UNH Materials Science Seminar

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DeMeritt Hall 240
University of New Hampshire

Lessons learned while watching paint dry: film formation, drying fronts, and cracking

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Several technologies depend on the removal of solvent from a thin film of fluid containing colloidal particles to create a continuous coating, with tape casting and architectural coatings being the most familiar. Once the surface is coated with the dispersion, the process is driven by mass transfer limited evaporation, which generates surface tension driven flow toward the edges of the film. Eventually enough solvent is lost to create a close packed layer of particles. Further evaporation produces a capillary pressure that either deforms the particles and closes the voids or pulls the air-water interface into the layer. In some cases the lateral stresses generated in the packed bed by capillary pressure causes cracks to appear, nucleated either in the bulk or at the edge of the film.
The phenomenon is amenable to relatively simple experiments in which the film dries either due to normal evaporation on a cantilever, which deflects in response to the lateral stresses, or under pressure in an ultrafiltration cell, with water ejected through a membrane. The former experiment reveals non-uniform drying for latices that form films and remarkable flows and cracking for those that do not. The latter experiment provides uniform consolidation and permits definitive characterization of the cracking phenomena. We interpret the results through fundamental models that incorporate all the relevant flows as well as the nonlinear viscoelastic deformation of spheres in contact and capture the drying fronts and cracks observed and the stresses detected with the cantilever. Comparison of the data with expectations from theory confirms that cracking is controlled by elastic recovery, though an energy criterion only provides a lower bound. Our experiments also identify the role of flaws as nucleation sites that initiate cracks.

Dr. Russel is A.W. Marks ‘19 Professor and Dean of the Graduate School at Princeton University. He received a B.A. and an M.Ch.E. from Rice University in 1969, and his PhD from Stanford University in 1973. Prof. Russel has received many awards and honors, including Award for Surface and Colloid Chemistry (2007) from American Chemical Society, Bingham Medal (1999) from Society of Rheology, William H. Walker Award (1992) from American Institute of Chemical Engineers, and visiting professorship at University of Utrecht (2001) and University of Wisconsin (1984). He was elected to American Academy of Arts and Sciences in 1995 and to National Academy of Engineering in 1992.

Host: Professor Don Sundberg x1878