National Renewable Energy Laboratory
Process Development and Integration Laboratory

Materials Deposition and Device Fabrication in the Atmospheric Processing Platform

This page provides details on materials deposition and device fabrication in the Atmospheric Processing platform. The four techniques highlighted are robotic inkjet printing, large-area ultrasonic spray deposition, sputtering, and thermal evaporator deposition.

Robotic Inkjet Printing and Aerosol Spraying

This tool will greatly enhance current industry and research laboratory capabilities in printing of metal grid lines on solar cells. This technique is ideal for patterning because it is a non-contact printing process.


Close-up of the aerosol spray system within the Atmospheric Processing Platform.

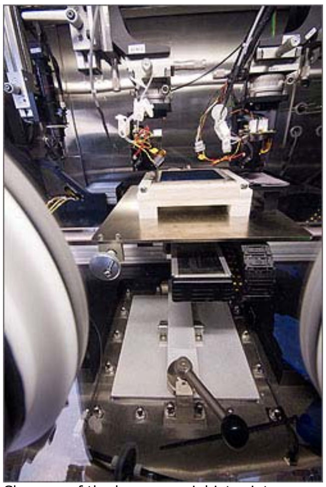
The robotic inkjet printing station enables the printing of inks at any point in creating a solar cell. A multi-head system makes it possible to mix inks in accurate proportions over 157-mm x 157-mm substrates in controlled ambient atmospheres. While depositing layers of the cell, the substrate can move in a controlled environment between inkjet and spray deposition units—even vacuum deposition—when appropriate.

Applications:
- Printing metal fingers/grid lines and dopants for junctions
- Printing the hole-injection layer and absorber layer in organic photovoltaics
- Printing narrow and interdigitated contacts
- Performing burn-throughs (in combination with rapid thermal processing)—e.g., to n-type layers in silicon solar cells through the antireflection coating
- Printing metal top contacts (Ni, Ag lines) for CIGS cells

Special features:
- Deposited film thicknesses from 10 nm to 20 µm
- Feature width <30 µm
- Position is accurate to within <1 µm
- Access to various atmospheres (e.g., argon, nitrogen)
- Two multi-heads
- Located in a glove box, with solvent trap and dual gas purifier for atmospheric control
- Various ink materials are available:
  - Metals—e.g., Ag, Cu, Ni, Al
  - Semiconductors—e.g., CdTe, Cu(In,Ga)Se_2 [CIGS]
  - Metal oxides—e.g., $Ba_xS_{1-x}TiO_3$ [BST], ZnO, SnO_2, SiO_x
  - Polymers—e.g., PEDOT:PSS, P3HT:PCBM
  - Commercial inks
- Inkjet and spray deposition systems are interchangeable
  - Universal platform, which will allow for other solution deposition techniques

Large-Area Ultrasonic Spray Deposition

At any point during deposition, the substrate can be moved in a controlled environment between the inkjet printing station and ultrasonic spray deposition chamber. In the glove box, single- or mixed-ink thin film can be deposited uniformly, across large areas—up to the 157-mm x 157-mm substrate standard. This technique is less expensive than inkjet printing for depositing uniform (i.e., non-patterned) layers.


Close-up of the large-area inkjet printer within the Atmospheric Processing Platform; the sample access port to the linear-motion transport system is in the foreground.

Applications:
- Depositing thin films
- Depositing absorber layers for CdTe, CIGS, or other materials
- Depositing transparent conducting oxides

Special features:
- Thicknesses are typically up to 20 µm
- Multi-head spray
- Located in a glove box, with solvent trap and dual gas purifier
- Position is accurate to within <1 µm
- Various ink materials are available:
  - Semiconductors—e.g., CdTe, CIGS
  - Metal oxides—e.g., BST, ZnO, SnO_2, SiO_x
  - Metals—e.g., Ag, Cu, Ni, Al
  - Polymers—e.g., PEDOT:PSS, P3HT:PCBM
  - Commercial inks
- Inkjet and spray systems are interchangeable
  - Universal platform, which will allow for other solution deposition techniques

Sputtering

Sputtering involves deposition performed in vacuum, for depositing transparent conducting oxides (TCOs), contacts, and other materials. This chamber can use a single target as well as multi-source sputtering. The capability includes research on TCOs and other layer compositions and their performance in conjunction with layers deposited at atmospheric conditions.

Applications:
- Producing sputtered contacts
- Depositing TCOs, absorber materials, and antireflective coatings (e.g., SiN_x)
- Using shadow masks for photovoltaic cell contacts

Special features:

- Has five sources: one large-area rectangular gun and four 3-inch circular guns
- Environment is vacuum (<10^{-6} torr)
- Provides uniformity over a coated area (<±6%)
- Access to process gases (Ar, O_2, Ar/H_2) with flow ranging from 0 to 100 sccm
- Heater well goes up to 400°C
- Multiple viewports (can be used for optical characterization)
- Layer thicknesses can be whatever is desired

The sputtering chamber on the Atmospheric Processing Platform.

Thermal Evaporator Deposition

The thermal evaporator uses evaporation to deposit layers at any point during the process of creating a solar cell. For air-sensitive source materials, the thermal evaporator source material can be loaded through the glove box.

The system uses electrical resistive heating to vaporize a source material in vacuum. The evaporated (or sublimated) material is deposited as it condenses on cooler surfaces.

This system uses thermal evaporation, where a source material is attached to a refractory-metal filament and is melted by high current flowing through the filament. An alternative approach is to use a "boat" made out of refractory metal that contains material to be evaporated; current passes through the boat to melt a source material.

Glove box (right) for loading sources into the thermal evaporator (left) connected to the central vacuum robot (far left) in the Atmospheric Processing platform.

Applications:

- Depositing materials typically deposited by evaporation
- Depositing air-sensitive materials, such as Ca/Al or Ba/Al layers in organic photovoltaic cells
- Using shadow masks for photovoltaic cell contacts

Special features:

- Samples are under vacuum (<10^{-6} torr)
- Film thickness monitored by thickness monitor
- Equipped with at least two viewports (can be used for optical characterization)
- Can heat a substrate to 200°C
- Has a multi-source of four boats or coils
- Integrated glove box for loading air-sensitive sources

Contact Maikel van Hest for more details on these capabilities.