Investigation of Electrostatic Forces and Charging of Anti-Dust Nanostructures

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Dust mitigation is one of the largest challenges that impacts long-term extraterrestrial space exploration and complicates the development of a sustainable lunar presence. The abrasiveness of lunar dust was a significant complication for the Apollo missions, as it damaged space suits and mechanical gears, as well as limited the functionality of their rovers and other equipment.[1] Additionally, excessive dust accumulation on photovoltaic cells has been demonstrated to give a 25-30% yield reduction,[2] which constrains the ability to harness, already limited, power on the moon. In prior work, 500 nm period structures with silane coating were nano-engineered to reduce Van der Waals adhesion forces by minimizing contact area. These structures proved to have anti-dust properties by having up to 93.1% reduction in dust adhesion while in atmospheric conditions.[3] However, questions remain regarding the contribution of capillary and electrostatic forces on dust coverage under non-atmospheric conditions, namely at higher and lower humidity.

In this work, a more thorough investigation of the relationship between humidity (RH%) and dust adhesion will be conducted. In a high humid environment, electrostatic charge dissipates through the air, reducing adhesion, while capillary forces increase adhesion by the formation of a meniscus between the contaminate and the substrate.[4] At lower humidity, electrostatic forces are assumed to dominate over capillary due to the low water vapor content in the air. While previous experiments were performed at varying humidity levels, a more detailed understanding of the nano-structures' performance at extreme humidity (namely 10% and 90% RH) is necessary to better determine the contribution of electrostatic and capillary forces to dust adhesion. Thus, this work will focus on leveraging the validated 500 nm structures with different surface conductivity to understand the impact of humidity on area dust coverage. The samples studied are fabricated using nano-coining and nanoimprint lithography, as described in previous work, [3] and then coated with around 5 nm thickness of Pt, TiO_2, and Al_2O_3. The structure is shown in Figure 1(a). These samples are placed in a humidity chamber and coated with dust while held horizontally. After a controlled amount of time, the samples are tilted vertically to 90◦ to allow the excess dust to fall due to gravity. Samples with residual particles, as shown in Figure 1(b), can be used to quantify the particle coverage. An understanding of the impact of surface conductivity on dust adhesion furthers the understanding of dust mitigating surfaces for applications on extraterrestrial environments.

Initial results, seen in Figure 2, show the higher conductivity textured samples TiO_2 and Pt having superior performance at lower humidity. High conductivity surfaces dissipate charge on particles as they contact the grounded surface, which reduces the electrostatic force built up in low humidity. In this work, three distinct coatings, $\mathrm{Al_2O_3, TiO_2, Pt}$, are applied to the polycarbonate 500 nm structures, to be tested under 10% - 90% RH in 10% increments. After testing, confocal images will be taken at all humidity levels to quantify dust removal as a function of RH% and relative to the samples' conductivities. Additionally, SEM captures of the samples at extreme RH% conditions, will provide improved understanding of the structure's performance. While the samples behave similarly under high humidity, platinum is optimal at lower humidity, where electrostatic forces dominate, due to its higher conductivity. Additional details, such as the structure's fabrication, testing procedure, and surface characterization will be discussed.

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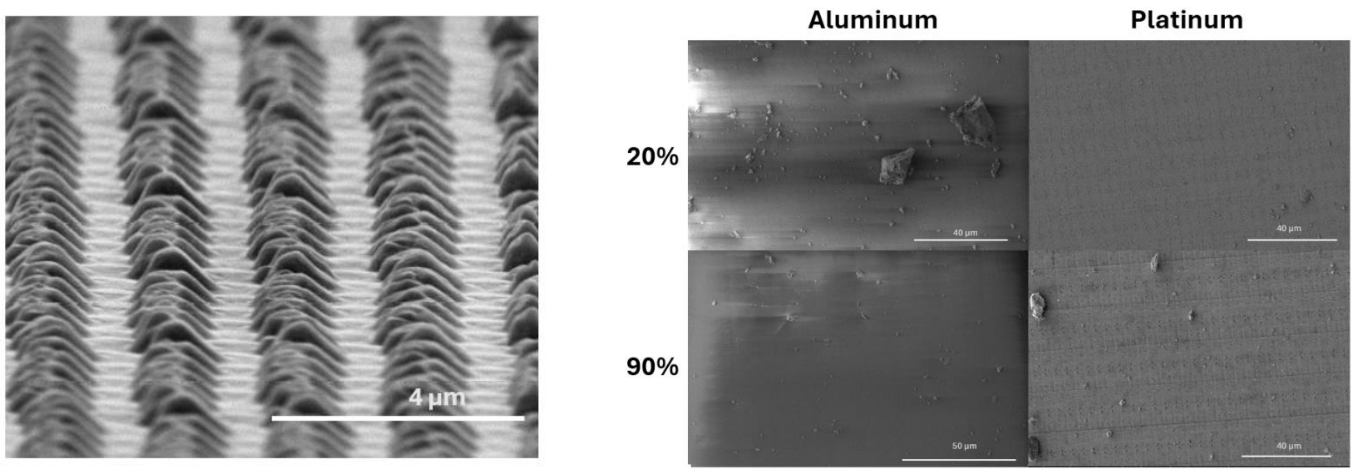

Figure 1. (a) SEM of nanostructures. **(b)** SEM image of Pt and Al_2O_3 samples tested at 20%RH & 90%RH

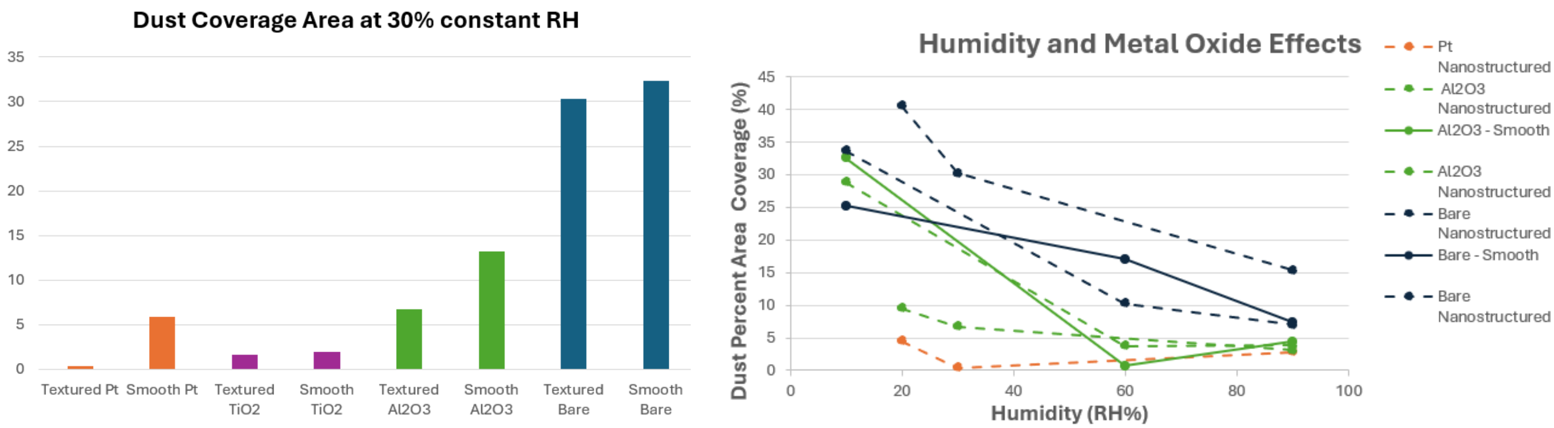

Figure 2.(a) Bar chart of coverage area for different samples at constant 30%RH. **(b)** Plot of dust surface area coverage at varying humidity levels. Substrates have a variety of surface coatings to alter conductivity and nanoscale roughness. RH% levels were captured for Al_2O_3, Au, Pt and bare.

References:

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