1. Goals

- Determine applicability of transmission line method (TLM) to evaluate sheet resistance of soils on module glass
- Evaluate various soils on glass for changes in surface resistance and their ability to promote potential-induced degradation with humidity (PID)

2. Introduction & Background

- PID is a critical degradation mode sometimes observed in crystalline silicon PV modules
- Factors promoting PID include increased conduction paths from the active cell circuit to ground
- Conductive soiling on glass may act as a conductive path from the glass face to the grounded metal module frame or edge clips
- Soiling may further trap or react with moisture and increase conductivity on the module face, promoting ionic conduction and PID

3. Apparatus

- Multi-probe board, 4 wire measurements
- Voltage power supply, current sense circuits
- Resolution of the apparatus: 5 x 10^-4 A, but surface conductivity of the probe holder board at 95% RH led to a background current of 1.5 x 10^-4 A
- Multi-probe board connected to sample and placed in an environmental chamber

4. Experiment

A) 162-cm² Square Starphire (low-iron) untextured glass TLM samples
- Conductor stripes: 3M Electrically Conductive Aluminum Tape #3302, 15.25 cm x 1 cm, 0.25, 0.50, 1.5, and 2.0 cm edge-to-edge
- Glass coupons weighed prior and post soil deposition to determine the mass loading
- Simulants of common soils applied:
  - Arizona road dust: 3M type grade, Powder Technology, Inc.
  - Sea salt: ASTM-1110-62, Dake Precision Co., Inc.
- Sheet-conductor formulation, consisting of 80% carbon black (Vulcan XC-1141) and 20% 10W30 motor oil, 0.1% β-pinene [Catalog No. AC13127-10, Sigma Aldrich, St. Louis, Missouri]
- Mass loading: 2.75 g/m²
- 60 °C, 100 V, step stress of relative humidity: 39% to 95%
- Samples used just once due to ion migration and Al corrosion

B) 60 cell mc-Si modules
- Sea salt mass loading: 25 g/m²
- 60 °C, -1000 V, step stress of relative humidity 25%, 65%, 85%, and 95%

5. Results

A) Sheet resistance of various soils on glass and an unsoiled control as a function of relative humidity at 60 °C

- Arizona road dust: Lower sheet resistance compared to the control
- Humidity-independent but elevated leakage current suggest increased PID in a low-humidity environment

B) Leakage current measured from three pairs of module types, one in each pair with sea salt on the surface, as a function of RH

- Leakage current measured on the modules with salt were a factor of two to ten times higher than the modules without sea salt
- At the 85% and 95% RH levels, the modules with sea salt showed relatively unstable leakage current as a function of time, usually increasing
- Type C module package is more resistive

6. Summary & Conclusions

- Soiling determined to be a factor promoting PID
- Arizona road dust showed a decreased resistivity at low relative humidity, but relatively little humidity dependence
- Sea salt showed an important decrease in resistivity and 3.5 orders of magnitude lower sheet resistance at 95% RH. PID risk due to soiling that causes increased module surface conductivity
- Sea salt on 60-cell mc-Si commercial modules promoted increases in leakage current, especially at 85% and 95% RH, leading to increased PID
- Distribution of leakage current and PID depends on module front bulk resistance
- Because of these results, examination of other soil types and further investigation into time-dependent effects are indicated