding or with adhesives

such as BCB or epoxies.

- Transferring working circuit layers from an SOI wafer to the polyimide wafer.
- Separating a silicon wafer and a glass wafer for packaging MEMS micro-mirror displays.
- Transferring silicon circuit layer with metal line interconnects to the polyimide wafer.

US Patents No. 6,563,998 and 6,807,328 cover the polyimide wafer. US and international patents are pending.



Figure 3. Polyimide substrate flexibility.

## PROPERTIES

### General

The substrate does not melt at any temperature. It retains most of its excellent mechanical, physical and thermal properties over a broad range of temperature. It has high chemical resistance to many substances. It is more ductile (has higher impact resistance) than ceramics and is lighter than metals, and can replace them in some high-temperature applications.

### Mechanical Properties

Tensile strength 86.2 MPa @ 23C 41.4 MPa @ 260C

Elongation 8%

Flexural strength 110 MPa @ 23C 62.1 MPa @ 260C

Flexural modulus 3.10 GPa @ 23C 1.72 GPa @ 260C

Poisson's ratio 0.41

### Thermal Properties

Coefficient of thermal expansion  $50 \times 10^{-6}$  m/m/C over 23 – 260°C temp range

Thermal conductivity 0.35 W/mC

Specific heat 1130 J/kg/C

Deflection temperature 360 C

Dimensional stability @ 260C < 0.04% change from original dimensions after cycling from 23C to 260C over a two-day period

### **Electrical Properties**

Dielectric constant @ 23C 3.2 – 3.5 @ 100 Hz – 1 MHz

Dissipation factor 0.001 – 0.003 @ 1 GHz – 10 GHz

Dielectric strength 23 MV/m

### **Physical Properties**

Average surface roughness < 5 nanometer

Specific gravity 1.34

Water absorption (base polyimide) 0.23% after 24 hours immersion

(higher grade) 0.08% after 24 hours immersion

### **Optical Properties**

Index of refraction 1.67

### **Dimensions**

Diameters: 2, 3, 4 and 6 inches standard. Larger or square wafers special order.

Thickness: 500µm (20 mils) standard. Thinner to 150µm or thicker special order.

Thickness Tolerance: Plus or minus 12.5 µm.

Total Thickness Variation: 5µm. Single or double side polishing available.

### **FOR MORE INFORMATION**

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