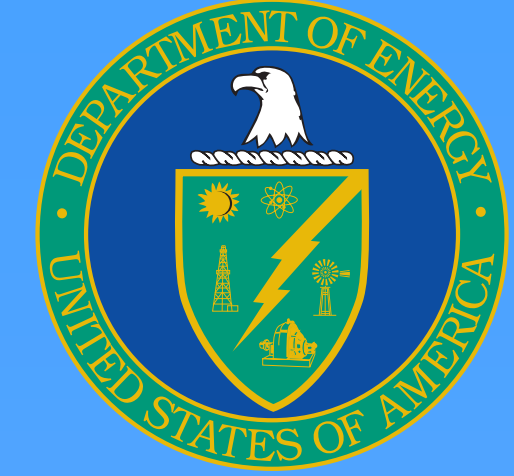


Multi-Layer Inkjet Printed Contacts for Si Solar Cells



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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/Multi layer printing
- Efficient use of materials

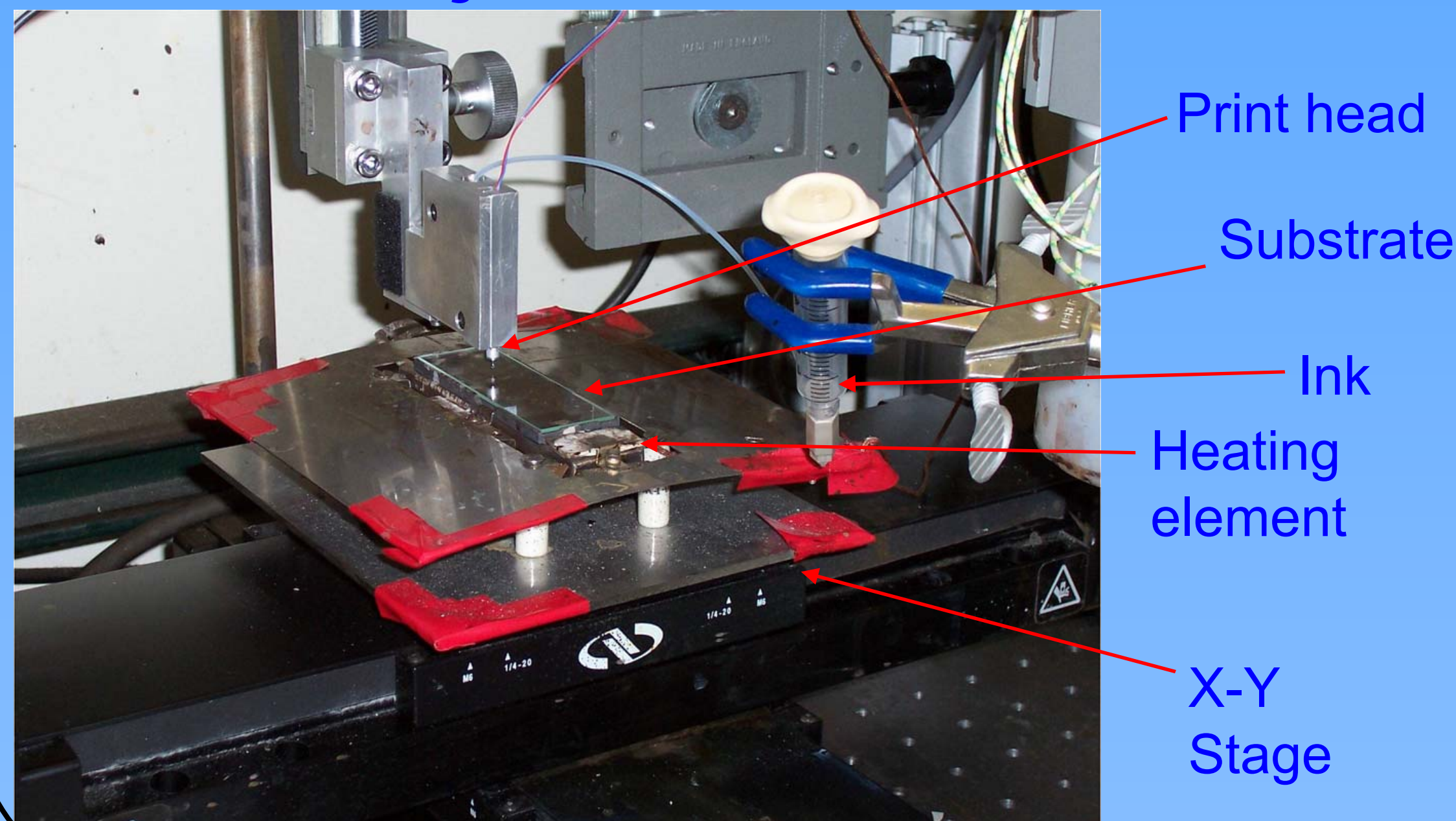
Approach

✓ 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)

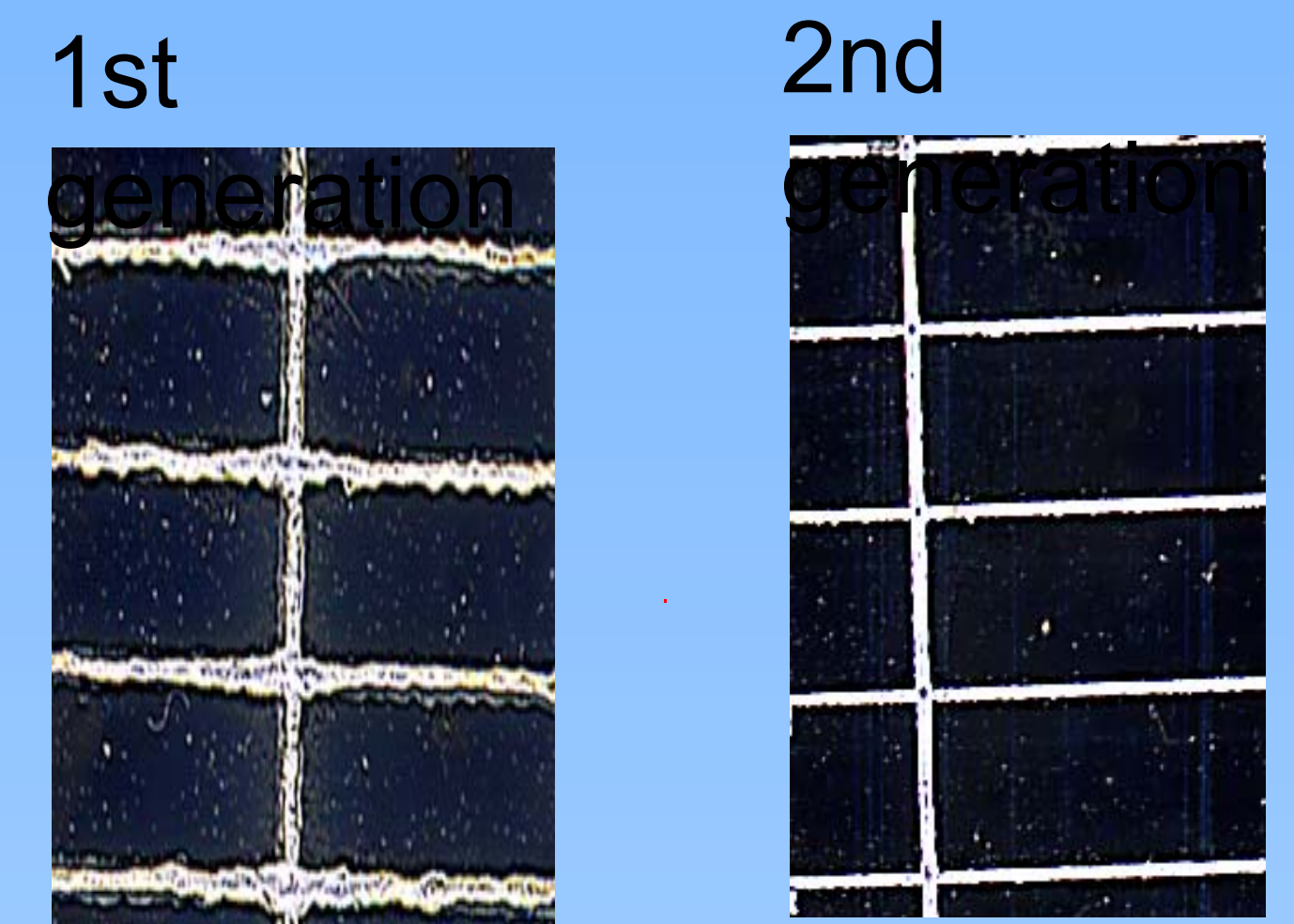
✓ Find optimal annealing conditions (temperature, duration, gas ambient)

MicroFab Piezoelectric Inkjet Printer



Solar Cells with Printed Contacts

	1st	2nd: Thicker contacts	3rd: Fire- Through
Line thickness:	10 μm	15 μm	15 μm
Line width:	400 μm	250 μm	220 μm
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			



Spray based processing has produced a 12% efficient cell

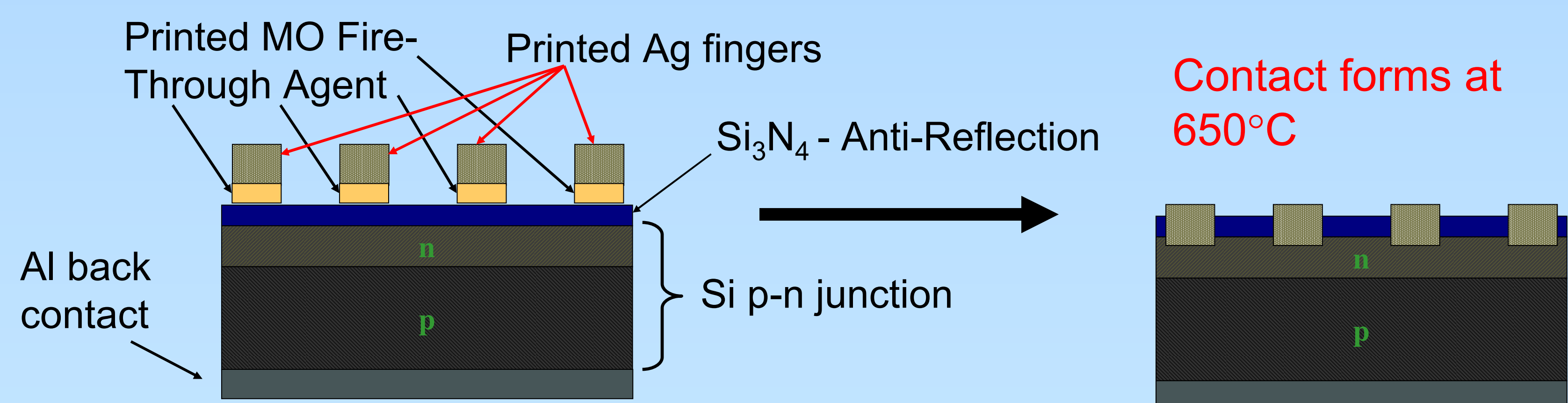
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Ag Printing with MO Ink

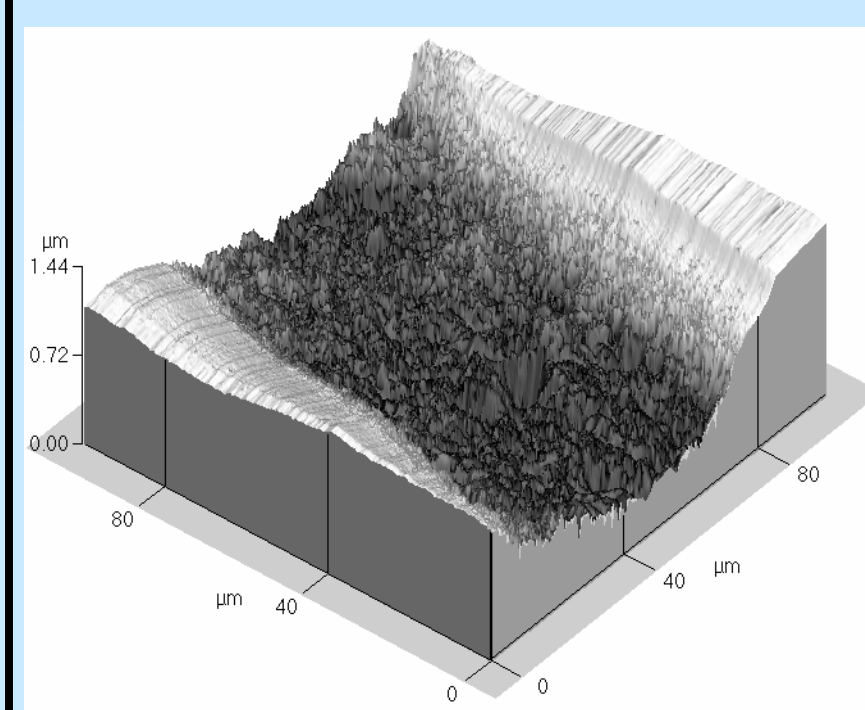
Ink: MO Ag complex + solvent + surfactant, 25% Ag by weight loading

- Ag Deposition rate: 1 μm /pass
- Substrate temp: 180°C
- Resolution: 85 μm for 1 μm thick line, 220 μm for 15 μm thick line
- Resistivity: 2.2 $\mu\Omega\cdot\text{cm}$ (1.6 $\mu\Omega\cdot\text{cm}$ for bulk Ag) Screen Printing produces 10-20 $\mu\Omega\cdot\text{cm}$ after firing

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 1 μm deep, 70 μm 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.