Permeation Barrier - Encapsulation Systems for Flexible and Glass-based Electronics and their Application to Perovskite Solar Cells

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The success of large area optoelectronics, such as photovoltaic modules and flat panel displays, lies in the advantageous properties of the materials (e.g. organic, hybrid) and fabrication processes used (e.g. evaporation, sputtering, solution processing via printing techniques). These can be manufactured on glass or flexible substrates. One of the issues that still needs to be resolved for widespread commercialization of flexible electronics is related to the fact that lifetimes of many of the constituent materials suffer when coming in contact with ambient moisture and oxygen permeating through the substrates and device layers. To this end, the development, application and understanding of effective barrier-encapsulation systems is crucial.

Researchers at the Centre for Hybrid and Organic Solar Energy (CHOSE), Department of Electronic Engineering, University of Rome – Tor Vergata, and at the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP, have unraveled the effects of architectures, application processes, and water vapor transmission rates (WVTR) of transparent flexible ultra-high permeation barrier films (UHPBFs) applied to substrates with adhesive resins for attaining long lifetimes, and compared these with polyethylene terephthalate (PET), and glass barriers. The effectiveness of barrier/adhesive systems, quantified via calcium tests, depends on barrier orientation, adhesion, handling, defects, storage and application procedures (Figure 1). For example, barriers properly dried in inert N_2 atmosphere extend the time to calcium sensor failure by one order of magnitude and those in which an additional adhesion-promoting layer is introduced lower WVTRs by an additional factor of 5.

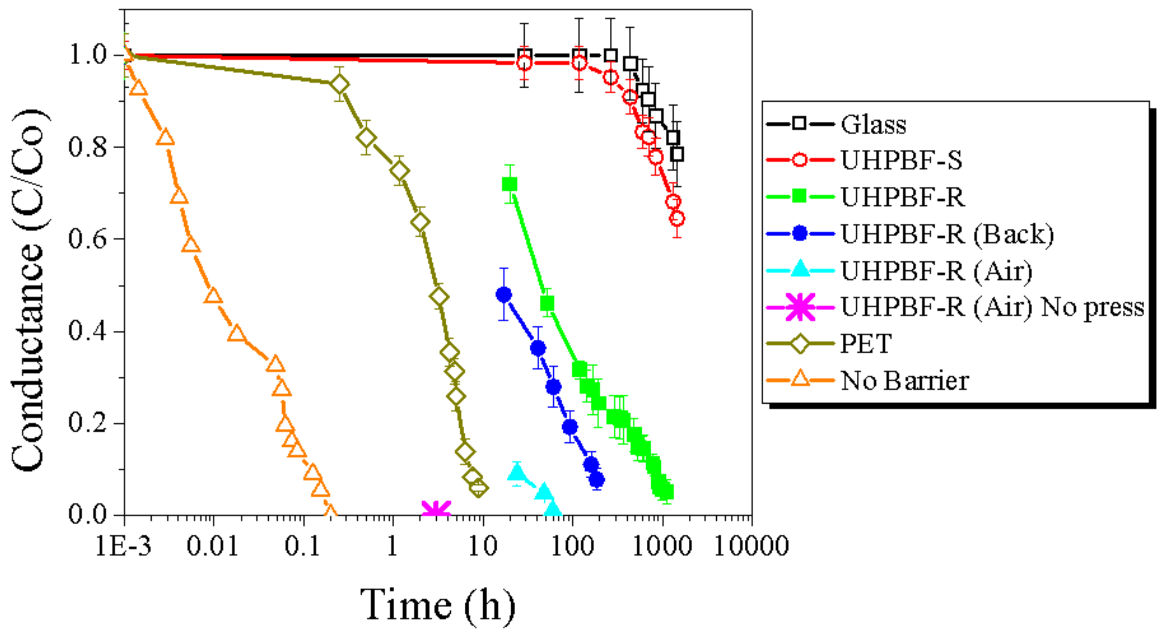

Figure 1: Normalized conductance vs time of Ca sensors encapsulated with PET, glass or flexible ultra-barrier films (UHPBF) in air using an adhesive resin. Strong variation can be noted if barriers are stored in air (instead of dried and stored in N_2 prior to application), and if properly uniformly laminated on the side coated with the multi-layer stack. UHPBF-S incorporates an additional adhesion-promoting layer on the stack.

The researchers applied permeation barriers for the encapsulation of perovskite solar cells and were able to extract a relationship between WVTRs of barrier/adhesive systems and degradation rates of solar cells (figure 2). Degradation rates as a function of WVTR follow an S-shape curve which falls exponentially when WVTRs decrease from 10^{1} to 10^{-3} g m^{-2} d^{-1}. Outside that range any gains or losses are mitigated by the tailing of the sigmoid curve relating the two parameters. Results highlight important factors which will help those developing strategies relating to encapsulation, barrier, adhesive and sealant systems, and stable optoelectronic devices on glass and flexible substrates that can be effective in cost as well as performance.

$$\mathrm{DR}\,[\%\,\mathrm{d}^{-1}] = \frac{\mathrm{DR}_{max} * \mathrm{WVTR}^{n}}{(\mathrm{WVTR}_{50})^{n} + \mathrm{WVTR}^{n}}$$

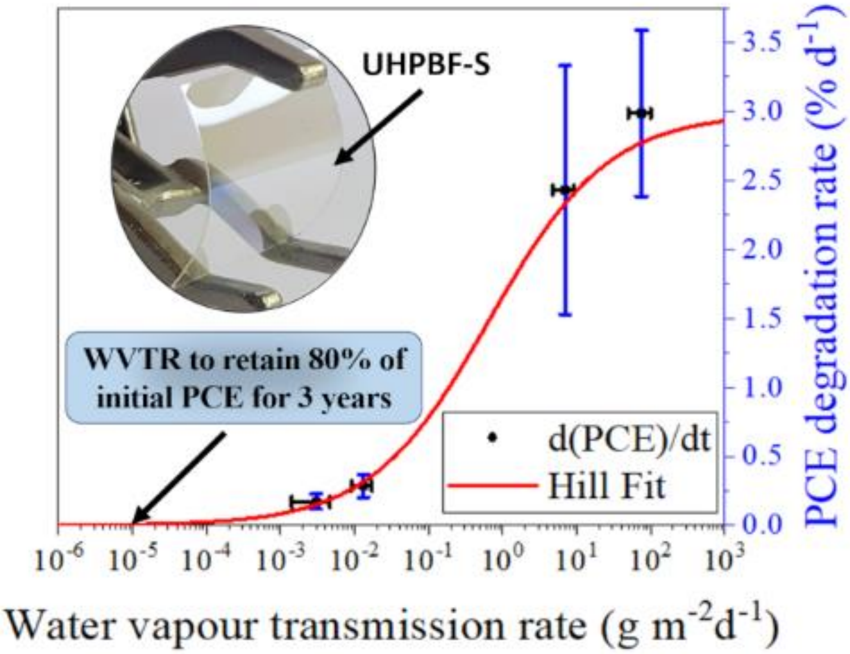

Figure 2: Degradation rates in power conversion efficiency of perovskite solar cells over time as a function of the estimated water transmission rate of different barrier/sealant systems used to encapsulate the cells and sigmoid fitting curve. The inset shows a photograph of a transparent flexible ultra-high permeation barrier film.

The results are published in Advanced Electronic Materials:

"Quantifying Performance of Permeation Barrier - Encapsulation Systems for Flexible and Glass-based Electronics and their Application to Perovskite Solar Cells", Sergio Castro-Hermosa, Michiel Top, Janardan Dagar, John Fahlteich, Thomas M. Brown, **https://doi.org/10.1002/aelm.201800978**

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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 Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP.

Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology (FEP) is one out of 72 institutes and research units of the Fraunhofer-Gesellschaft e. V., the largest European institution for applied research [26,600 employees (qualified scientists and engineers); 2.2 billion euros annual research budget]. The core competences of the Fraunhofer FEP are electron beam technologies, vacuum thin film deposition techniques (Sputtering, Evaporation and PECVD) and technologies for manufacturing vacuum-deposited small molecule organic electronic devices in sheet-to-sheet and roll-to-roll processing on pilot scale. Fraunhofer FEP has made substantial contributions for the industrial application of vacuum thin film deposition processes such as reactive-pulsed magnetron sputtering and high-rate evaporation for a wide range of high-volume application products. The institute has strong experience in the field of permeation barrier coating technologies from food packaging grade up to high-end applications using a set of large area roll-to-roll coating machines from lab (200 mm web width) up to pilot scale (600 mm web width).

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