What are Metal-Complex Inks?
- New class of non-particle based inks
- Metals are suspended in solution as cations
- Metals “precipitate” out to form continuous metallic films upon annealing at low temperatures

What are the benefits?
- Dense films (up to 93% of bulk metal)
- High conductivity (up to 80-90% of bulk metal)
- Screen printable
- Ink Jet compatible with no particle clogging
- Low annealing temps (160 °C – 300 °C)

Compared with particle-based pastes:
- 22% less Ag
- 33% less cost

Two Types of Metal Inks

- **Nanoparticle Inks**
  - Particle in suspension
  - Evaporation of solvent
  - Contributes to poor passivation due to high porosity

- **Metal-complex Inks**
  - Molecule in solution
  - Metal species are cations
  - Precipitate onto surface upon annealing

Initial Tests on PV Surfaces

**Poly-Si/SiO₂ Contacts**
- Non-optimum screen-printed Ag Metal-Complex Ink
- Anisotropic Ag Metal-Complex Ink
- Annalized in air 160 °C – 300 °C
- HF etch prior to printing
- Good screen printing fidelity
- Dense honeycomb-like metal film, but still quite porous
- Low recombination: \(J_{\text{op}} = J_{\text{field}}\)
- Poor contact resistivity: Ohmic, but very high resistance

**TCO Contacts**
- Good adhesion to TCO
- Low contact resistivity to ITO
- No dielectric blocking layer detected

**ITO (10 nm)/Poly-Si/SiO₂ contacts**
- Excellent Metal Resistivity
  - Thin metallic layers 175 nm – 250 nm
  - \(\rho_{\text{metal}} = 3.7E-8 \Omega\cdot m \approx 2.4 \times 10^3\) ohm-m
  - Non-uniform coverage especially over the pyramid tips

**Excellent Passivation Preservation**
- The metal-complex inks do not aggressively etch the poly-Si surface
- The low-temperature annealing conditions preserve the field passivation (< 300 °C)
- \(J_0\) is preserved under the metal
- \(J_0\) is preserved in the field region
- \(J_{\text{op}} - J_{\text{non-metal}} < 1 A/cm²\)

**Photoluminescence Image (1/20 s)**
- \(iV_{\text{oc, metal}} \approx 720 mV\)
- \(iV_{\text{oc, field}} \approx 730 mV\)

**Conclusions:**
- Metal-complex inks are a promising new path for PV contacts to lower cost, Ag usage and improve passivation.
- Dense, thin films
- High metallic conductivity
- Low contact resistivity
- High passivation preservation under the metal
- Low-temperature anneal (preserves \(J_{\text{op}}\))
- Need to improve screen-printing uniformity
- Need to improve direct contact to Poly-Si
- Cu-based metal-complex inks are under development

Interested in a post doc at NREL? We are looking for a post doc with experience in metallization to continue this study using Cu-based metal-complex inks. Contact Dr. David Young for more information.

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