

Waterborne Nanocomposite Pressure-Sensitive Adhesives: Achieving Enhanced Adhesion Combined with Electrical Conductivity

Tao Wang, Chun-Hong Lei, Alan B. Dalton and Joseph L. Keddie*

Department of Physics, School of Electronics and Physical Science, University of Surrey, Guildford, Surrey GU2 7XH, United Kingdom

José M. Asua and Mihaela Manea

The University of the Basque Country, Institute for Polymer Materials (POLYMAT), San Sebastian, Spain

Pressure-sensitive adhesives (PSAs) adhere instantly and firmly to nearly any surface under the application of light pressure, without covalent bonding or activation. PSAs are increasingly used for demanding applications, such as interconnects in electronic assemblies, which require electrical and thermal conductivity coupled with good adhesive properties. The debonding of PSAs occurs by a cavitation process followed by cavity expansion to create fibrils that extend in traction. These processes contribute to the energy of adhesion, E_a . To be an effective PSA, a material must be neither too stiff nor too liquid-like, so that it will dissipate significant energy in deformation.

Here, a nanocomposite PSA was created from waterborne colloidal dispersions of poly(butyl acrylate) (P(BuA)) and single-wall carbon nanotubes (SWNTs). In order to disperse the SWNTs in water, they were functionalised with poly(vinyl alcohol) (PVA). The percolation threshold of the PVA-SWNT is found near a concentration of 0.3 wt.% (on the polymer), around which point the electrical conductivity increases by ten orders of magnitude. Also at this threshold, abrupt changes in the adhesion characteristics are observed, as found with probe-tack measurements. The amount of strain at failure in the nanocomposite PSA is greater by a factor of two compared to the pure latex PSA. Likewise, the adhesion energy increases by about 85% with the addition of PVA-SWNTs at the same concentration. Using experimental values for the elastic modulus and yield stress of the nanocomposite, a scaling theory for adhesives predicts a maximum in adhesion energy at around 0.3 wt%, which is consistent with experiments. Because of the relatively low percolation threshold, the electrically conducting PSAs are optically transparent.

The effect of the PVA-SWNTs on the mechanism of the de-bonding process can be explained in the light of recent models of cavitation and fibrillation, coupled with optical observations of the de-bonded surface. Nanocomposite PSAs are stiffer but more dissipative of mechanical energy, contributing to stronger and stable fibrils which are critical for high performance PSAs. This nanocomposite PSA offers many attractive characteristics, including ease of processing, no organic solvent emission, high electrical and thermal conductivity, increased adhesion energy, and optical clarity.