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Development of a Spray Deposition Method for Polysilsesquioxane Coatings in Thin Film Photovoltaic Applications

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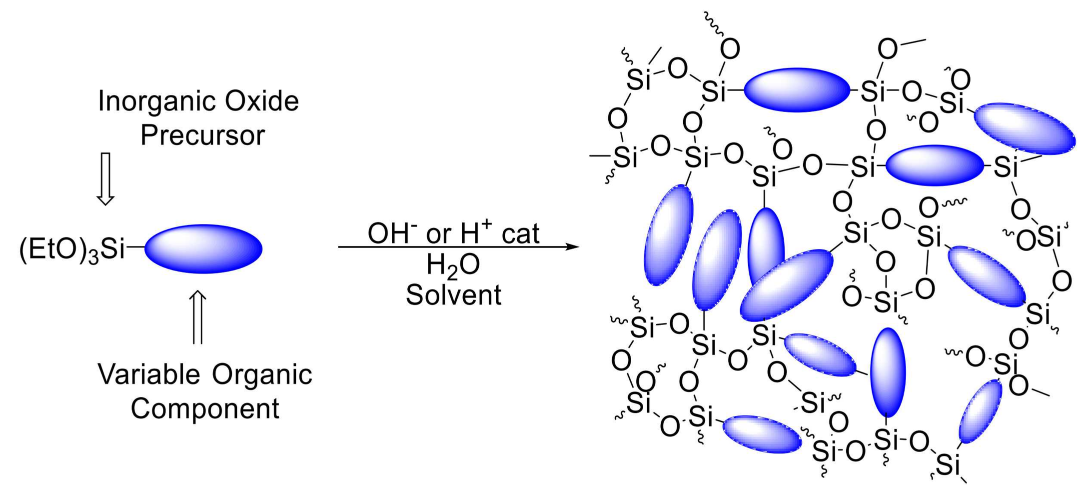
Goal

The goal of this DuraMAT SPARK project is to develop a methodology to spray deposit thin films of commercially available polysilsesquioxane (PSSQ) precursors onto thin film photovoltaic substrates to serve as barrier materials.

Background

Polysilsesquioxanes (PSSQs), a class of organosilicon polymers with the empirical formula $[RSiO_{3/2}]_n$ where R is a hydrogen or carbon moiety. PSSQs offer the opportunity to combine the favorable properties of an inorganic oxide (thermal stability, hardness, etc.) with those of an organic (functionality, processability, etc.) to create materials tailored for barrier film applications. A range of hydrocarbon "R" groups enables a range of carrier solvents which, may in turn, offer control of the wetting characteristics of the PSSQ coating across the range of different metal, glass and organic polymer materials that comprise a thin film PV module. In addition polymerization and deposition conditions may be also altered to influence the film morphology (e.g. low porosity/permeation).



Spray deposition, as opposed to spin or dip coating, is highly amenable to manufacturing processes associated with the production of thin film photovoltaic modules with relatively large surface areas. However the production of a pinhole free, environmentally robust, PSSQ coating via this deposition method is challenging because a number of variables can impact the final quality of the coating.

Project Scope

- 12 month timeline, $50k budget
- Application of commercially available, partially polymerized, PSSQ solutions onto glass and metalized (Al and Cr) coupons to evaluate impact of spray deposition variables on film quality and thickness. Variables include nozzle size, pressure, flow rate, surface preparation, solution concentration, number of coatings and thermal cure.
- Spray deposition of PSSQs onto thin film photovoltaic substrates.

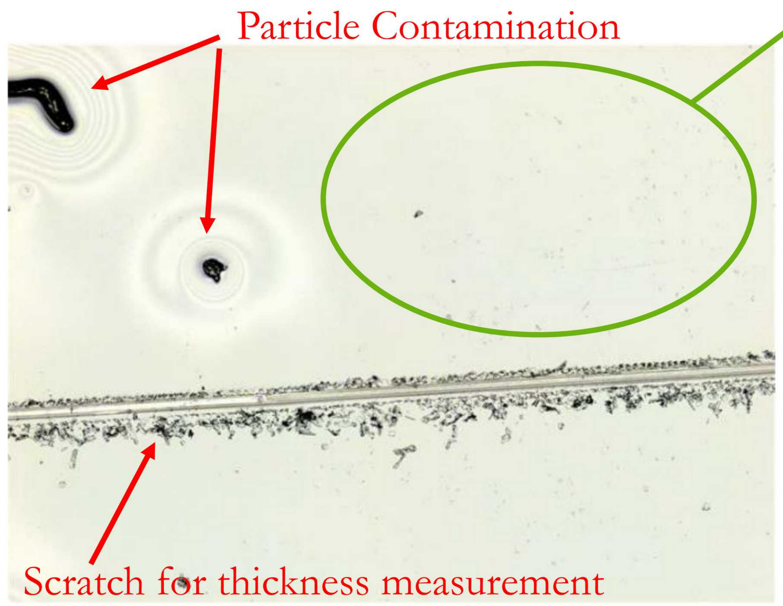
Materials & Methods

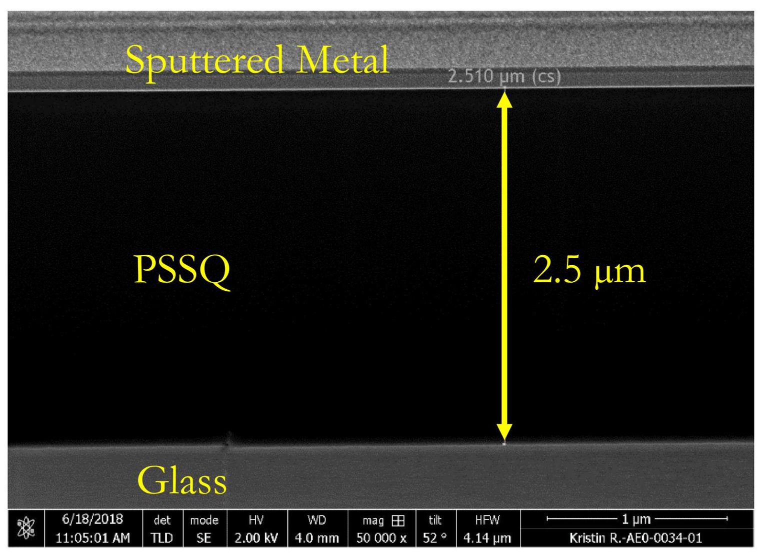
- 10 x 10 cm float glass (uncoated, Al coated or Cr coated) and thin film photovoltaic substrates.
- 3M Accuspray® spray gun
- Commercially available PSSQ solutions.
- PSSQ coatings prepared by spraying solutions onto a horizontally oriented float glass coupon by sweeping the spray gun across the coupon.
- PSSQ coatings typically cured in air for 1 h at 25 °C, then 1 h at 220 °C.
- Characterization using visual observation, optical microscopy, profilometry and SEM.

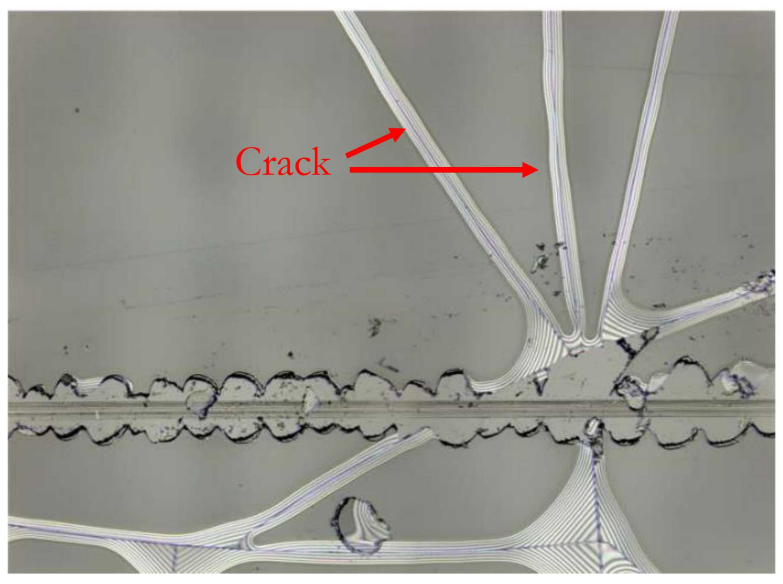
Results

Spray Coat Variable	Impact
Delivery Air Pressure	Higher pressures resulted in substantial amount of overspray
Spray Gun Nozzle size	Smaller nozzle size (e.g. 1.2 mm) reduced overspray
Dilution	More dilute solution = thinner coating. Dilution optimized to stay under final coating thickness of 5 μm.
Diluent	Glycol ethers with different vapor pressures did not improve wettability.
Coupon Surface Preparation	Sonication in 1-methoxy-2-propanol preferred. More agressicve cleaning with $HNO_{3(aq)}$, $NaOH_{(aq)}$ or Ar plasma did not improve wettability.
Multi-coat process	High temp cure required between applications to build up thickness and seal defects.
Filtration	Coating defects due to particle contamination greatly reduced with filtration (0.45 μm) of coating and cleaning solutions.

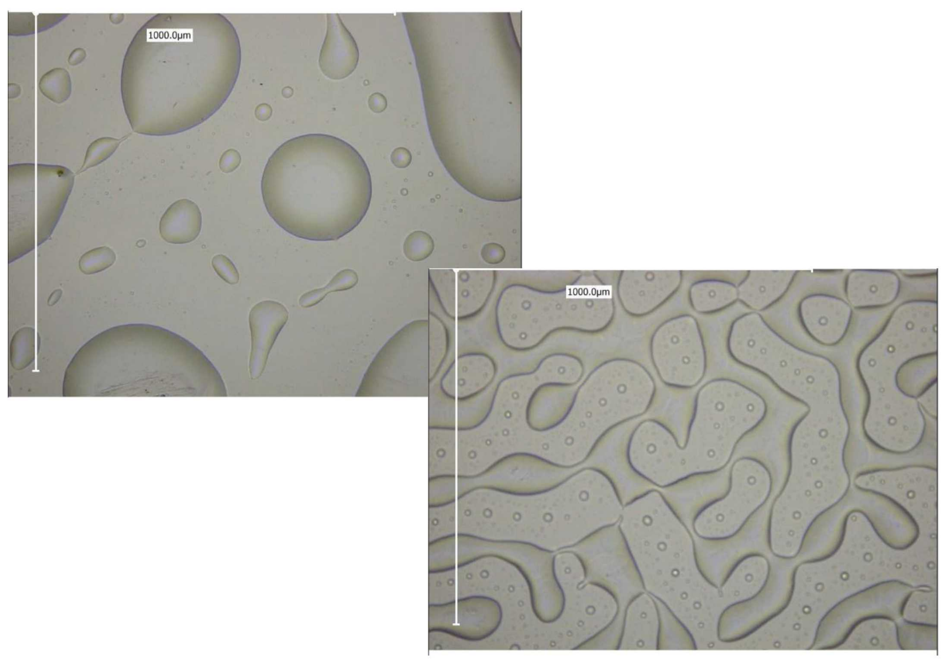
Coating quality is good in absence of particle contamination. Coatings dense by FIB-SEM cross-section.







Thicker coatings (> 5 μm) prone to stress cracking and delamination after thermal cure.



"High" volumes of solution per unit area required to overcome wetting issues.

- Thin film photovoltaic substrates have been coated with PSSQ and film quality are currently being evaluated.

Conclusions

- Dense coatings with a uniform thickness have been prepared on the float glass coupons.
- Wettability remains an issue, particularly with the metalized coupons.
    - More sophisticated surface preparation may be required OR
    - Reformulation of PSSQ solution
- Particle contamination in a laboratory environment represents a significant challenge.
    - Multi-coat coat process to seal defects
    - Utilize cleanroom for single coat operations

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