Scalable Roll Coating for Anti-Dust Layer based on Microscale Interfacial Instability Behavior in Polymer Nanocomposite Materials S. Liu[1], M. Harbinson[1], M. Pudlo[1], S. Khan[2], J. Genzer[2] and J.E. Ryu[1], [1]Department of Mechanical and Aerospace Engineering, North Carolina State University, 1840 Entrepreneur Dr., Raleigh, NC 27606, [2]Department of Chemical and Biomolecular Engineering, 911 Partners Way, Raleigh, NC 27606 (Contact: jryu@ncsu.edu)

The goal of this study is to investigate a scalable manufacturing method for passive lunar dust mitigation by utilizing the roll-coating induced surface roughness on polymer composites. The 3-dimensional (3D) micro-topographical surface inspired by the Lotus leaf is generated in a fast and scalable manner to improve the dust removal efficiency by reducing the Van der Waals adhesion force [1]. In addition to the dust mitigation, the composite coating enhances the infrared (IR) emission, and therefore, is expected to facilitate the thermal radiation to lower the surface temperature in space instrumentation, such as solar panels and thermal radiators.

In this study, we exploited the instability at the interface of viscoelastic coating material and air, which spontaneously occurs due to shear stress applied by the coating roller [2,3]. Similar interfacial behavior is often observed in the texture of walls painted by the roll-brush. The custom-built two-roll coating machine was used as an experimental tool. The diameter and the length of the stainless-steel rolls are 5 cm and 30 cm, respectively. The rotation direction and speed of the rollers can be independently controlled between 0 and 360 rpm. The roller gap can be adjusted from 0 to 10 mm with 10 μm accuracy. Since the instability behavior is independent of the length of the roll, we can scale up the area of the coating layer by extending the roll length and adopting a roll-to-roll process.

We employed both SiO_2 – polydimethylsiloxane (PDMS) and TiO_2 – PDMS composites for the proof-of-concept. The purpose of SiO_2 and TiO_2 particles is to tune the viscoelasticity for the instability and absorb/emit mid-infrared (MIR) for radiative cooling [4–6]. Therefore, the composites were designed to satisfy two criteria in this study: (1) Rheology criteria: High shear yield stress and shear thinning behavior, (2) Optical criteria: Visible light transmission, and high MIR emission. The rheological behavior of the composites was measured by a temperature-controlled rotational rheometer. The shear moduli (G' and G'') and the characteristic relaxation time were characterized by the oscillatory dynamic shear test with the rheometer. The surface tension σ and the water contact angle (WCA) were measured by a goniometer. The dielectric permittivity of composites was measured by the LCR meter. The transmission and absorption of the composite films were measured by UV-visible-near-IR (UV-vis-NIR) and Fourier-transform infrared (FTIR) spectrometer. The surface roughness and topography were characterized by the scanning electron microscope (SEM) and the non-contacting laser scanning confocal microscope.

Lunar simulant (LMS-1) was purchased from Exolith Lab (FL, USA). The dust size range is 0.04 – 300 μm (mean 50 μm). The simulant was sieved into different size fractions (< 65 μm, 65 – 125 μm, 125 – 250 μm). Lunar simulant was kept in a vacuum oven at 120 – 140 ^{o}C for several days to dry before the experiment [7,8]. Tribocharge, which mimics the surface charge of lunar dust, will be induced on dust by tumbling the simulant against small Teflon beads in a stainless steel container [9]. The dust settlement and removal test was performed by the following procedure: 1) sprinkle lunar simulant and measure the dust weight on the anti-dust film, 2) tilt the surface 90^{o}, 3) measure the weight of dust that remained on the surface, 4) spin the film with 3G-force, 5) measure the weight of dust that remained on the surface.

References

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