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Drying and Microstructure of Monodisperse Latex/Ceramic Nanoparticle Coatings

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The properties of coatings prepared from suspensions of latex and functional ceramic nanoparticles depend on the distribution of ceramic particles in the coating microstructure. Drying conditions can greatly affect the distribution. In this research, coatings with a special microstructure were prepared from a dispersion of large, monodisperse latex (550 nm diameter) and nanosized ceramic (~10 - 50 nm diameter), and then dried at 60°C in a convection oven. This unique coating has a surface consisting of an ordered packing of latex particles with ceramic nanoparticles uniformly filling their interstices, and a cross-section consisting of nanoparticles preferentially located in upper portion of the coating with a compacted latex structure beneath. Such a microstructure has the advantages of a functional, ceramic-rich surface and good adhesion to substrates.

The distribution evolution of large latex particles and nanoparticles during drying was investigated by cryogenic scanning electron microscopy (cryo-SEM) technique. Cryo-SEM images of coatings dried for different times reveal the sequence of events that leads to the ordered, gradient microstructure during drying. The microstructure formation mechanism was postulated as: (1) packing of latex particles into ordered rafts with formation of curved menisci between packed latex particles at the top surface, (2) formation of a layer of consolidated latex particles at the top surface, (3) convective transport of ceramic nanoparticles toward the surface through the interstices between the latex (in response to capillary pressure) concurrent with the accumulation of latex to the consolidation front, (4) accumulation of nanoparticles in interstitial spaces among the top layer of latex particles, (5) the growth of the consolidation front until it reaches the substrate, and (6) deformation and compaction of latex particles throughout the coating.

The microstructure forms when the monodisperse latex is large enough to create pore channels for the transport of nanosized particles, the interactions between particles are dominated by repulsion, and the drying conditions favor “top-down” drying. Effects of drying condition, glass transition temperature of the latex, nanoparticle size, and as-deposited coating thickness on the microstructure formation were investigated. These indirect evidences support the proposed mechanism. The simple preparation method works with a variety of nanoparticles.