Docket #: S16-376

Ultrafast, scalable fabrication of mechanically robust perovskite films

Stanford researchers have developed a new way to deposit robust and efficient photoactive perovskite materials in open-air and at rapid linear processing rates in excess of 1 cm/s. By coupling ultrasonic spray coating to the reactive environment of a plasma, this one step process minimizes manufacturing speed and the volume of raw materials without any external heating, while resulting in the world's toughest perovskite thin film. Atmospheric plasma is used to rapidly cure photoactive perovskite films in ambient air, resulting in thin films with enhanced mechanical integrity. This method, Rapid Spray Plasma Processing (RSPP), enables deposition of metal halide perovskite films in open air at an ultrafast linear processing rate. The atmospheric plasma system can easily be adopted and adapted on a roll-to-roll or sheet coating processes.

Figure

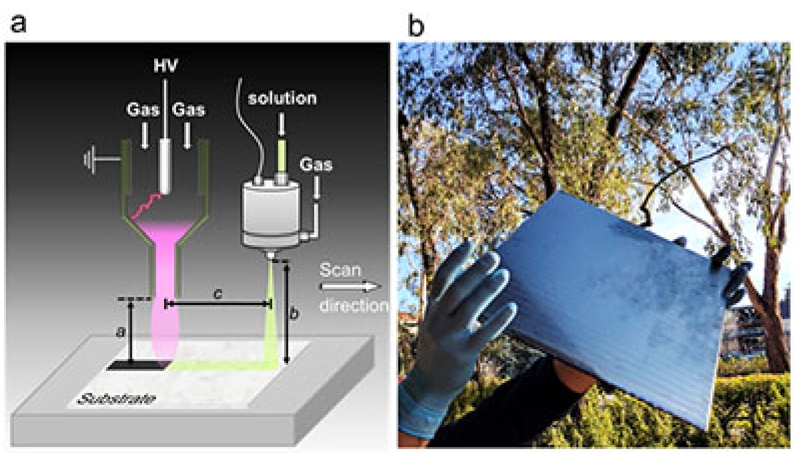

Figure description -Material deposition system and $MAPbI_3$ sample picture. (**a**) Atmospheric plasma deposition system for the synthesis of perovskite films. *a* is the plasma nozzle-to-substrate distance, *b* is the spray nozzle-to-substrate distance and *c* is the plasma nozzle-to-spray nozzle distance. (**b**) Photograph of a $MAPbI_3$ film deposited by RSPP on a 930 cm^2 glass in under 4 min.

Stage of Research

- **Experimental Results** - In an open air environment, films were sprayed and immediately exposed to an atmospheric plasma to form crystalline and photoactive metal halide perovskite. No additional annealing or post-deposition processing is required. Furthermore, RSPP has a high conversion yield; in contrast to spin coating which may require up to 50 ?L/cm^2, RSPP requires around 1 ?L/cm^2.
- **Device was capable of obtaining 13% PCE and a V_{OC} of 1 V in an inverted PSC**

Applications

- **Photovoltaic device**
- Other applications: Light-emitting device, a ferroelectric device (BaTiO3), a superconductor device (YBaCuO3) (broadly speaking, ionic conductivity)

Advantages

- This technology addresses several challenges that need to be overcome within the field of perovskite photovoltaics, particularly with regards to material synthesis and device reliability:
- Synthesis:
  - **One step deposition process**: No additional step is required.
  - **High conversion yield**: Almost 100% of the sprayed solution is instantaneously converted into crystalline perovskite.
  - **High-rate deposition**: With a linear deposition rate of >1 cm/s, this process forms the perovskite in less than one-hundredth the time of typical solution-processed material.
  - **Open air**: Deposition occurs in an open-air environment and at atmospheric pressure, unlike typical solution-processed material.
  - **Can tolerate humid conditions**: Despite the presence of >45% relative humidity during synthesis, the material performs competitively with other methods.
  - **Low cost raw materials**: Raw materials usage is significantly lower (50x) compared to the spin-coated method due to a very high conversion yield. In addition, the plasma is operated with compressed air, further promoting an inexpensive process.

- Thermomechanical Reliability:
  - **Fracture Toughness**: the formed perovskite shows outstanding mechanical properties with a tenfold increase in fracture toughness compared to typical solution-processed material. The near-instantaneous cure results in an extremely tough grain structure, which is significantly more resistant to fracture. This improvement in perovskite reliability is particularly important to prevent the device from mechanical failure due to stresses that are introduced during device fabrication, installation, cleaning and throughout the operational lifetime via thermal cycling and external forces such as wind and precipitation.
- Upscaling:
  - **Roll-to-roll manufacturing**: a special consequence and an additional advantage based on the setup of the method is a process which is extremely amenable to roll-to-roll and high volume manufacturing. Integration into tandem devices becomes feasible as well, where deposition on module-scale silicon is easily achievable.
  - **Industrially Relevant**: Atmospheric plasma machinery is commonly used in industrial settings, and the process is adaptable to manufacturing-scale equipment. Without the need for any external heating source or other equipment to form the perovskite, this technology is readily adaptable to large-scale processing.

Publications

- Florian Hilt, Michael Q. Hovish, Nicholas Rolston, Reinhold H. Dauskardt. **Rapid Processing of Robust Perovskite Photovoltaics in Air** (*under Review*).

Patents

- Published Application: 20180204709
- Issued: 10,636,632 (USA)

Innovators

- Reinhold Dauskardt

- Florian Hilt
- Nicholas Rolston
- Michael Hovish

Licensing Contact

Jon Gortat

Licensing & Strategic Alliances Director for Physical Science

Email