

CRACK PREVENTION IN SOFT LATEX COATINGS

C. C. Roberts (*) and L. F. Francis (*)

(*) Department of Chemical Engineering and Materials Science
University of Minnesota, Minneapolis, MN 55403

Presented at the 15th International Coating Science and Technology Symposium,
September 13-15, 2010, St. Paul, MN¹

Latex-based coating formulations are the environmentally friendly substitutes for many traditionally solventborne polymeric coatings. Coatings such as paints, varnishes, floor coatings, and reflective roof coatings are increasingly becoming latex-based as environmental restrictions are placed upon the coating industry. In these latex systems, water suspends a polymer colloid, often with other additives in the dispersion such as ceramic particles to modify the color or hardness of the coating. When this dispersion is applied to a substrate and dried, the polymer particles deform during the drying process to create a homogeneous, porosity-free coating.

Replacing solventborne coatings with latex formulations is often a challenge when the final product requires a high modulus. A conflict exists in formulating such a dispersion because the latex modulus must be sufficiently low so that the particles deform during drying, yet sufficiently high that the tack resistance, dirt pickup resistance, and protective nature of the final coating are not compromised. Understanding the factors that influence particle coalescence is therefore valuable for designing high modulus latex coatings.

Studies have shown that depending on the latex modulus and size, particle deformation can occur at various stages of film formation. Routh and Russel created a model for predicting whether latex deformation occurs in the submerged, wet, moist, or dry stages of latex film formation, based on the particle modulus, size, and other coating properties.^{1,2,3} These stages are illustrated in Figure 1.

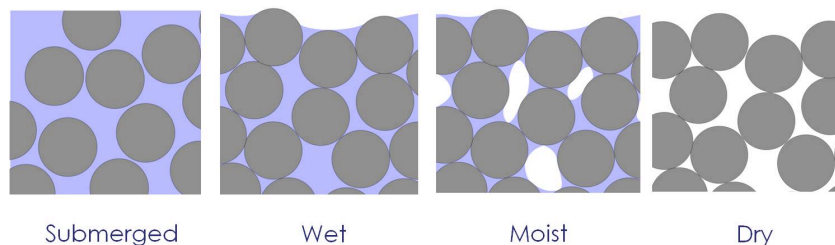


Figure 1: Stages of film formation

¹ Unpublished. ISCST shall not be responsible for statements or opinions contained in papers or printed in its publications.

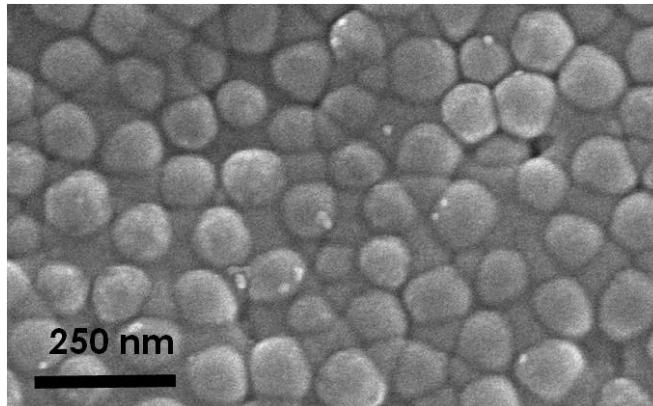


Figure 2. CryoSEM image of the top surface of a latex coating in the wet drying stage. Partial flattening of the latex particles is noticeable. This coating was dried under 10 °C flowing air.

When the particles in the coating do not coalesce, it is well established that the drying stresses can cause cracking in the film. Cracking occurs when the energy required to create two new surfaces is less than the elastic energy that would be released in opening the crack³. Tirumkudulu and Russel⁴ predicted that the critical stress to required to crack a colloidal film of non-coalescing particles of shear modulus G increases with $G^{1/3}$. This relationship arises because the elastic energy recovered by a crack scales with G . When the film coalesces completely into a pore-free film, Griffith crack theory³ for brittle materials and Irwin's modification for ductile materials⁵ both predict that the fracture stress increases with $G^{1/2}$.

Although many studies have looked at film formation and stress development in the two limits of particle modulus: coalescing and non-coalescing, environmentally conscious restrictions on coating formulations are now necessitating a more detailed understanding of the factors that influence the boundary between these two regimes. In this research, the microstructure and stress development of an acrylic latex was studied just above and just below its critical cracking temperature.

Cantilever beam stress measurement techniques show that initially there is a mild compressive stress followed by a large tensile stress in the coating. Almost all of the stress then relaxes away. Cryogenic Scanning Electron Microscopy (cryoSEM) of the coating as it dries shows that the large tensile stress corresponds to the end of the wet drying stage. When the latex is dried at warmer temperatures, the particles deform almost completely in the wet drying stage. When the latex is dried at colder temperatures, the latex particles deform partially in the wet and

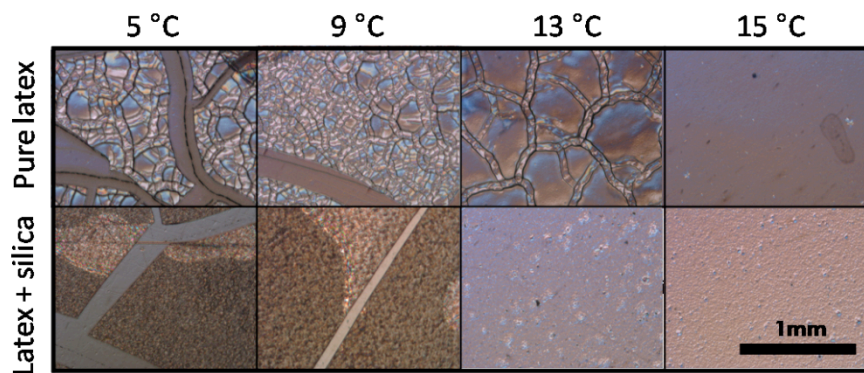


Figure 3. Cracking of latex films at various drying temperatures, with and without silica.

moist drying stages, but porespace remains after all of the water has evaporated (Figure 2). After over approximately a day, the latex particles deform under van der Waals forces to a pore free film.

When the latex is dried at low temperatures, the coating cracks. CryoSEM shows that the cracking begins in the early moist stage. The spacings between cracks, a measure of the coating fracture toughness, were measured for various drying temperatures to investigate the effect of particle modulus on fracture toughness. The spacings increased with G^2 , which contradicts previously established crack theories. It is postulated that partial coalescence of the latex particles provides this G^2 relationship.

Adding small amounts of silica aggregates reduces the amount of cracking in the latex when dried at low temperatures without affecting the clarity of the film (Figure 3). It is shown that silica increases the modulus of the composite coating, and therefore the fracture toughness.

References

1. Routh, A.F. & Russel, W.B. A Process Model for Latex Film Formation: Limiting Regimes for Individual Driving Forces. *Langmuir* **15**, 7762-7773 (1999).
2. Routh, A.F. & Russel, W.B. Deformation Mechanisms during Latex Film Formation: Experimental Evidence. *Industrial & Engineering Chemistry Research* **40**, 4302-4308 (2001).
3. Griffith, A.A. The Phenomena of Rupture and Flow in Solids. *Phil. Trans. R. Soc. Lond. A.* **221**, 163-198 (1921).
4. Tirumkudulu, M.S. & Russel, W.B. Cracking in Drying Latex Films. *Langmuir* **21**, 4938-4948 (2005).
5. Irwin, G. Analysis of stresses and strains near the end of a crack traversing a plate. *J. Appl. Mech.* **24**, 361-364 (1957).