METAL OXIDE AND LOW TEMPERATURE PROCESS BASED PEROVSKITE SOLAR CELLS AND HIGH EFFICIENCY DEVELOPMENT

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With certified highest efficiency of 22.1%, research of perovskite solar cell is being directed to ensure compatibility of stable efficiency and high stability (durability) for practical applications. Creation of low cost and large area manufacture process for industrialization is also desired in R&Ds of perovskite solar cells, in which vacuum-free and sinter-less high-speed coating technology lead to considerable reduction of process cost. Our study has been focused on development of low temperature cell fabrication process and design of high quality hetero-junction interfaces of perovskite crystals, which plays a central role in suppressing charge recombination and enhancement of voltage output and efficiency. High open-circuit voltage ($V_{oc}$) of perovskite cells (1.1-1.2V vs band gap energy of 1.6 eV) is the key advantage over existing solar cells.

Using TiO$_2$ as electron transporter and preparing defect-less interfacial structures, our triple-cation based perovskite cells give hysteresis-free high performance with power conversion efficiency (PCE) more than 20.5% (Fig.1). Good proportionality of photocurrent and light intensity relationship is confirmed without large change in voltage output against light variation. The logarithmic intensity dependence of $V_{oc}$ gave an ideality factor of 1.5~1.7, which indicates that the device can work with high efficiency and voltage even under weak indoor light. Such characteristics guarantees usefulness of perovskite device as high voltage power source not only for solar battery modules but also in applications to consumer electronics, now rapidly evolving with IoT technology.

Low temperature fabrication process enables high throughput roll-to-roll manufacture of device on flexible substrates such as plastic films. Lightweight device is always sought after for all kinds of applications. We could achieve stable efficiency up to 21.6% with high $V_{oc}$ of 1.18V by improving the continuous interfacial structure between TiO$_2$ and perovskite, which was all based on low temperature solution processes (<150°C) to prepare compact and mesoporous TiO$_2$ layers. Stability of I-V characteristics (hysteresis suppression) and durability of the high performance device can also be improved by interface structure engineering in material and film preparation. To stabilize perovskite material against thermal impacts, replacement methyammonium (MA) with formamidinium (FA) is an essential direction of R&Ds. In combination of low temperature process and FA-based perovskite materials, we conducted various experiments with use of TiO$_2$ and ZnO as electron collectors. Both of metal oxides worked with efficiency up to 19%. ZnO has an advantage as morphology-controllable non-photo-catalytic semiconductor and showed good stability of Cs-FA-MA triple cation perovskite solar cell capable of PCE 19%.

Fig. 1 Structures of a triple cation perovskite photovoltaic cell and power generation performance

References