Organic and Perovskite Solar Cells based on 3D-Printed Transparent Conducting Electrodes

Hock Beng Lee, Barkha Tyagi and Jae-Wook Kang*

Department of Flexible and Printable Electronics, Jeonbuk National University, Jeonju, Republic of Korea.

*jwkang@jbnu.ac.kr

The optimized PEDOT:PSS/Ag hybrid transparent conducting electrodes (TCEs) exhibited a sheet resistance (R_{sheet}) of ~4 Ω/□ and an optical transmittance of >80% transmittance in the UV-visible region. Moreover, the hybrid TCEs demonstrated excellent mechanical robustness and high fatigue strength. The dimensions of the PEDOT:PSS/Ag TCEs were successfully scaled up to 5 cm × 5 cm without compromising the R_{sheet} or transmittance. Large-area (3.1 cm × 0.1 cm) flexible organic solar cells (OSCs) based on the 3D-printed bottom TCE achieved a maximum power conversion efficiency (PCE) of ~8.2%. On the other hand, the optimized *a*-ITO/Ag mesh TCE shows an an R_{sheet} below 1 Ω/□ and an optical transmittance >85%. Large-area (1 cm × 1 cm) semitrasparent perovskite solar cells (PSCs) based on the 3D-printed top TCE recorded a maximum PCE of ~15.5% with >85% transmittance in near-infrared region. Moreover, the semitransparent PSCs also displayed remarkable ambient and thermal stability due to the presence of an *a*-ITO barrier (in the top TCE) that prevents moisture ingress and halide ions migration.

The multi-layer 3D direct-ink-writing (3D-DIW) technique introduced herein enables the preparation of large-area TCE with a high aspect ratio and a balanced R_{sheet}-transmittance trade-off. Through layer-by-layer printing strategy, the geometry, aspect ratio, and the fundamental properties of the Ag subelectrodes can be tailored down to the sub-micrometer scale, thus made less visible to the human eyes. The 3D printing technique introduced here shows promising potential to be used for industrial-scale roll-to-roll manufacturing of energy harvesting/storage devices.