## Polymer Composites with Enhanced Thermal Conductivity:

This research is funded by Honeywell Corporation and the Florida High Tech Corridor. The purpose is to develop polymeric composites used as underfills in fiber optic gyros. The composites must exhibit high thermal conductivity (TC), cure with a minimal or, no exotherm, resist dissolution and function at temperature extremes. Boron nitride is a typical filler for these systems, as it has excellent thermal conductivity, 250-300 W/mK (49). We have found that inexpensive diamond material is available; this filler has a thermal conductivity > 1,500 W/mK (50).

Earlier work with Honeywell focused on the development of boron nitride/epoxy composites. We produced some moderately effective systems and this broadened our insight into the problems encountered with thermal management materials. As a result, we turned our attention to systems that are more effective and more easily processed. We are developing novel underfills based polymerization cyclic butylene terephthalate monomers (51). We are the only group that we are aware of that is using these materials for underfills. The cyclic PBT monomers, unlike commonly used epoxies, do not exotherm upon polymerization. This eliminates a significant problem encountered with epoxy systems, since, high polymerization exotherms destroy solder joints on the circuit board. The polymerization scheme is given in fig. 14.

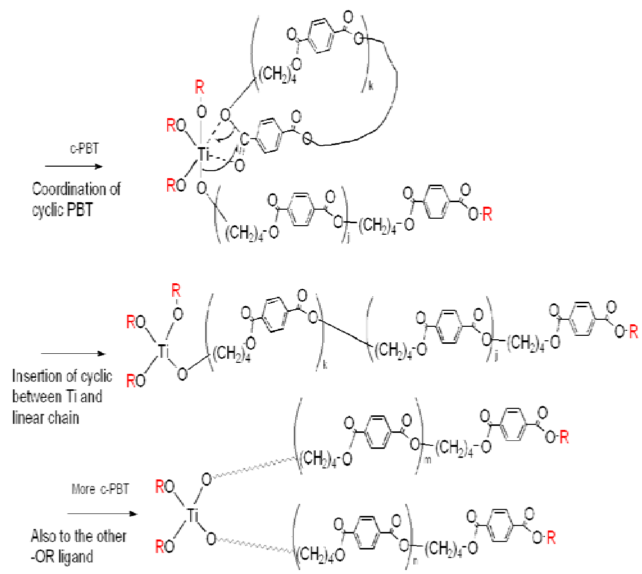


Figure 14

Another group examined the use of PBT in underfills, but the fillers were compounded into the polymer base (52). Since compounding breaks the filler particles TC's were quite low. The cyclic monomers that we used exhibit ultra-low viscosity when melted. This means that high amounts of fillers can be added to the system without processing problems.

The cyclic monomer material was melted and filled with 40 wt %. boron nitride. We applied a vacuum under heat and were able to draw the material through 7 mil copper spacers added to simulate the thickness of the solder (Fig. 15). The temperature was increased and curing ensued. Encouraging results prompted Honeywell, Inc to file a patent application with us (53).

The target thermal conductivity for an efficient underfill is 1.3 to 4 W/mK in the plane of the sample. (54). One of our 40% diamond composites, tested by Cool Polymer, Inc. in Warwick. Cool Polymers measured a value of 4.21 W/mK in the plane of the specimen; this exceeded our expectations. The highest value that we have seen recorded in the literature, estimated from a plot of thermal conductivity versus filler content, was just under 4 W/mK (55).

We published a detailed study characterizing the thermal and mechanical properties of these systems (51) .Our current and future work focuses on the mechanism of heat transport in these materials. Phonons transfer heat in nonmetal materials and any phonon scattering will decrease heat transfer efficiency. Xu et. al. (56) discussed three methods of decreasing phonon scattering, forming conductive filler networks, increasing the size of the filler, and minimizing flaws at the filler-polymer interface. We are pursuing the use of nanofillers to form conductive filler networks.  Some recent interest in this topic has appeared in a patent application (57).

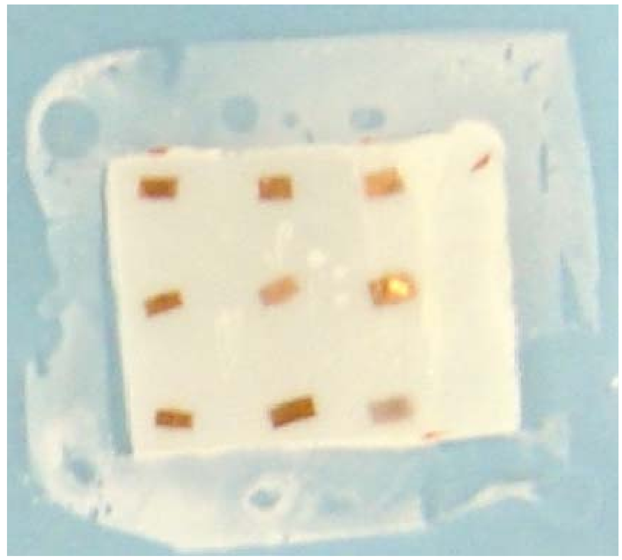

Figure 15: An image of an underfill prototype

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