# Durable Antireflective, Anti-Soiling, and Self-Cleaning Glass for Solar Modules

## Technical assistance request

We are looking for partners that may work with our team that are established glass manufacturers, help provide validation of the approach with the PV or glass industry, partners with experience in module level field and durability testing, and partners with access to module durability test apparatus such as damp-heat chamber and module field-test facilities. The development of this proposed technology includes the following five tasks described in Plan under Question 4.

The development of this proposed technology includes the following tasks:

**1. Develop Scalable Etching Methods for Creating Various Nanostructures in Glass.** This task seeks to demonstrate a roll-to-roll system to create antireflecting nanostructures on large area glass of 10 cm x 10 cm. The first task is to create a patterned roller-based NIL process that can imprint the randomly ordered butterfly nanostructures onto a resist layer coated on low-iron tempered glass. The patterned roller material will be a flexible polymer mold capable of large-scale replication while the resist will be polymer-based have an index of refraction close to that of glass that can be solidified through UV and/or thermal curing. This process will then be combined with a conveyor-based roll-to-roll line process that can be efficiently scaled up to a larger substrate size and industrial-level production volume.

The roll to roll NIL process will reproduce nanostructures equivalent to those on the glasswing butterfly-inspired glass by patterning a deposited resist on the glass and subsequently curing it. The planned resist will be polymer-based, offer high resolution imprinting capabilities, and have an index of refraction extremely close to that of glass, so as to minimize reflection at the resist-glass interface due to a drastic change in the index of refraction. The rolling mechanism, which forms the nanostructures in the resist, will be composed of dies supporting a patterned rolling belt, which contains the negative imprint of the nanostructures. This belt will be composed of a polymer material with excellent mechanical and thermal properties that can be easily removed from a master mold with little to no deformation, such as polymethyl-methacrylate (PMMA) or polydimethylsiloxane. Finally, the patterned resist will be cured through either UV light, baking, or a combination of both.

**2. Characterize Optical and Wetting Properties of Nanostructured Glass.** The second task will characterize the wetting and optical properties of various glass substrates through optical imaging as well as spectrophotometry. The printed nanostructured will be functionalized with a hydrophobic coating to provide a low surface energy surface. Wetting properties will be characterized using a goniometer (VCA 2000 Optima XE). Optical properties of fabricated samples will be characterized through the PI's UV-vis-NIR spectrophotometer (PerkinElmer, Lambda 750). Both the direct transmitted light and total transmitted light of the samples will be characterized. NETL will work with Pitt in characterizing the antireflection of the glass over a broad range of incidence angles.

**3. Test Anti-Soiling and Self-Cleaning Properties.** Anti-soiling and self-cleaning properties will be tested in a custom built chamber that utilizes a humid deposition technique.[39] Arizona road dust (ISO 12103-1) will be suspended into humidified air with nitrogen gas and gravity will cause the mixture to settle onto the glass. The chamber has been shown to deposit road dust uniformly on glass and the amount deposited per cycle is approximately constant in terms of % transmission decrease. To examine the anti-soiling properties, the transmission loss through the glass will be compared with that of a control glass.

To assess self-cleaning properties, a rain simulation setup will be used to apply a set amount of water to the glass. The transmittance through the glass will be assessed after the sample has dried. We will additionally test dew formation as another means by which the glass may be cleaned. A stage will cool the glass below the dew formation point and the cleaning of the tilted glass from rolling dewdrops will be assessed by measuring the transmission through the glass after cleaning.

**4. Scratch resistance and mechanical durability characterization**

As opposed to other nanomaterial coatings being pursued by other researchers and startups, which are easily abraded, this proposal focuses on monolithic structures where nanostructures are directly etched into the tempered solar glass. As such, the covalent bonds in the glass are maintained, which should eliminate potential delamination issues and allow for greater durability. In order to test the mechanical durability of our nanostructures, abrasion test (Using ABER® Linear Abrader - Model 5750) and scratch test will be used. Corning will work with Pitt to perform mechanical durability tests.

**5. Solar cell fabrication and efficiency measurement on our nanostructure glass**

The final step of this project is to fabricate a real solar panel using our proposed nanostructured glass and analyze the efficiency of that in real environment. In order to do that, we need some collaborators in solar industry to help us on fabricating a new solar cell and measuring the efficiency and performance of that. We are open to collaborate with the groups or companies who has this capability.