

Crack Formation in Films of Latex Nanoparticles with Varying Surface Charges

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Colloidal dispersions have been subjected to drying in the recent times to draw parallels with the process of solvent evaporation occurring in thin films of wet paint or coating. The inherent particle properties and inter-particle interactions determine the macroscopically observable attributes of dried thin films. Thereby attempts at achieving uniform particle distribution by altering the strength of inter-particle interaction brought about by changing suspension pH [1], addition of salts [2] and surface functional group[3].

The present study outlines the differences in crack pattern and dynamics on introduction of particles possessing surface charge. To ensure consistency in substrate wetting condition as well as faster evaporation of the colloidal droplet, hydrophilic substrates are chosen to perform the experiments. Thereby, glass slides were subjected to plasma treatment for 60 seconds (Harrick Plasma Cleaner) to obtain the hydrophilic glass substrates. Hydrophilicity has been characterized based on the equilibrium contact angle $\sim 5^\circ$; measured using a Goniometer (Ramehart, Germany). The particles used are polystyrene latex beads in the nanoscale regime with similar nominal diameter with varying surface charge (53nm; (neutral), 48nm (Carboxylate-Modified, Negative) and 55nm(Amine-modified, Positive) respectively. These particles in the form of colloidal suspensions are obtained from Sigma-Aldrich and Life Technologies and diluted to a concentration of 1% (w/w) using de-ionized water (Millipore, 99.9% purity).

Colloidal droplets of 1 μL were placed on the hydrophilic substrates using a micropipette and were subjected to evaporation at ambient conditions (25°C) and observed under a microscope at 20X magnification. Time lapse videos were grabbed from the onset of crack initiation till its cessation. Post-processing of these videos comprised of extraction of images from these videos followed by frame-by-frame analysis to obtain the instantaneous velocity of the crack tip.

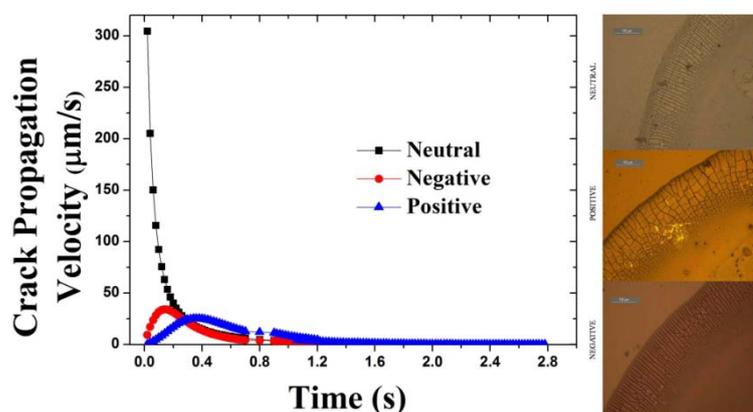


Fig.1. Instantaneous crack tip velocity and morphology variation for charged particles (Scale Bar: 50 μm)

The instantaneous initiation velocity decreases by an order (from $\sim 300\mu\text{m/s}$ to $\sim 40\mu\text{m/s}$) on introduction of charged colloidal particles. However, parallel and straight primary cracks are observed in all the three cases. It can thus be inferred that the presence of surface charge on the latex nanoparticles does not significantly influence the overall crack morphology but alters the initiation velocity. Thus the surface charges of the colloidal particles may be manipulated to decelerate crack initiation in colloidal thin films without altering the crack morphology. Additional work involving molecular dynamic simulations are required to ascertain the influence of charge on inter-particle interactions and to further analyze the physics of the process.

References

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