FAILURE MODES IDENTIFIED DURING ADHESION TESTING OF METAL FINGERS ON SILICON SOLAR CELLS

Ran Chen, Wei Zhang, Xi Wang, Xi Wang and Alison Lennon

Never Stand Still | Faculty of Engineering | School of Photovoltaic and Renewable Energy Engineering

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

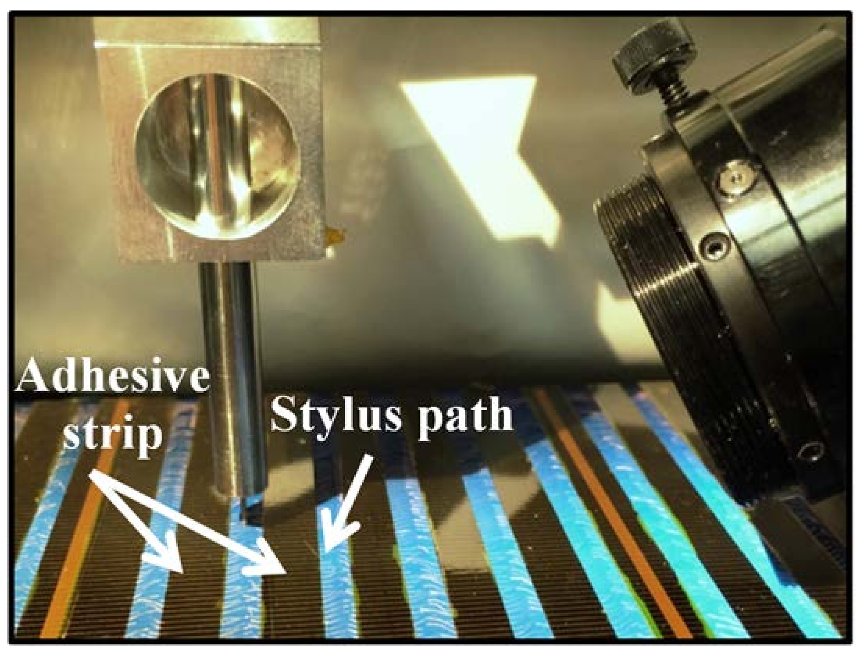
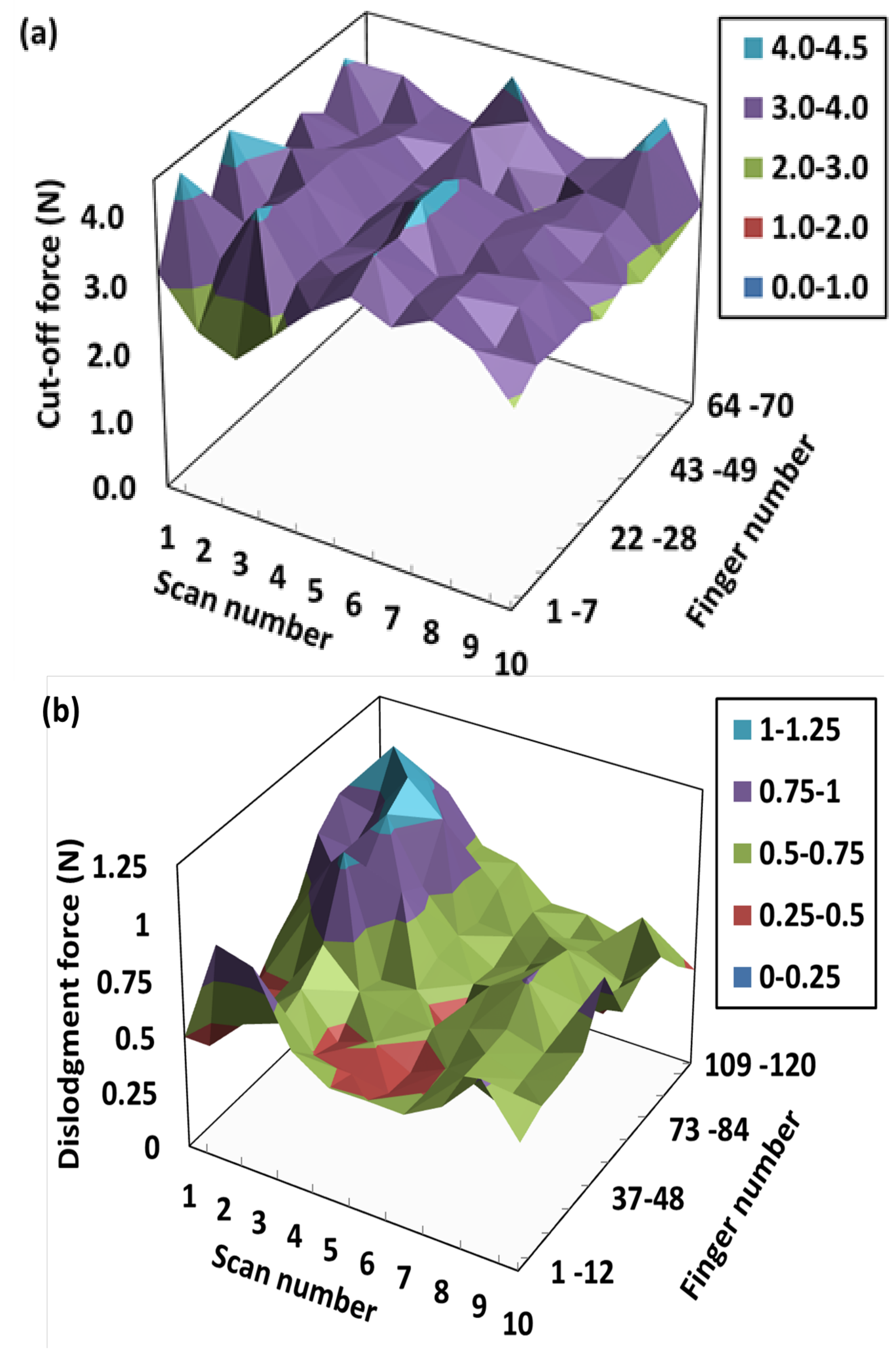


Fig. 1: Image of the adhesion tester with the stylus moving across the cell.



The measured forces were averaged fro smoothing. Contours were used to map the variability in contacting over the surface of the cell.

The cut-off force appeared to have:

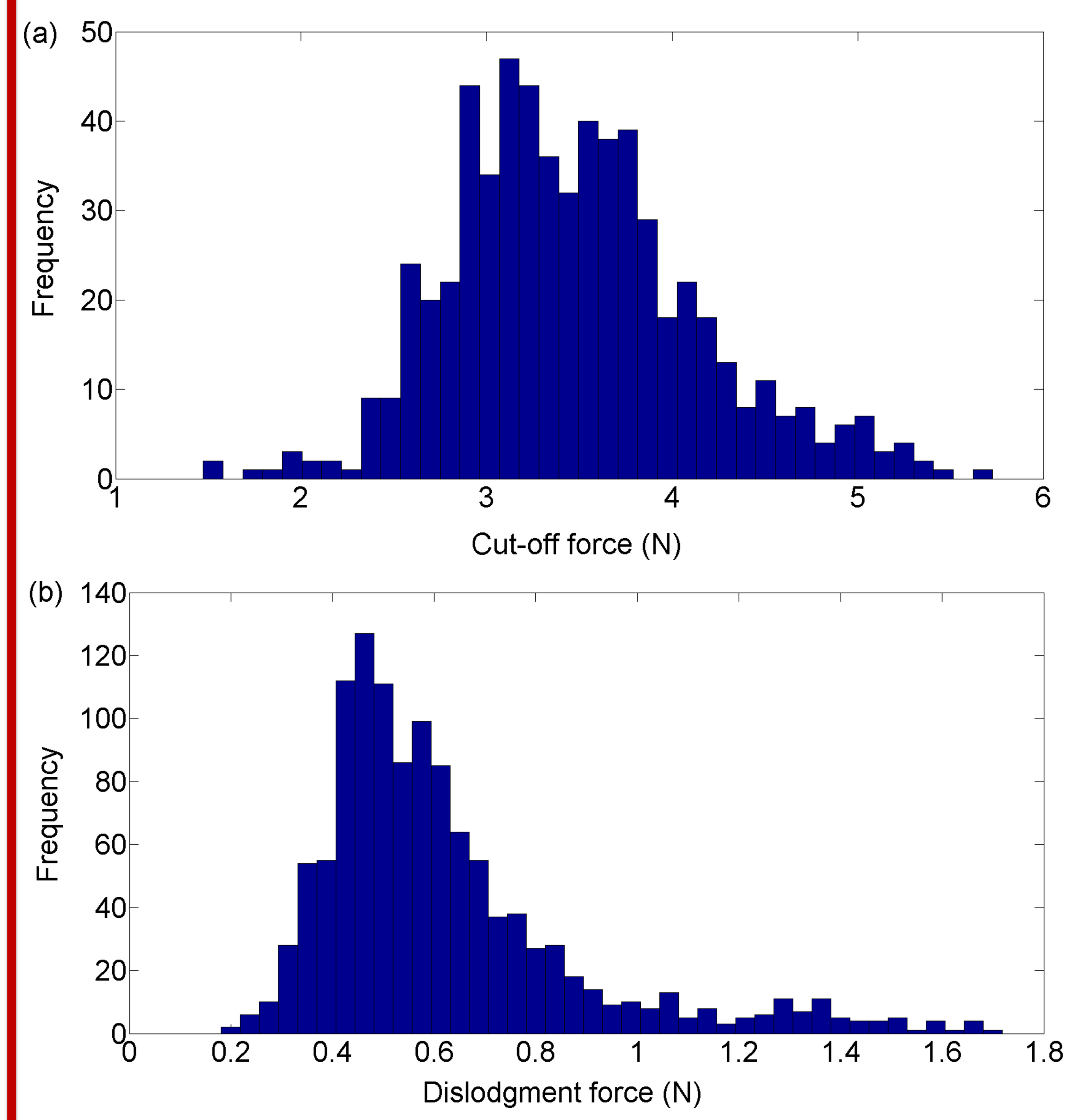
- No overall distinguishable pattern
- Local maximum near the beginning of scan #1 and end of scan #10
- Local minimum near the beginning of scan #2 and before end of scan #10

The dislodgement force appeared to have:

- Greater variability
- Peak near the end of scan #1 and scan #2
- Valley near the beginning of scan #4 and scan #5

Fig. 4: Contour map of cut-off force and dislodgement force for: (a) a screen-printed cell; (b) a LDSE cell.

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
- Slightly positively skewed distribution.

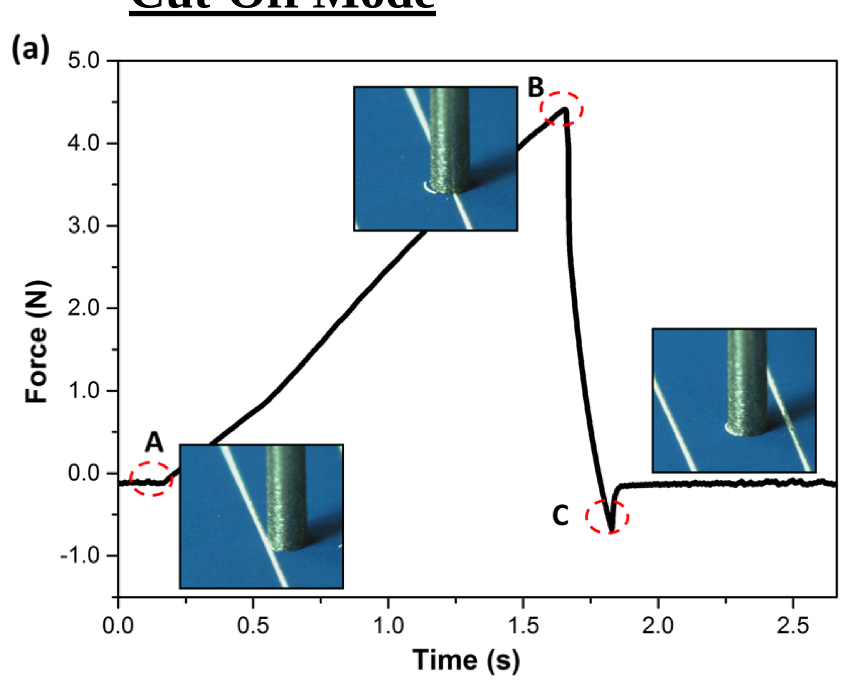
For Ni/Cu fingers:

- Mean force: 0.62 N
- Standard deviation: 0.26 N
- Significant positive tail in the distribution

Fig. 5: Histogram of the cut-off force and dislodgement force for: (a) a screen-printed cell; and (b) a LDSE cell.

Results & Discussion

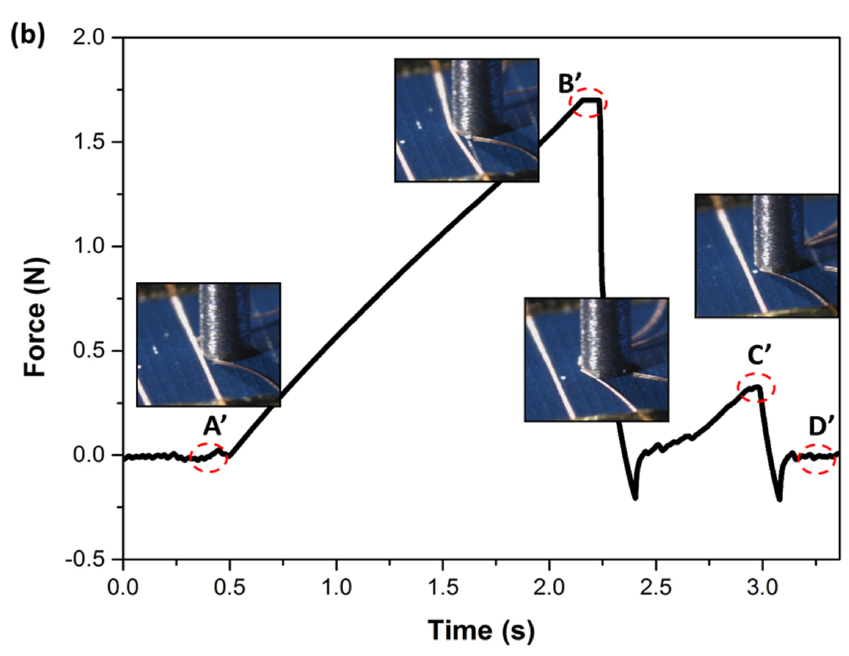
Cut-Off Mode



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

Dislodgement Mode



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.

Fig. 2: Time series of lateral forces under one finger testing : (a) cut-off mode; (b) dislodgment mode.

For screen-printed Ag fingers:

- Most fingers are cut-off.
- Metal residue evident at the cut-off region
- Applied shear stress can be estimated from a knowledge of the cut-off force and the area of cut-off finger.

For plated LDSE fingers:

- Fingers typically dislodge at the Si/metal interface
- Young's modulus of plated metal determines the finger breaking point

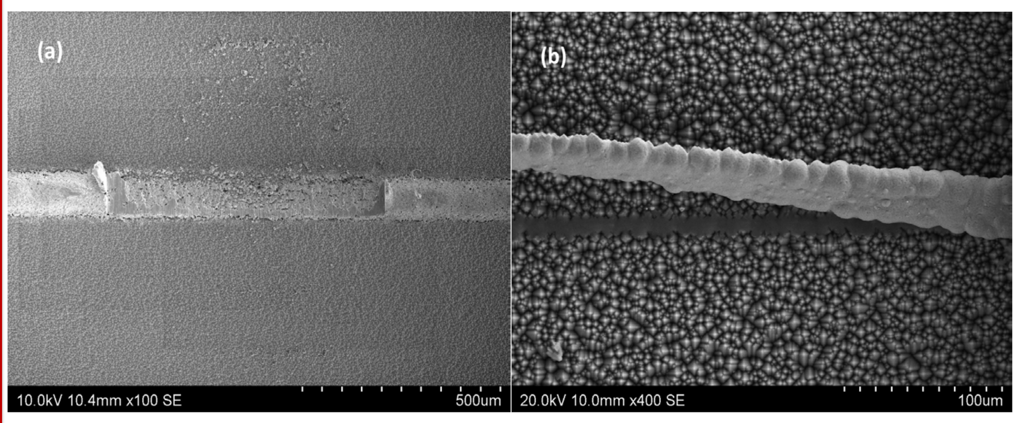


Fig. 3: SEM images of: (a) a cut-off region of a screen-printed Ag finger; and (b) a dislodged region of a Ni/Cu plated finger.

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

[1] R. Jacobsson, "Measurement of the adhesion of thin films," Thin Solid Films, 34, 191-199, 1976.
[2] J. Wendt, M. Trager, R. Klengel, M. Petzold, D. Schade, and R. Sykes, "Improved quality test method for solder ribbon interconnects on silicon solar cells," 2th IEEE Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm), 1-4, 2010
[3] T. Young, A. Lennon, R. Egan, O. Wilkie, and Y. Yao, "Design and characterization of an adhesion strength tester for evaluating metal contacts on solar cells," presented at the 40th IEEE Photovoltaics Specialist Conference, Denver, CO, USA, 2014.

This work was funded by the Australian Government through the Australian Renewable Energy Agency (ARENA). Responsibility for the views, information or advice expressed herein is not accepted by the Australian Government.