Fabrication of perovskite solar cells with just a piece of paper? A new method tells you how!

Perovskite semiconductor solar cells are a very exciting photovoltaic technology possessing similar efficiencies to silicon but cast or printed in thin films via liquid inks. A new method that uses a simple sheet of paper to deposit the perovskite films that does without any expensive equipment at all has been developed by a team from Tor Vergata University and University of Zanjan. The trick to achieve high performance with this remarkably cheap method is to soak the paper applicator in anti-solvent which almost doubles efficiencies compared to when using it dry, reaching 11% on flexible plastic substrates. Paper, compared to other soft applicators, possesses the right porosity and smoothness for deposition of high quality perovskite films.

Perovskite semiconductor solar cells are a very exciting photovoltaic technology because they possess similar power conversion efficiencies to those based on conventional silicon but can be cast in thin films via precursor inks providing benefits in manufacturing. Most perovskite films in laboratories around the world are deposited through spin coating which guarantees high control on film thickness as well as morphology. However, most of the ink is expelled during deposition and wasted. There has been an effort in developing coating techniques for deposition over large areas. The most efficient solar cells fabricated via spin coating involve adding drops of anti-solvent (i.e. a liquid with differing properties to those used in the perovskite precursor inks) during spinning which enables to improve the morphological quality of the perovskite semiconductor films. This method is very difficult to implement when employing large area coating techniques, where the careful engineering of drying processes which involve heaters or gas flows have been preferred up to now to control morphology of the perovskite film.

An international team of researchers from Italy and Iran has published a completely new method that uses a simple sheet of paper to deposit the perovskite films that does without a spin coater or other large area techniques such as slot-die coating or blade coating. Results of their project have been published in *iScience*, the open access interdisciplinary journal from Cell Press, highlighting the recipes that are required to achieve efficient solar cells with this method.

“When I joined CHOSE labs in Rome for my internship, I serendipitously noticed that leaving a piece of cleaning paper soaked in solvent over a wet perovskite precursor film, it turned brown turning in what looked like a rather promising perovskite semiconductor film. My supervisor in Rome, Prof. Brown, suggested I developed a coating method based on this discovery during my time there” described Nazila Zarabinia, first author of the work. “We worked on trying different soft applicators: the one that work best was paper possessing the most beneficial properties of porosity and

smoothness" she added. The highest efficiency of a flexible cell fabricated with this Deposition via Anti-Solvent-Soaked Applicator method (termed DASSA) was 11%. The researchers believe this is a satisfying efficiency, particularly for flexible solar cells on plastic PET substrates, and utilizing a completely manual procedure. The corresponding efficiency achieved with spin coating devices with the anti-solvent method was 14.9 % so there is scope for further improvement. In the manuscript, the authors propose an automated procedure for further future optimization.

"We think this simple method will appeal to all those labs setting up a line in perovskite research who have not been able (for money or time) to buy expensive deposition equipment (a bit like manual blade coating of titania films which was widely used to enter the field in the days of dye sensitized solar cells) since it enables the deposition of the perovskite film incredibly cheaply. It can also be of particular interest to groups developing automated printing techniques by applying the anti-solvent, not on the perovskite film as usual, but on the applicator instead. Furthermore, it will be interesting to endeavour to extend this method also to the transport layers for full cell manufacturing." commented Thomas M. Brown, corresponding author of the work.

The researchers show that soaking the paper used as an applicator in an anti-solvent increases the power conversion efficiency of solar cells by 82% compared to the solar cells where the application of the perovskite film was carried out with a sheet of dry paper.

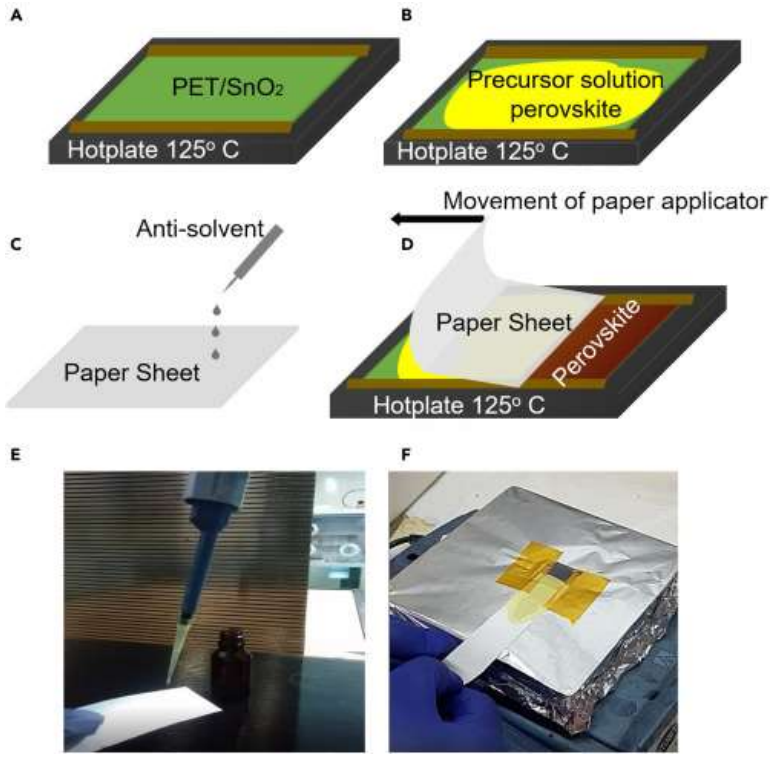

Figure 1. Schematic illustration of the deposition via an anti-solvent soaked applicator (DASSA) method. A) The PET/ITO/SnO_2 substrate with two parallel segments made of tape at the edges (the substrate is placed on a hot plate); B) spreading of the perovskite precursor on PET/ITO/SnO_2 substrate; C) soaking of the piece of paper applicator in antisolvent; D) drawing of the paper

applicator over the perovskite precursor solution and tape separators from one side of the substrate to the other; E) photograph of application of antisolvent on the piece of paper; F) photograph of soaking the piece of paper applicator in Antisolven and the DASSA method in which the piece of paper previously soaked in anti-solvent is drawn over the substrate, with the brown-coloured perovskite film being formed at the trailing edge of the applicator.

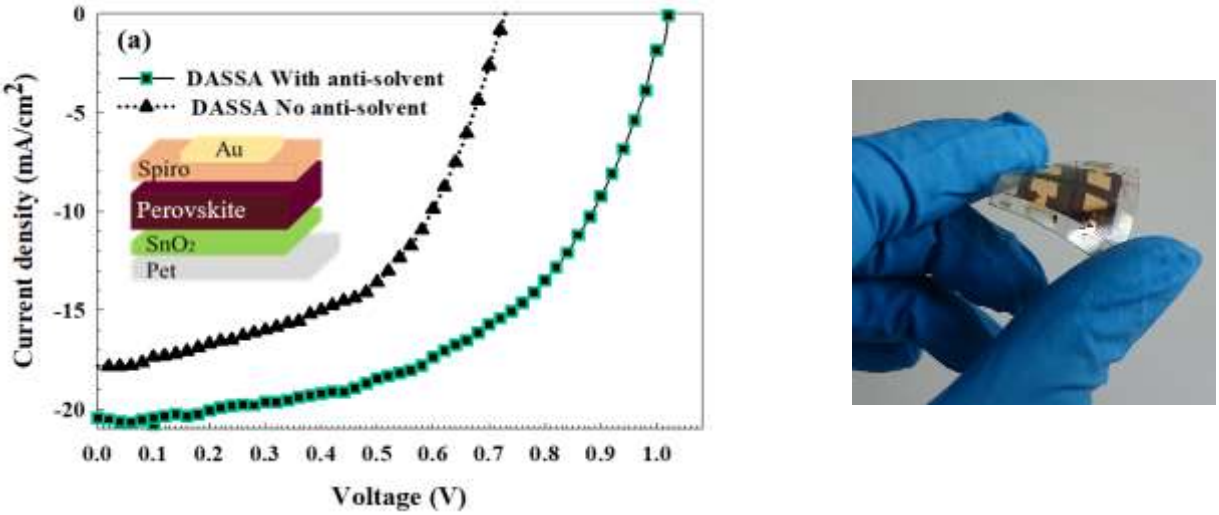

Figure 2. (left) J-V curves of solar cells where the perovskite layer was deposited with an anti-solvent soaked applicator (DASSA) made of a small sheet of paper under standard test conditions. (right) photograph of the solar cell with PET/ITO/SnO_2/perovskite/Spiro/Au architecture.

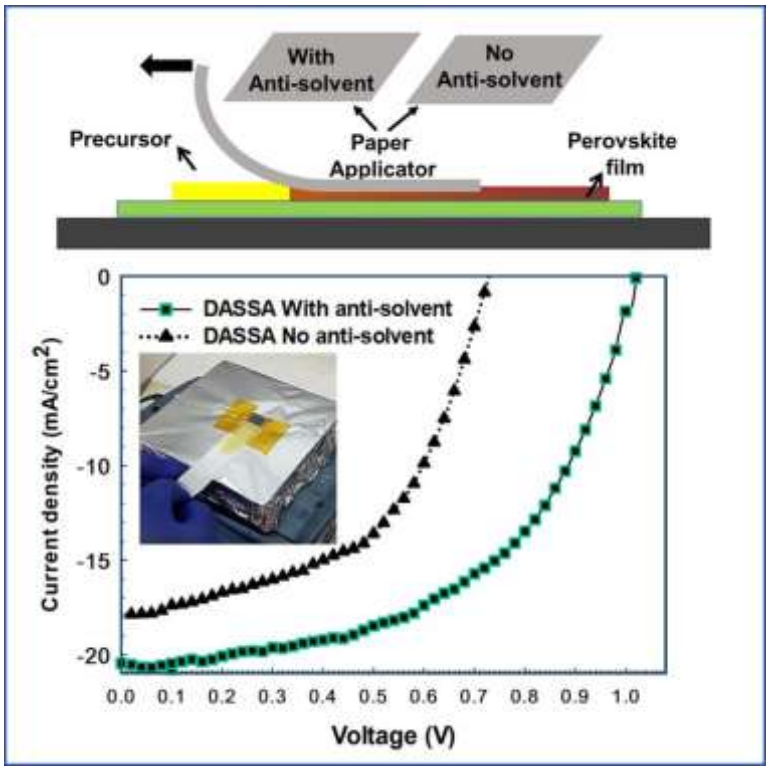

Figure 3. (top) Schematics of the method; (bottom) J-V curves of solar cells under solar illumination (inset photograph of the perovskite film being applied with a paper applicator soaked in antisolvent).

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The team members are from the Department of Physics, Faculty of Science, University of Zanjan, Iran, and CHOSE (Centre for Hybrid and Organic Solar Energy), Department of Electronic Engineering, University of Rome Tor Vergata, Italy.

The results are published in iScience (open access):

"Simple and effective deposition method for solar cell perovskite films using a sheet of paper", Nazila Zarabinia, Giulia Lucarelli, Reza Rasuli, Francesca De Rossi, Babak Taheri, Hamed Javanbakht, Francesca Brunetti, Thomas M. Brown, iScience, 25, 103712 (2022)

https://www.cell.com/iscience/fulltext/S2589-0042(21)01682-5

DOI: 10.1016/j.isci.2021.103712

A video of the full deposition process can be seen at the following link:

https://youtu.be/4qrKZtuc1Ho

About the Centre for Hybrid and Organic Solar Energy (CHOSE)

The Centre for Hybrid and Organic Solar Energy (CHOSE) was founded in 2006 from the will of the Lazio Region and the University of Rome Tor Vergata to create a center of excellence in the field of next-generation photovoltaics. CHOSE is distributed across several laboratories including the new main laboratory within the Campus of Tor Vergata University in Rome. The latter consists of a more than 400 square meter laboratory that houses equipment for the fabrication and characterization of organic, hybrid, dye sensitized and perovskite photovoltaic cells, modules and panels. More than 25-30 researchers work at CHOSE including graduate students, postdocs and staff. CHOSE has also many collaborations at the regional, national and international level. The main objectives of CHOSE consist in the development of fabrication processes for organic and hybrid organic/inorganic solar devices, the definition of a process for the industrialization of these innovative photovoltaic technologies, the technological transfer of these and the development of photovoltaic applications in collaboration with institutes and companies at both the national and international level.

Source: Centre for Hybrid and Organic Solar Energy (CHOSE), http://www.chose.uniroma2.it/en/

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About the Department of Physics, Faculty of Science, University of Zanjan, Iran

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The Faculty of Science of the University of Zanjan first launched its academic activities in winter 1990 with the establishment of bachelor of Pure Chemistry having 44 students and 6 full-time professor. Following its establishment, it started admitting students in other fields such as Bachelor of Chemistry teaching, Physics teaching, Mathematics teaching, Geology, Biology as well as Pure Chemistry, Pure Mathematics, Pure Physics, Applied Mathematics, and Applied Chemistry (both in first and second semester). Chemistry, Physics and Mathematics programs also started admitting postgraduate students for Master of Science since respectively 1994, 1994 and 2000. Currently, the faculty consists of 7 academic groups with 27 Bachelor, Master and PhD programs. The faculty has also 112 professors, and 1733 student (including 500 male and 1233 female students). Academic and research facilities of the Faculty includes: 26 laboratories and workshops, Museum of Natural History of the University of Zanjan, Library, IT Center equipped with software programs related to scientific fields of the Faculty, and computer courses.

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