Multi-Layer Inkjet Printed Contacts for Si Solar Cells

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Objective

To develop inkjet printing (including tools, inks, and processing conditions) for high-quality Ag contacts for Si solar cells.

Advantages of inkjet

- Non-vacuum process
- No contact between print head and substrate
- Liquid precursors
  - Good compositional control
  - Available for a variety of electronic materials
  - Multicomponent/Multilayer printing
- Efficient use of materials

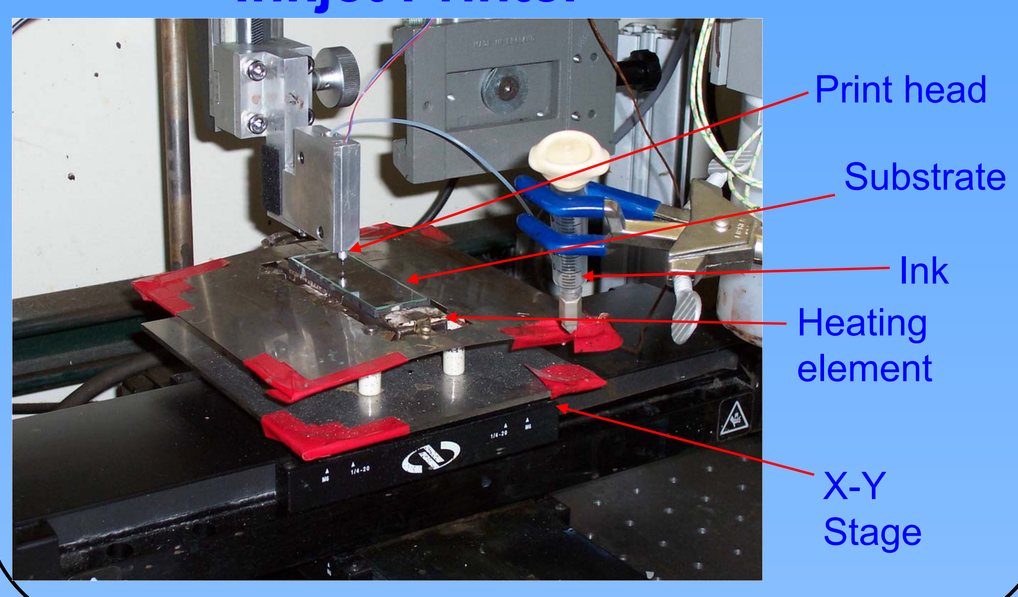
Approach

✓Formulate inks using nanoparticle and/or metal-organic (MO) precursors + additives (surfactants, reducing agents, etc.)

✓Find optimal printing conditions (temperature, drop generation rate, drop volume, sample translation speed)

✓Find optimal annealing conditions (temperature, duration, gas ambient)

MicroFab Piezoelectric Inkjet Printer



Ag Printing with MO Ink

Ink: MO Ag complex + solvent + surfactant, 25% Ag by weight loading

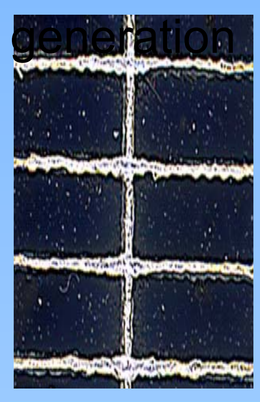
- Ag Deposition rate: 1μm/pass
- Substrate temp: 180°C
- Resolution: 85 μm for 1μm thick line, 220μm for 15 μm thick line
- Resistivity: 2.2 μΩ·cm (1.6 μΩ·cm for bulk Ag) Screen Printing produces 10-20 μΩ·cm after firing

Solar Cells with Printed Contacts

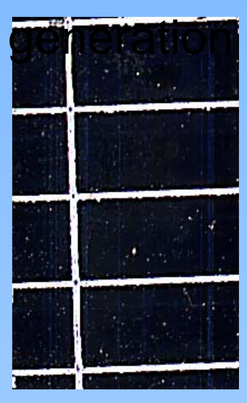
	1st	2nd: Thicker contacts	3rd:Fire-Through
Line thickness:	10 μm	15 μm	15 μm
Line width:	400 μm	250μm	220μm
Dep. Temp. :	180°C	180°C	180°C
Ann. Temp.:	850°C	850°C	750°C
Cell efficiency	8%	8%	10%

AR-coated Si substrates from Evergreen Solar

1st generation



2nd generation



Spray based processing has produced a 12% efficient cell

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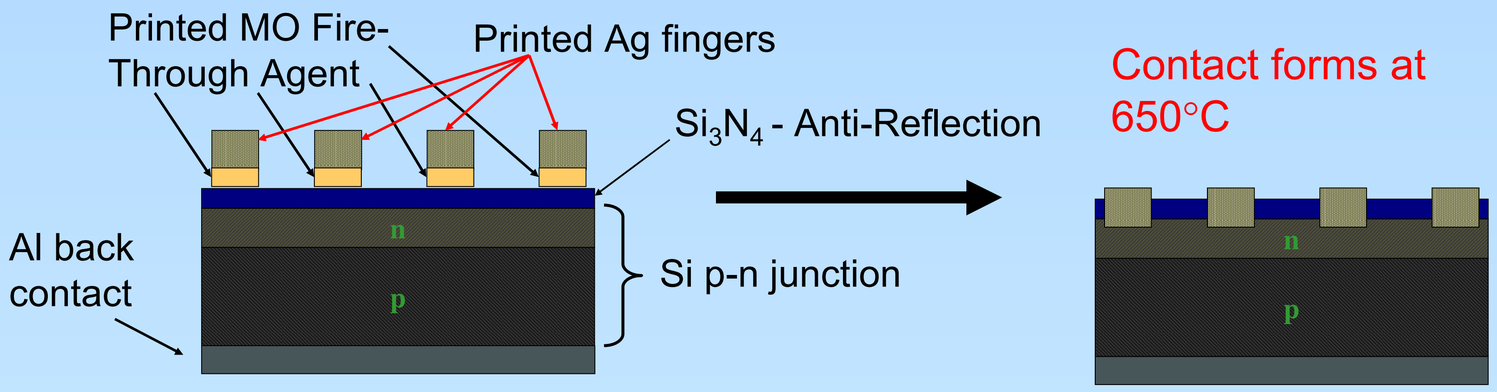
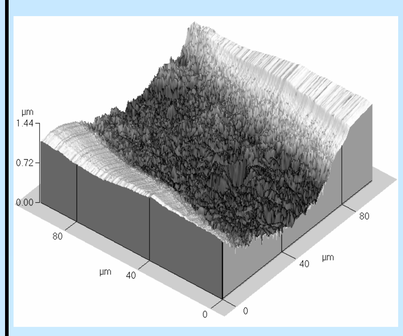
Lowering the Processing Temperature: Layered Printing of a"Fire-Through" Agent



Ag ink alone fires through the Si_3N_4 AR coating at 850°C to give 8% efficient cells

MO "fire-through" ink was developed to facilitate penetration of Si_3N_4 layer



AFM of 1μm deep, 70μm wide trench produced by inkjet-printed "fire-through" agent onto an AR-coated Si wafer processed at 650-750°C.

Summary

- Tools and inks for the atmospheric inkjet printing of Ag metallization for Si solar cells have been developed.
- Line widths, conductivities and thicknesses comparable to, or better than, those produced by screen printing.
- A new fire-through ink and layered printing were found to decrease the processing temperature for contact formation to as low as 650°C and improve printed cell performance.
- Future work: Improve resolution of printed lines, optimize fire-through layer thickness, processing time and temperature for best contacts.