Drying Regime Maps for Particulate Coatings

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Particulate coatings are commonly used for applications such as paper coatings and functional layers in fuel cells and batteries. The properties and performance of particulate coatings depend on their microstructure. Hence, characterizing the particle distribution through the thickness of a coating during drying leads to useful information for microstructure design. Past researchers have modeled the competitive effects of evaporation and diffusion, and evaporation, diffusion and convection induced by Marangoni effects on the distribution of particles during drying.[1,2] In this research, the 1D conservation equation for the drying of particulate coatings, including diffusion, evaporation, and sedimentation, is used and solved using COMSOL. The effect of particle concentration on diffusion and sedimentation[3,4] is included. From the results, drying regime maps are constructed.

To draw drying regime maps, two dimensionless variables, Pe, and Gr, are used, and accumulation zones are noted. The Peclet number, Pe, describes the strength of evaporation vs. diffusion of the particle, and the gravity number, Gr, is the rate of sedimentation divided by the rate of evaporation. A drying regime map is divided into three parts – evaporation, sedimentation, and diffusion dominant regions. As Gr is increased, at constant high Pe, there is a transition from the evaporation region, where particles tend to accumulate at the free surface, to the sedimentation region, where particles tend to accumulate at the base. In the diffusion region, particles are uniformly distributed during drying. Regions where the particle concentration reaches 99% of maximum packing fraction in less than half the time for the entire coating to reach that concentration are noted as accumulation zones. If particles accumulate at the free surface, a well packed particle 'skin' is formed. Accumulation at the base forms a 'sediment'. The drying regime maps were compared to experimental studies, using cryogenic-SEM, that were designed to capture the transient particle distributions during drying.

References:

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