Development of Spatially Engineered Microtextures Inspired by Lotus Leaf Structures for Enhanced Passive Photovoltaic Surface Cleaning

Wuthoo, Avighna (School: Independence High School)
Veselovskiy, Catherine (School: Independence High School)

Particulate soiling reduces photovoltaic panel efficiency by 5-30% in arid environments. Current mitigation relies on water-intensive cleaning or chemical coatings containing per/polyfluoroalkyl substances, which degrade over time and harm surrounding ecosystems. This study investigated whether a chemical-free, bio-inspired push-pull microtextured surface alternating hydrophilic and hydrophobic regions could achieve superior passive cleaning performance using rainfall alone. Clear acrylic coupons served as photovoltaic cover analogs. Hydrophobic regions were fabricated via CO2 laser ablation replicating lotus leaf microarchitecture at 30% dot density, selected for optimal hydrophobicity and optical transmission. A standardized particulate mixture was applied via sieve and water delivered at 45 degrees inclination. Residual contamination was quantified using ImageJ threshold analysis across 10 trials per surface type. The push-pull alternating design achieved mean residual contamination of 2.02%, compared to 2.57% for plain hydrophilic and 2.43% for fully hydrophobic controls, representing a 21.7% reduction. A Kruskal-Wallis test confirmed statistically significant differences across all surface types ($p<0.01$). Post-hoc Dunn's test with Bonferroni correction confirmed the alternating design significantly outperformed both controls, while the two controls did not differ significantly from each other ($p = 0.30$). These results demonstrate that a bio-inspired alternating microtexture outperforms either wettability regime alone, offering a scalable, coating-free solution to photovoltaic soiling with broad applications across solar installations worldwide.

Awards Won: