IOWA STATE UNIVERSITY

Materials Science & Engineering Department

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Final Oral Examination
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"Multifunctional polymer composites containing inorganic nanoparticles and novel low-cost carbonaceous fillers"

Advanced polymer composites containing inorganic nanoparticles and novel carbonaceous fillers were processed and evaluated for the multifunctional purposes.

To prepare the high performance conformal coating materials for microelectronic industries, epoxy resin was incorporated with zirconium tungstate (ZrW_2O_8) nanoparticles synthesized from hydrothermal reaction to alleviate the significant thermal expansion behavior. Three types of ZrW_2O_8 at different loading levels were selected to study their effect of physical (morphology, particle size, surface area, *etc.*) and thermal (thermal expansivity) properties on the rheological, thermo-mechanical, dynamic-mechanical, and dielectric properties of epoxy resin. Epoxy resin incorporated by Type-1 ZrW_2O_8 exhibited the overall excellent performance.

Hexagonal boron nitride (h-BN) nanoplatelets were non-covalently encapsulated by a versatile and mussel-adhesive protein polydopamine through the strong π-π* interaction. The high-temperature thermoset bisphenol E cyanate ester (BECy) reinforced with homogenously dispersed h-BN at different volume fractions and functionalities were processed to investigate their effect on thermo-mechanical, dynamic-mechanical, dielectric properties and thermal conductivity. Different theoretical and empirical models were successfully applied for the prediction of CTE, thermal conductivity and dielectric constant of h-BN/BECy nanocomposites. On the basis of the improvement in dimensional stability, the enhancement in storage modulus in both glassy and rubbery regions, associated with the increment in thermal conductivity without deterioration of thermal stability, glassy transition temperature and dielectric properties, pristine h-BN/BECy nanocomposites exhibited the prospective application in microelectronic packaging industry. Polydopamine functionalized h-BN significantly increased the dielectric constant of cyanate ester at lower frequency region.

Asphaltene, a carbonaceous by-product of crude oil extraction, was studied as a novel and low-cost additives in polymer matrices. Two kinds of asphaltene were extracted and investigated using different analytical techniques for the comparison of their elemental composition, molecular structure, and morphology. One asphaltene underwent the successful molecular functionalization *via* two silane coupling agents prior to the preparation of epoxy composites. Another asphaltene was incorporated into poly(styrene-butadiene-styrene) copolymers (SBS) for the fabrication of hybrid composites using melt compounding technique. Based on it intrinsic rigid molecular structure, the reinforcement effect of asphaltene was recognized to be more pronounced in a softer matrix (SBS) than the rigid one (epoxy).