Introduction

- Strong adhesion of metal contacts is required for reliable silicon solar cells.
- At the busbar level, adhesion can be measured using a pull-test [1-2] but this test does not assess the adhesion of metal fingers (e.g., for cells without busbars).
- Young et al. reported a new stylus-based adhesion tester that can be used to assess the adhesion of metal fingers. This method was derived from the theory of scratch testers used for thin films [3].
- This paper extends the work of Young and attempts to correlate the measured force with the physical deformation of fingers. Specifically it:
  - Identifies two distinct finger failure modes; and
  - Demonstrates the mapping adhesion properties of metal fingers over 156mm solar cells.

Experimental

Two groups of cells were tested.

- 156 mm industrially-produced screen-printed solar cells
- 125 mm p-type, Cz-Si (100), Ni/Cu plated laser-doped selective emitter (LDSE) cells

Results & Discussion

Steps in the Cut-Off Mode
- A: Stylus contacts a Ag finger
- A-B: Force increases due to load cell bending
- B: Finger is instantaneously cut-off
- C: Restoring force causes a slight dip in the measure force

Steps in the Dislodgement Mode
- A': Stylus contacts a plated finger
- A'-B': Force increases due to load cell bending
- B': Metal finger is dislodged
- C': Dislodged finger breaks
- D': Force is restored to the baseline value.

For screen-printed Ag fingers:
- Most fingers are cut-off.
- Metal residue evident at the cut-off finger.
- Young’s modulus of plated metal determines the finger breaking point.

For Ni/Cu fingers:
- Most fingers dislodge at the Si/metal interface
- Applied shear stress can be estimated from a knowledge of the cut-off force and the area of cut-off finger.

Frequency histograms can also be constructed for the measured forces.

For screen-printed fingers:
- Mean force: 3.5 N
- Standard deviation: 0.7 N
- 55% data in interval of 3-4N

For Ni/Cu fingers:
- Mean force: 0.62 N
- Standard deviation: 0.26 N

Conclusion

- A stylus-based adhesion tester with the in-situ visualization of failure modes was developed to quantify the adhesion properties of metal contacts across a silicon solar cell.
- The two distinct failure modes of finger cut-off and dislodgement were identified.
- The failure mode that is observed depends on the competing contributions of interfacial adhesion and the material bulk strength.
- Contour maps of cut-off force and dislodgement force can be used to demonstrate the uniformity of the corresponding adhesion properties of metal contacts across the surface of cells.

References