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Avatrel™ Dielectric Polymers for HDP Applications

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In order to realize the performance advancements in silicon technology, complementary advances in packaging technology are necessary. Advance materials must be developed to achieve the full potential of advance packaging processes. A family of dielectric polymers based on polynorbornene is under development to address the broad needs of high density packaging (HDP). Properties common to this family of materials include a low dielectric constant, low loss tangent, low moisture absorption, good adhesion, and isotropic properties. This family's tailorability allows materials to be developed for a number of applications including wafer redistribution, passivation, sequential, and parallel build-up processes.

Key words: low dielectric constant, low moisture absorption, polynorbornenes, Avatrel™ Dielectric Polymers

INTRODUCTION:

The electronic industry's requirement for speed, miniaturization and lower costs is driving the need for advancement in silicon or wafer technology. These advancements have created a concomitant need for performance improvements in the packaging arena to ensure that the full benefits of silicon technology are realized. New materials are required by the packaging industry to produce products capable of capitalizing on the high density interconnection resulting from higher speed and smaller products. The development of higher performance dielectric materials is a major key to the continued advancement of packaging technology. This higher performance must also be achieved while continuing to lower the packaging cost.

A new family of materials, functionalized polynorbornenes, are being developed and commercialized by BFGoodrich under the trade name Avatrel™ Dielectric Polymers. This family of materials can fulfill the requirements of a wide range of dielectric applications in High Density Packaging (HDP) and Multichip Modules (MCMs).

Specific areas of highly active development include wafer redistribution, passivation, sequential, and parallel build-up processes.

INHERENT PROPERTIES:

Polynorbornene (PNB) has a number of inherent properties very suitable to microelectronics applications. The bi-cyclic hydrocarbon backbone yields a material with a high glass transition temperature (Tg) and very low moisture absorption. The Tg is important, since it typically determines the maximum processing temperature that a material can withstand.

Low moisture absorption is critical for a number of reasons. Since water is a poor insulator, having a dielectric constant (ε^*) of 78, any water absorbed into a dielectric material would certainly degrade its insulating properties. Corrosion can also be a direct result of water absorbed into a dielectric material. Therefore, a material with very low moisture absorption aids device reliability.

Low moisture absorption also aids in processing. Since changes in humidity influence the dimensions of a material in direct proportion to its moisture absorption, a substrate constructed of a low

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moisture absorption material will exhibit reduced dimensional fluctuation with changes in humidity. A reduction in dimensional fluctuation will increase alignment yields and decrease cost associated with controlling the humidity. Throughput can also be increased due to the decreased in time necessary to allow the substrate to equilibrate before alignment operations.

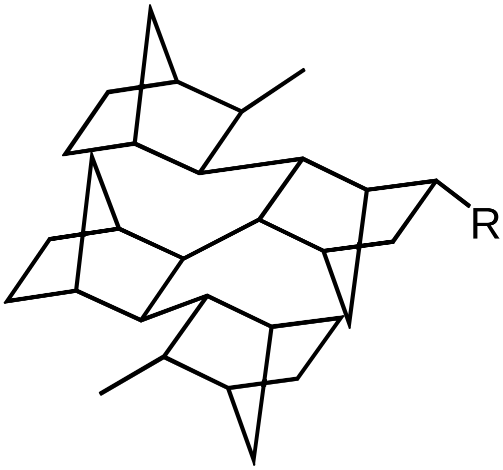

Figure 1. chemical structure of polynorbornene with functional group.

TAILORABILITY:

Because of a novel catalysis system developed by BFGoodrich, the polymer properties can be radically tailored to fulfill the needs of individual applications. The primary means of tailoring the polymer composition is by varying the "R-Group", which represents a functional group attached to the polymer backbone. Monomers with different functional groups are randomly copolymerized to form the final material. The types and ratios of monomers used dictate the material properties.

In order to produce the proper balance of properties, typically a combination of monomers from several different categories are utilized. For example, varying the length of an alkyl functionality attached to the backbone controls the modulus and Tg. Table I shows the effect of different chain lengths on both the modulus and on wafer stress at room temperature. Anhydride, ester, and epoxy functional groups can be used to promote crosslinking and to modify solubility characteristics. Polar functionality, epoxy and triethoxysilyl groups, is used to engender adhesion to metals, silicon, and oxides.

Due to polymer architecture, a small amount of a polar functionality such as a triethoxysilyl group significantly effects adhesion. For example, a norbornene homopolymer is devoid of reactive functionality. Therefore, it does not stick to metals, but the addition of a small fraction of triethoxysilyl groups allows greater than 4 pounds per inch Cr/Cu peel (90^o).

Table I: Correlation between length of alkyl chain attached to norbornene and thermo-mechanical properties of polymer.

Alkyl Chain Length	Tg (^{o}C)	Modulus (GPa)	Stress on Silicon (MPa)
4	330	1.0	19
6	225	0.5	10
10	180	0.15	3

From this flexible system, products for several different application areas are in various stages of development.

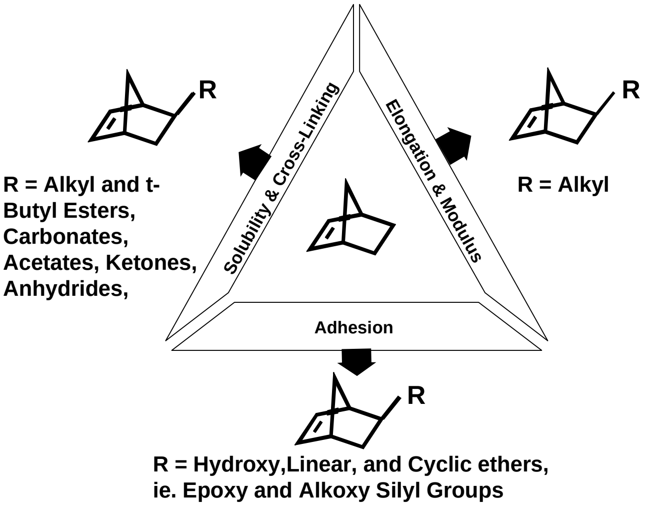

Figure 2. Listing of polynorbornene functional groups and respective roles.

APPLICATIONS:

By appropriately tailoring the polymer through functionality and formulation, functionalized polynorbornenes have been developed which are suitable for passivation, build-up on laminate including build-up applications utilizing conductive paste from Ormet Inc., multi-chip and wafer level packaging.

Passivation:

Avatrel™ Dielectric Polymer for Passivation has been developed for passivation applications on laminate, polyimide, and silicon substrates. This material has a glass transition temperature of 330^{o}C and a modulus of 1 GPa. Figure 3 provides a graphical representation of these thermo-mechanical properties. The high glass transition temperature allows for high temperature processing. The moderate modulus limits the stress imparted on the system by the polymer. Another result of product tailoring is the materials elongation to break value of 20%, which is a demonstration of mechanical robustness.

Avatrel™ Dielectric Polymer for Passivation applications has a dielectric constant of 2.55, a loss tangent less than 0.002. These electrical properties hold constant to above 1 GHz.

For passivation applications, Avatrel™ Dielectric Polymer can be deposited using typical processes such as spincoating, meniscus coating, or solvent extrusion. The final properties are generally independent of cure conditions, because Avatrel™ Dielectric Polymer is delivered fully polymerized, instead of polymer precursors or short chain oligomers. The curing simply imparts solvent resistance through light crosslinking.

This version of Avatrel™ Dielectric Polymer is delivered out of a hydrocarbon solvent, mesitylene. Planarization is typically 40 to 70% depending on feature size. The low moisture absorption, 0.1%, provides excellent environmental protection to the underlying circuitry.

Currently, this material can be patterned using laser ablation or reactive ion etching. Photodefinable formulations have been demonstrated and are under active development.

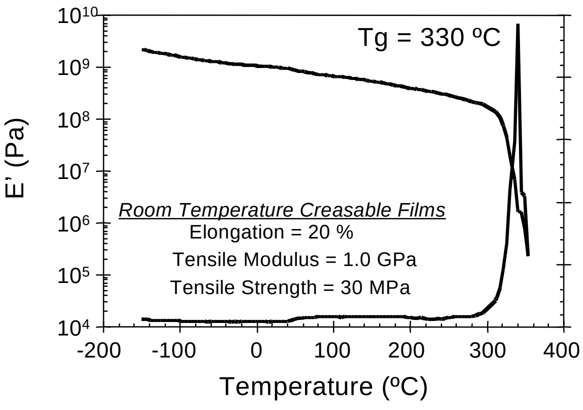

Figure 3. Mechanical properties of polynorbornene with butyl-functionality.

Wafer Redistribution:

Because of functionalized polynorbornene's inherent properties and high degree of tailorability, they are being developed to aid the advances in wafer redistribution. A high Tg, low moisture absorption, low dielectric constant, and low stress when coated on silicon make functionalized PNB a good material for wafer redistribution.

Another requirement for most wafer redistribution applications is that the dielectric material be photosensitive. BFGoodrich is currently working actively with Georgia Tech and industry partners to optimize a photosensitive version for wafer redistribution applications. Our current system is negative acting and developed with an environmentally "friendly" solvent from the terpene family.

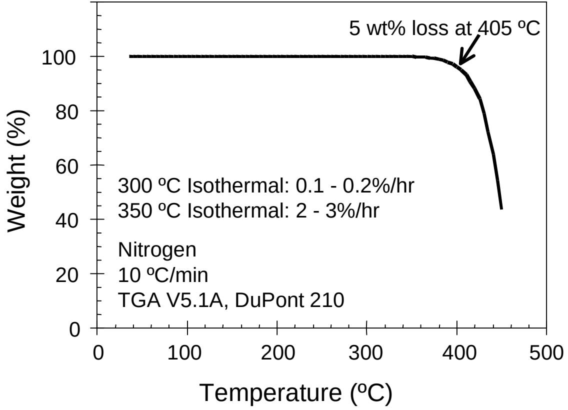

Figure 4. TGA of Polynorbornene.

Build-up:

Avatrel™ dielectric polymers are being developed for a number of build-up approaches. For sequential approaches, Avatrel™ Dielectric Polymers are being optimized in liquid form. Although semi-additive metallization schemes are of primary focus, Avatrel™ Dielectric Polymers have successfully been used with a fully additive metallization process involving screen-printable conductive paste from Ormet Inc.

Parallel processing schemes are also being developed. In these applications freestanding films would be processed separately and then laminated together at the end to form a complete package. These freestanding films could be unreinforced or reinforced. The mechanical robustness, low dielectric constant, low loss tangent, and extremely low moisture absorption of Avatrel™ Dielectric Polymers are critical properties to his application area.

Dielectric patterning for build-up applications can be accomplished by laser ablation with either an UV or infrared laser source. A via created by a tripled YAG laser (355 nm) in Avatrel™ Dielectric Polymer is shown in Figure 5.

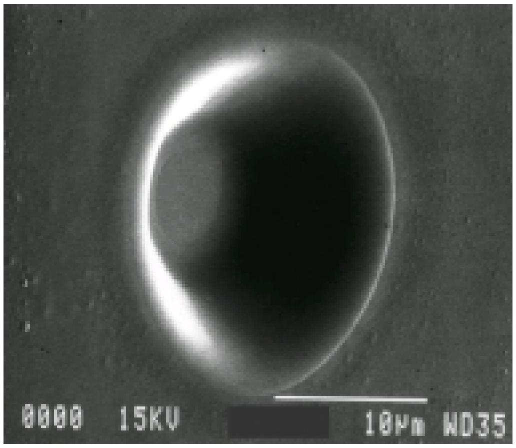

Figure 5. Laser drilled via in Avatrel™ Dielectric Polymer. Created with a 3X YAG courtesy ESI.

Conclusions

Polynorbornenes have inherent properties suitable to high density packaging. The ability to polymerize a variety of functionalized polynorbornenes allows materials to be developed for a number of applications. Areas of active development include wafer redistribution, passivation, sequential, and parallel build up.