Anisotropic Conductive Adhesives for Inter-digitated Back Contact (IBC) Silicon Solar Cells

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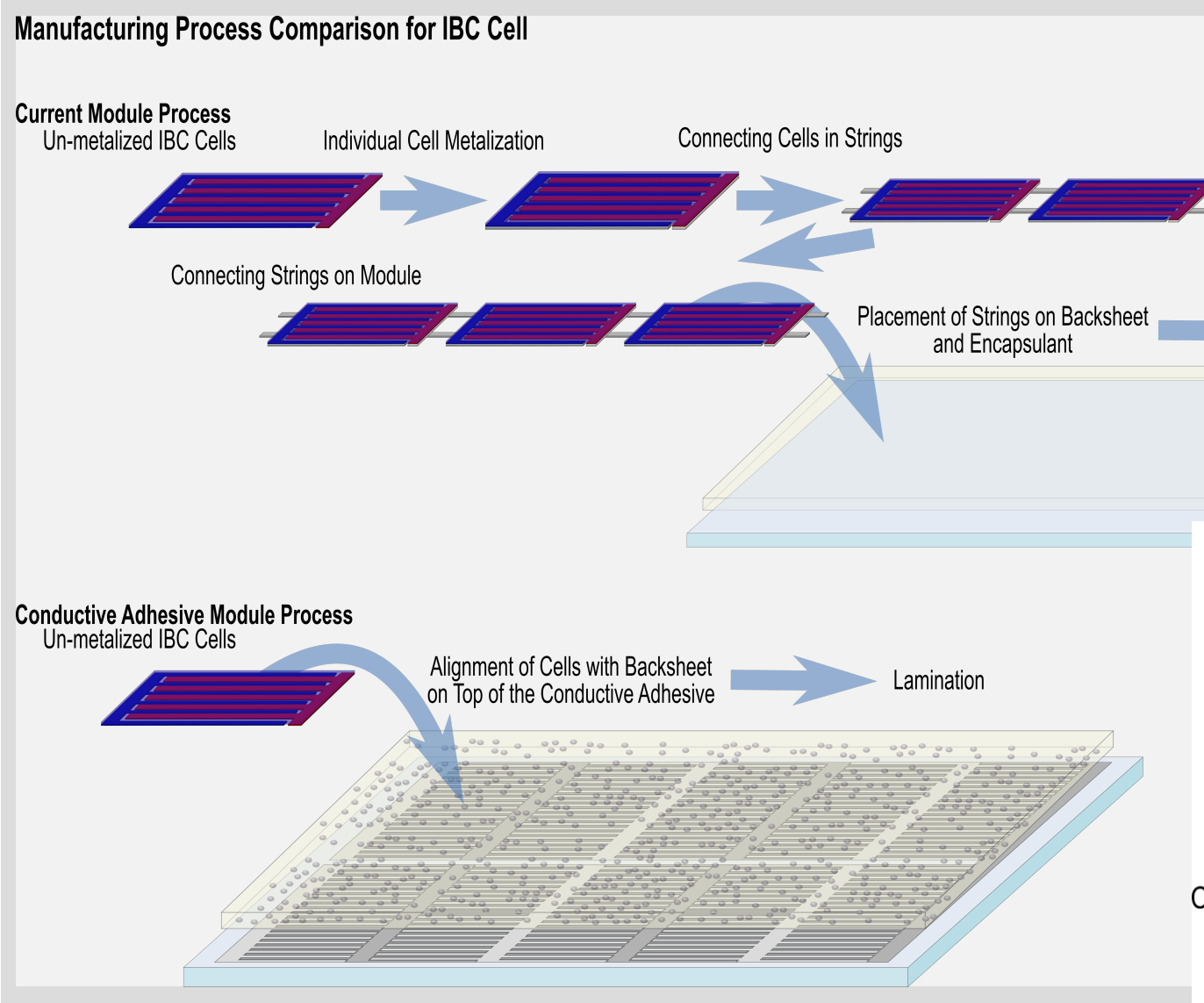
Background

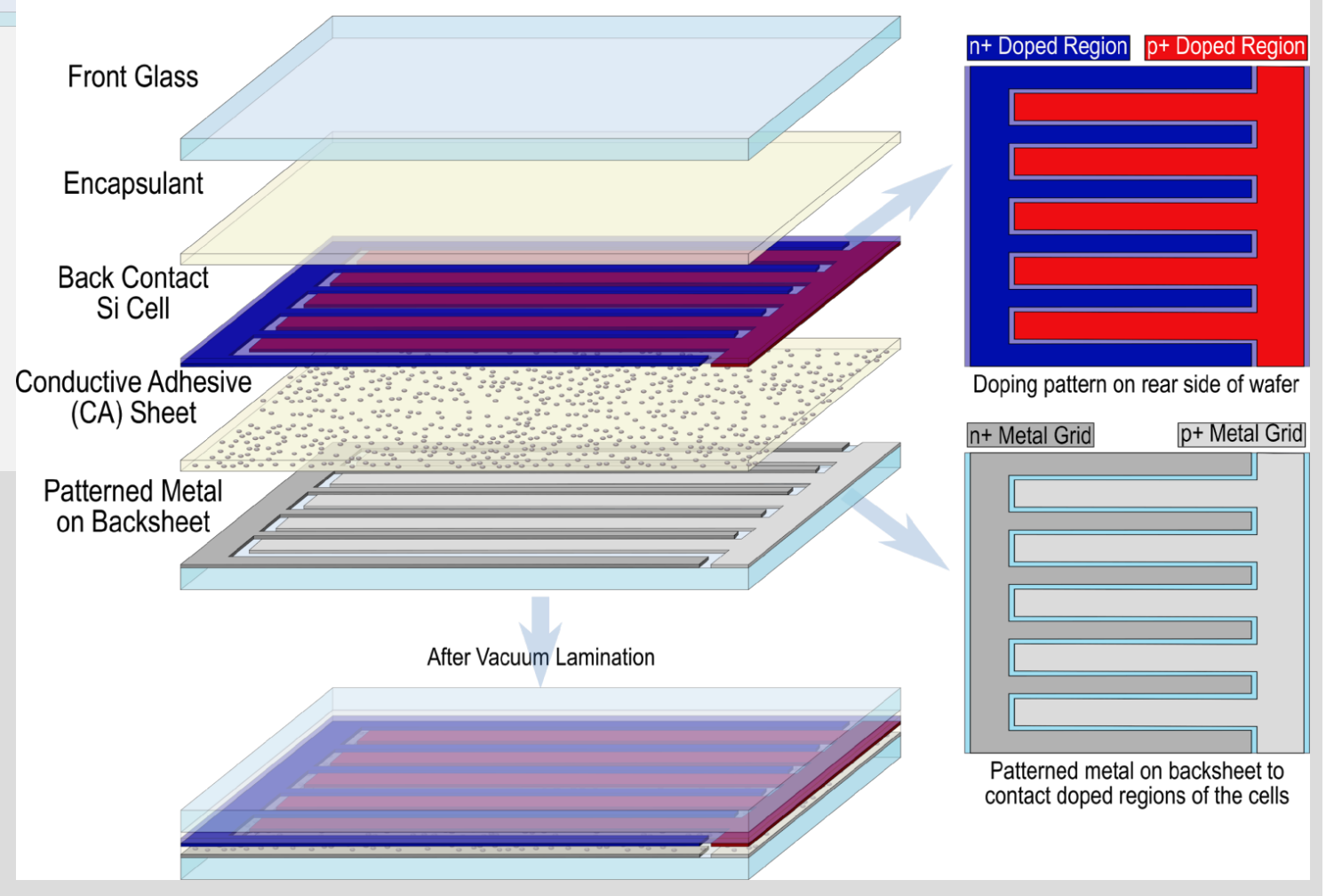
- Metallization and assembly process for IBC panels requires multiple steps and a lot of silver:
  - Screen printing
  - Soldering into strings
  - Lay-up on back sheet & lamination

- Conductive adhesives (CA) would use a one-step metallization and interconnection process that combines with encapsulation using little silver for lower cost.

- No direct metallization of Si → fewer defects, higher voltage.



Current metallization and assembly process for IBC panels (top) and proposed CA process (below).



One-step metallization and interconnection process using conductive adhesives.

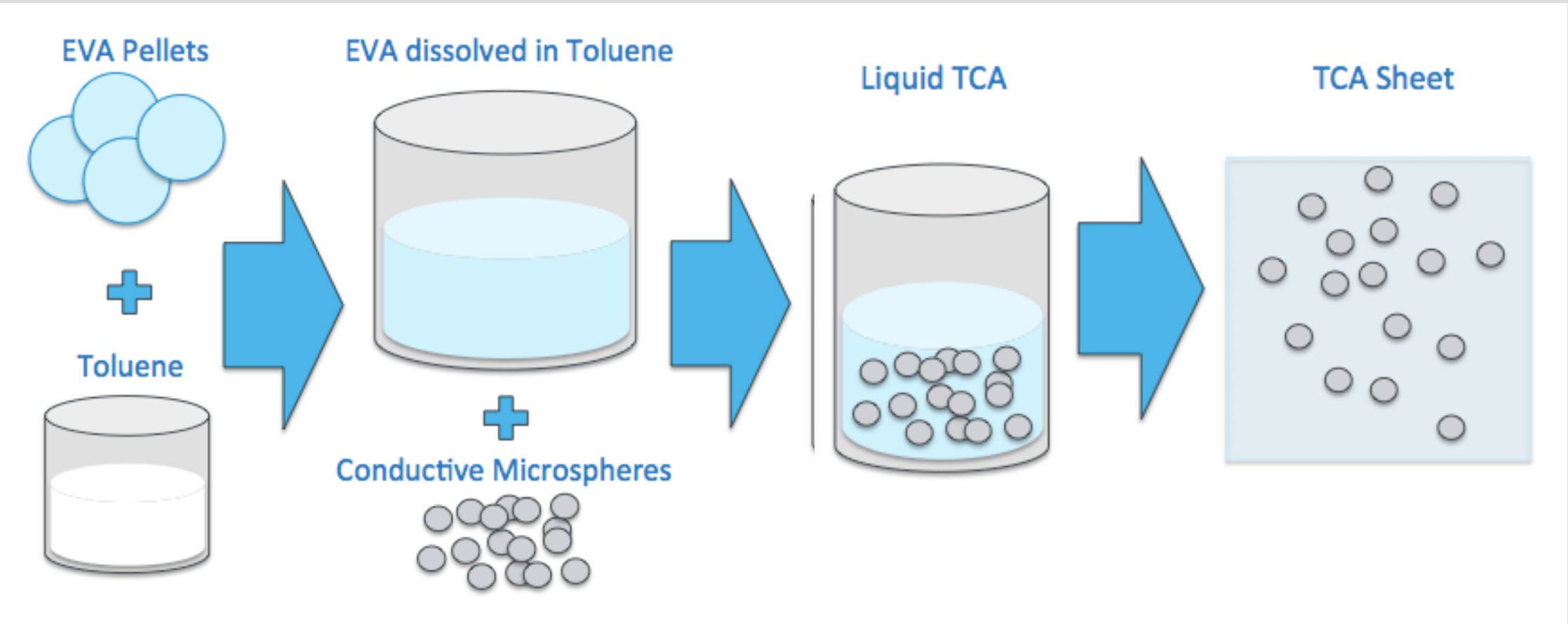
Methods

- Ethyl vinyl acetate (EVA) pellets mixed with toluene (in a 1:3 ratio) for 5 hours on hot plate at 120ºC.

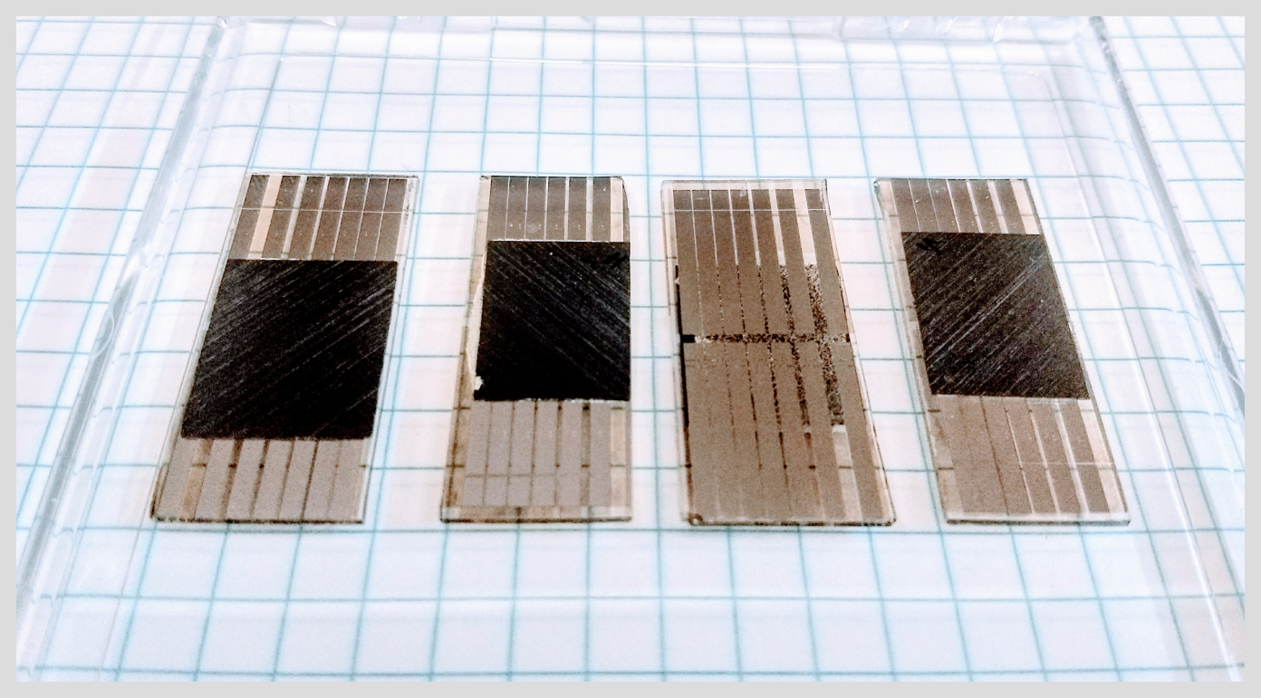
- EVA/toluene then used to make CA with silver-coated Poly(Methyl Methacrylate) Microspheres (AgMS) or 325 mesh indium powder.

- The CA mixture is used to produce a 300µm sheet using a universal applicator.

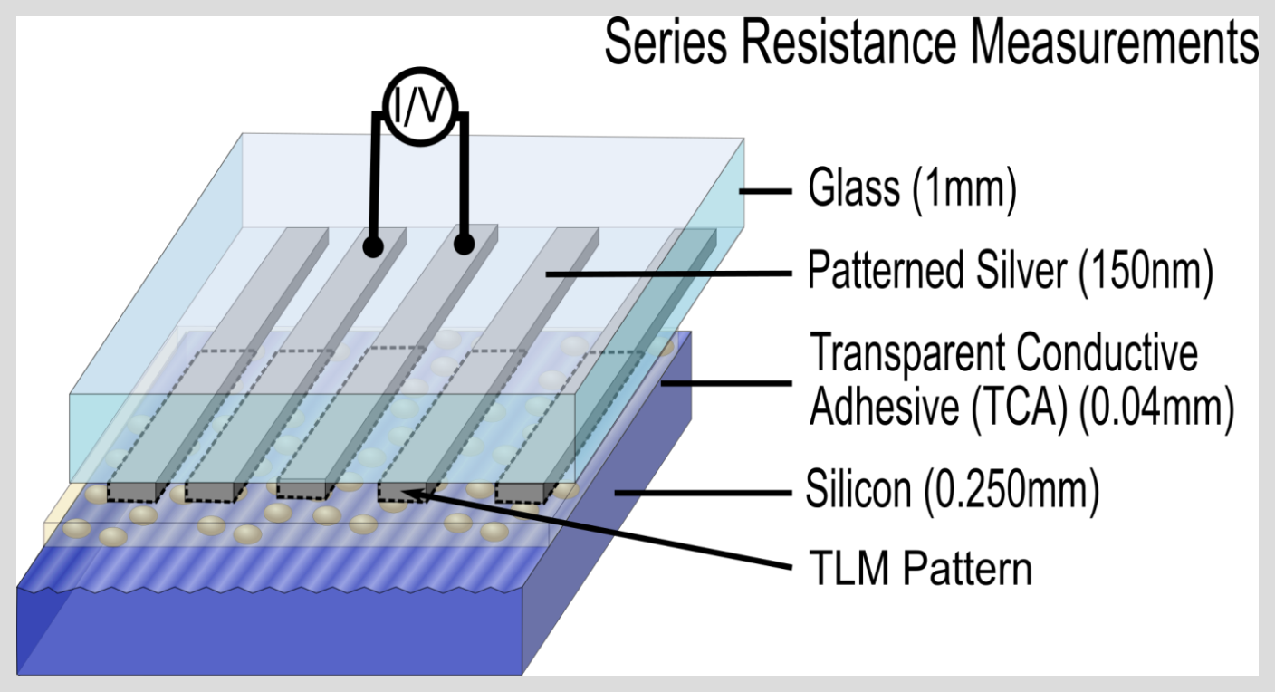
- Pieces of CA sheet are cut and hot pressed between a piece of glass with coplanar Ag electrodes (Ag-glass) and an HF-dipped Si wafer with a highly phosphorous-doped polysilicon surface.



Schematic of CA sheet making process.



Photograph of Ag-glass/Si samples using AgMS CA.

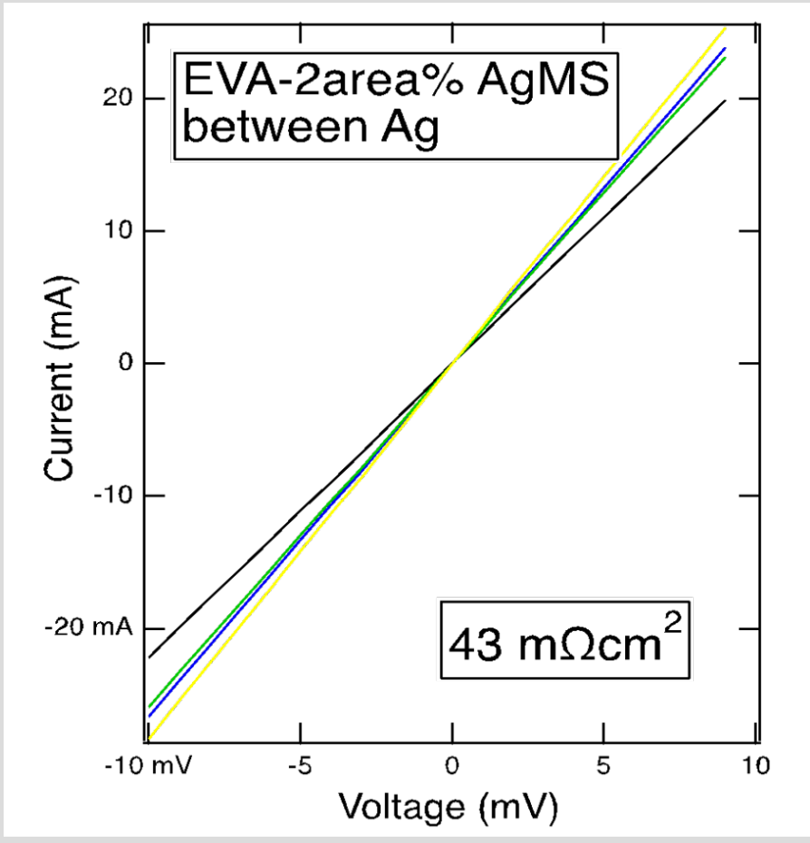


Schematic of layering of Ag-glass/Si samples and TLM pattern for series resistance measurements.

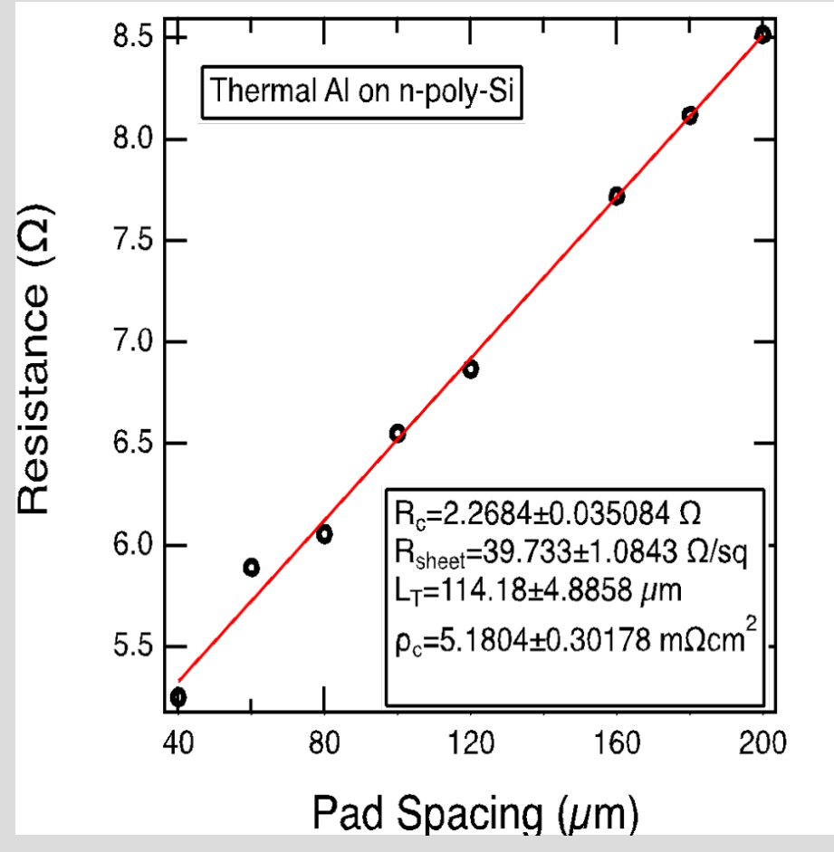
Reference Experiments

- Tested the different components of samples before combining CA and Si.

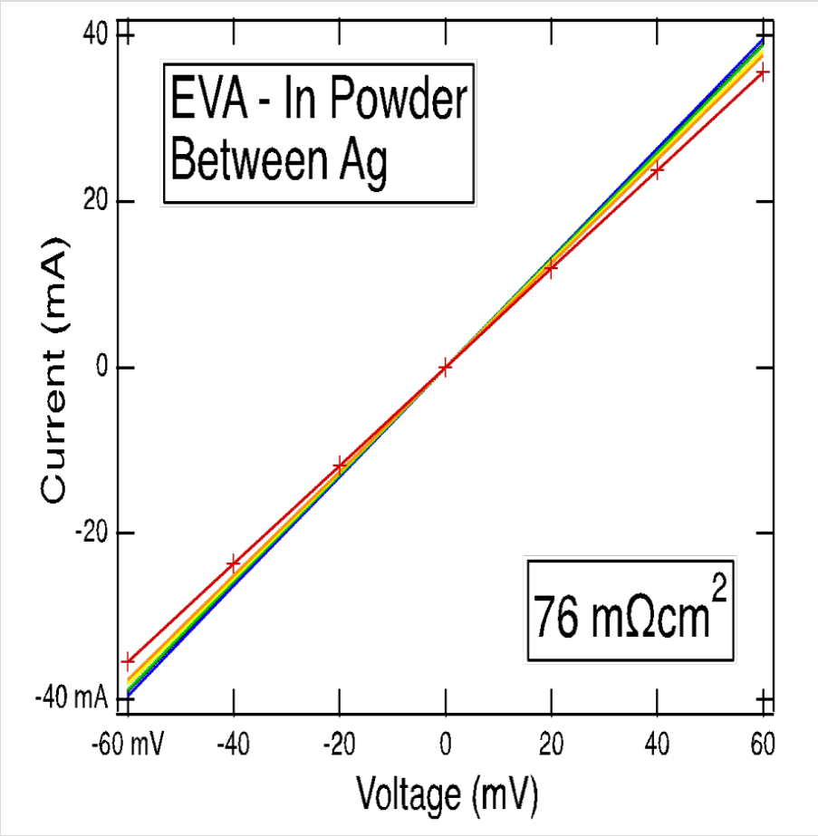
- Data shows EVA/AgMS and In-based CA should work.



EVA/AgMS between Ag indicates that EVA/AgMS alone is conductive.



Si used lends itself to a decrease in contact resistivity.



EVA/In between Ag indicates that EVA/In alone is conductive.

- Used Ag-glass/glass samples to test 5, 10, 15, and 20wt% CA.

- Selected 10wt%, which is highest wt% without too many shunts (gap sizes: 100µm, 150µm, 230µm, 400µm, 720µm, and 1500µm).

Weight % AgMS	Smallest gap without shunt (µm)
5	150
10	230
15	400
20	400

5wt% yielded too little coverage while 15 and 20wt% yielded too much causing shunts.

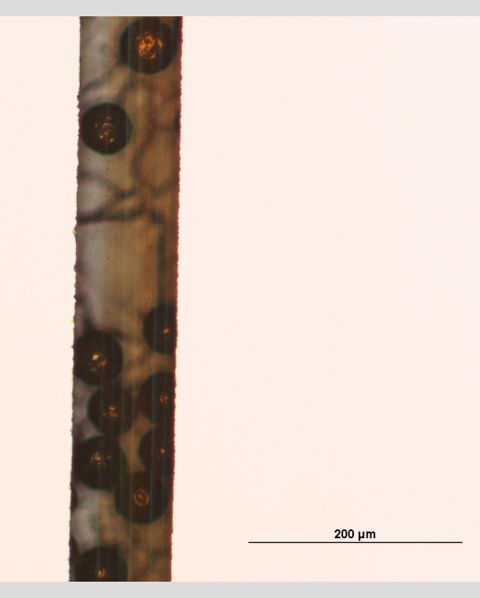
EVA with AgMS Filler

- Repeatedly getting ~20 Ωcm² with baseline experiment.

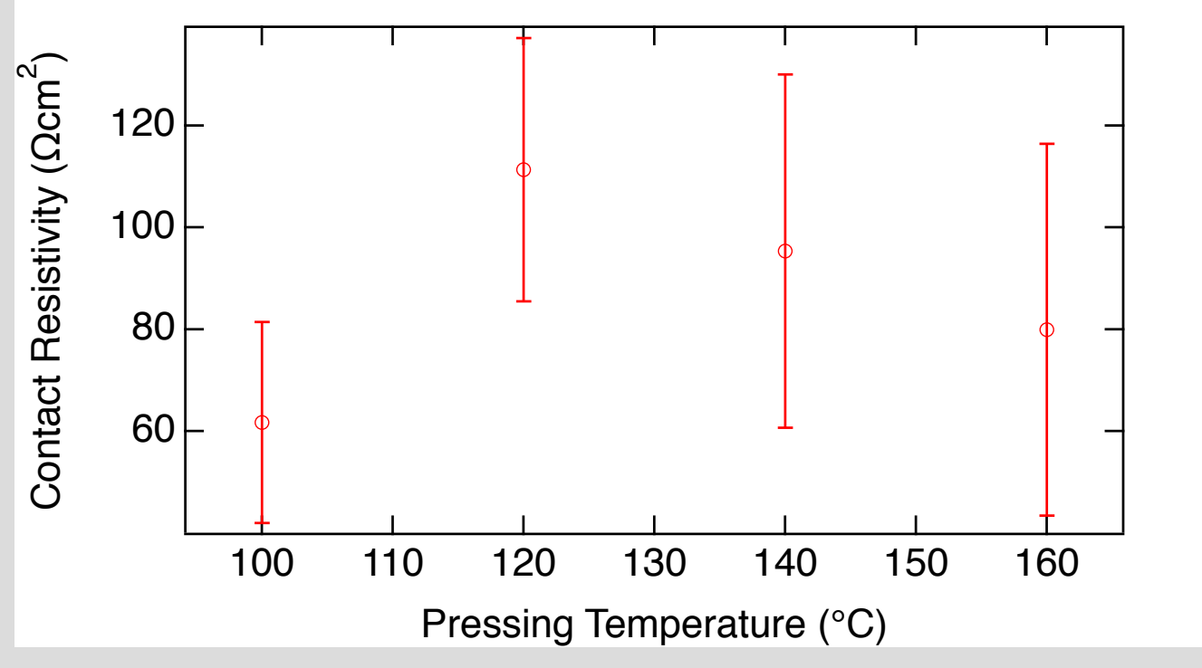
- Pressure series shows optically that 190 psi for 10 min. at 120ºC is enough to produce good contact with microspheres.

- AgMS electrical data not ohmic and varies across samples after optimizing temperature and pressure.

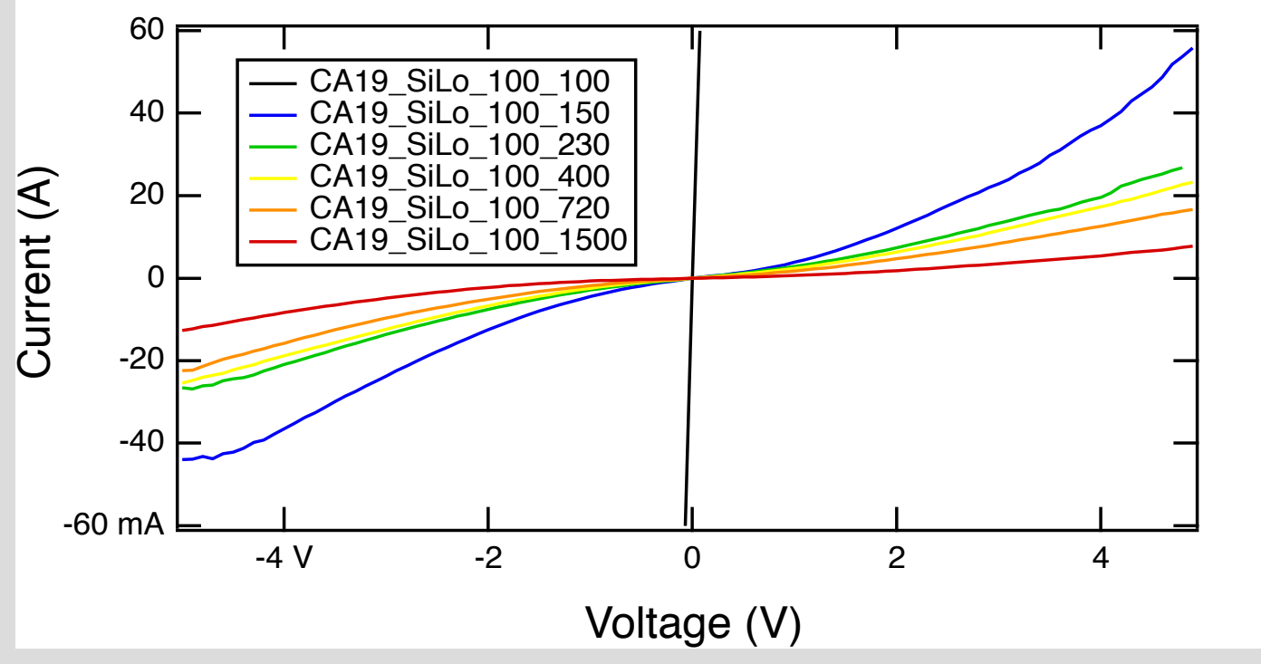
Optical micrograph shows reflective spheres suggesting good contact.



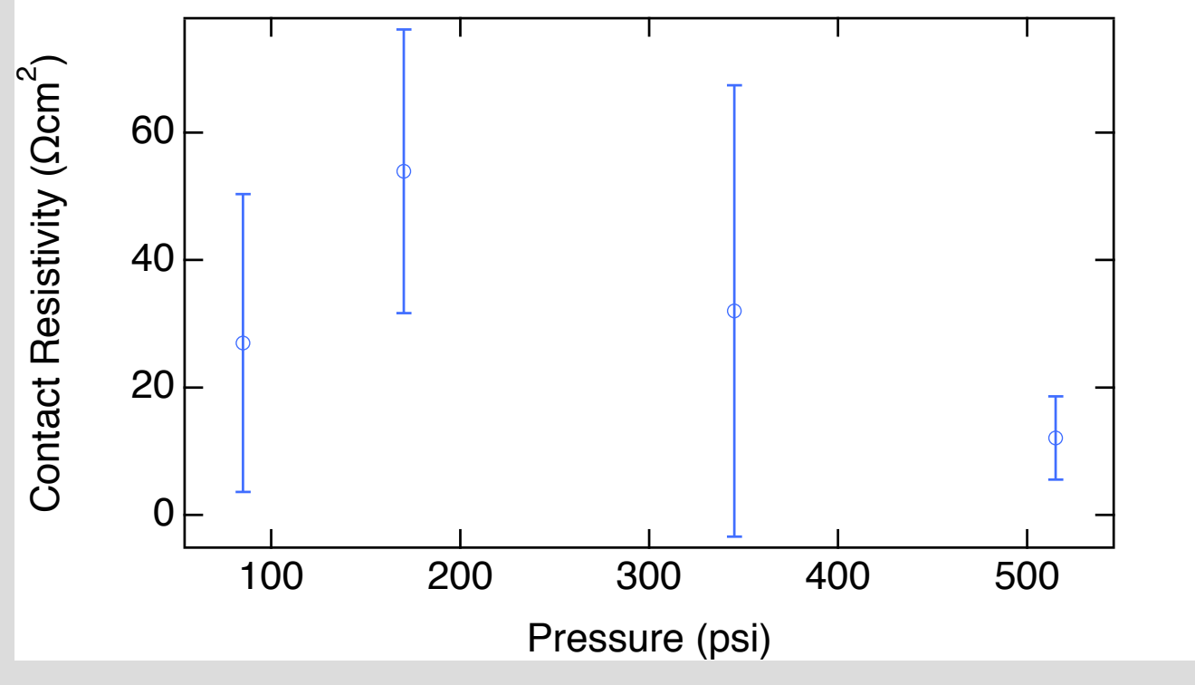
Spheres not as reflective indicating bad contact.



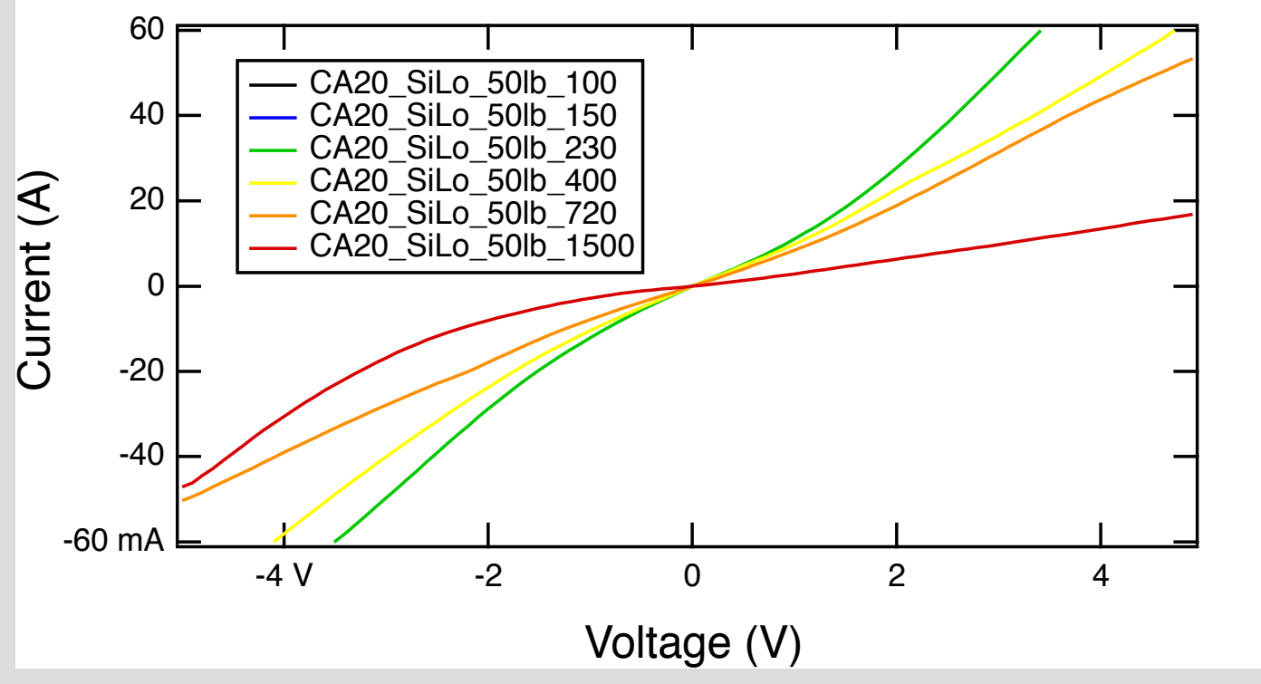
Mean contact resistivity as a function of temperature.



EVA/AgMS IV from temperature series.



Mean contact resistivity as a function of pressure.



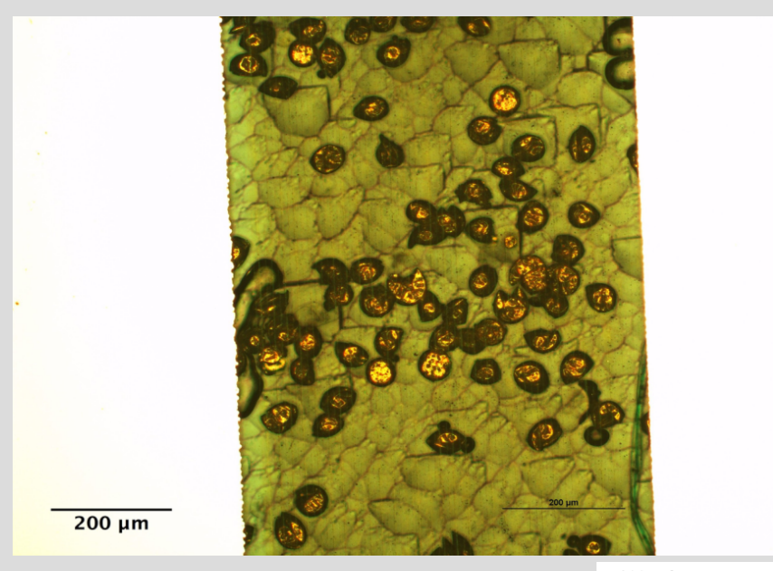
EVA/AgMS IV from pressure series.

- Indium might be better since In solder is known to have 1000x lower contact resistance to Si than Ag-based conductive paint.

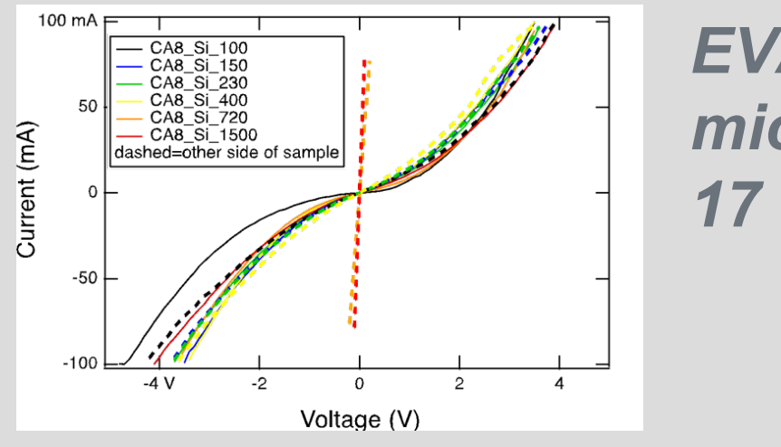
EVA with In Filler

- Compared AgMS and In using samples with 10wt% conductive filler, pressed at 130 psi for 20 min. (AgMS: 120ºC, In: 100ºC).

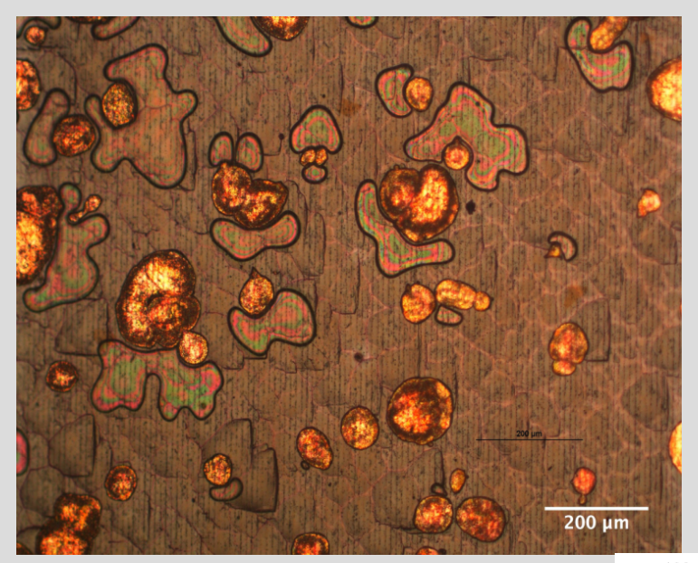
- Conductive particles are reflective, but no significant improvement in electrical data switching from AgMS to In.



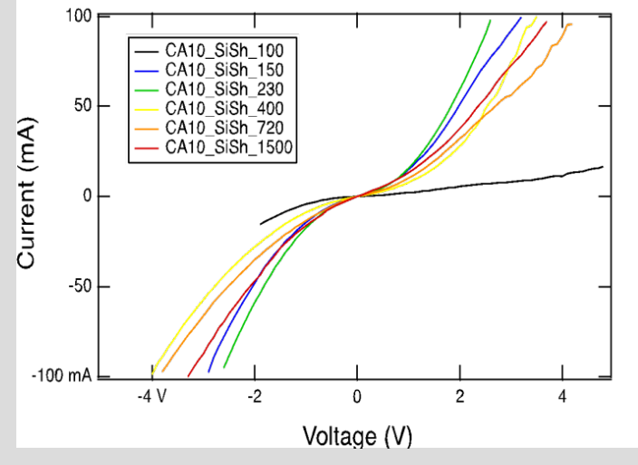
EVA/AgMS optical micrograph image, 15 ± 5 area%



EVA/AgMS IV, ~10 Ωcm²

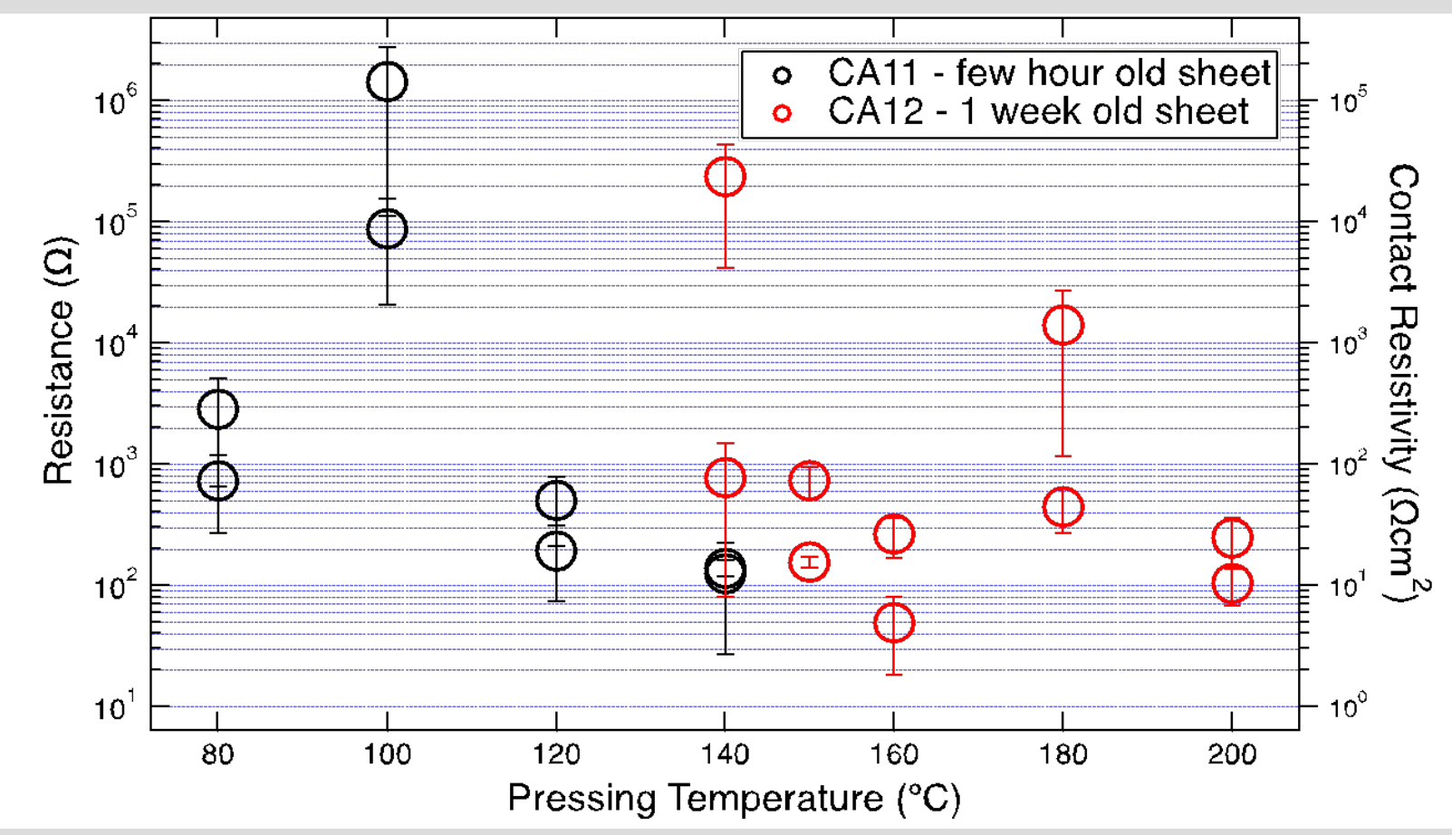


EVA/In optical micrograph image, 17 ± 8 area%



EVA/In IV, ~12 Ωcm²

- Poor electrical data might be due to pressing In at the wrong temperature. A temperature series shows 140ºC is optimal.



EVA/In temperature series shows variation and no clear trends from 120ºC to 200ºC

EVA Reaction with Si

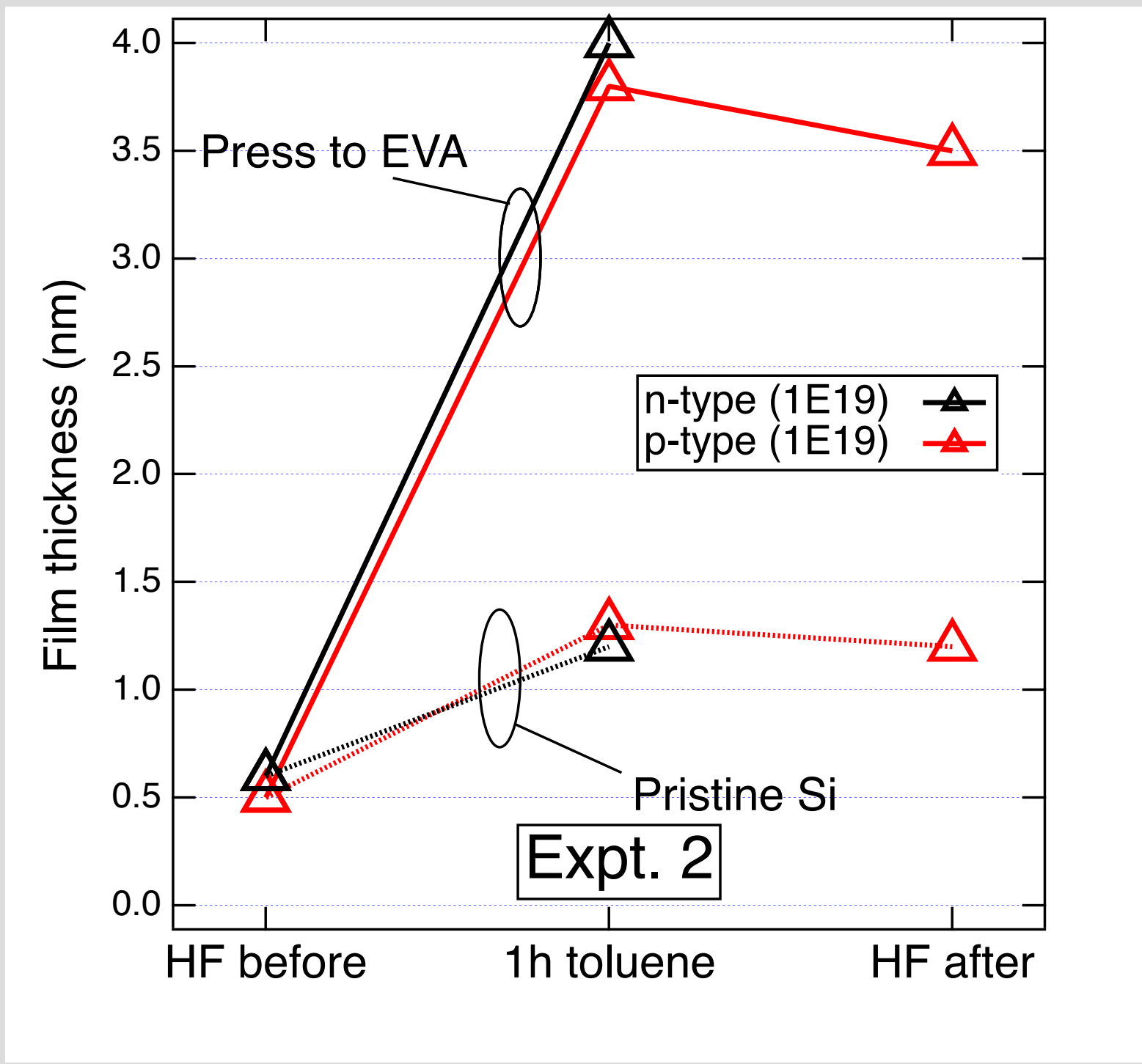
- EVA might be re-oxidizing Si keeping it from making good contact.

- EVA is acidic containing O_2 and water.

- HF-etched p+ and n+ Si hot pressed to 8wt% EVA/AgMS at 120ºC for 10 min. and 190 psi.

- Soaked in toluene for 1 hr. to remove CA and did ellipsometry with SiOx model.

- Samples have 3-4 nm film compared to 1.0-1.5 for EVA-free references.



Conclusion & Outlook

- Varying temperature and pressure yields over 10 Ωcm² for CAs with AgMS and In in EVA.

- Poor contact and multiple orders of magnitude difference across samples is tentatively attributed to an interfacial film revealed with ellipsometry and to be identified by XPS spectroscopy.

- An alternative adhesive must be found that does not create a resistive interfacial film.

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