Cathode composition greatly influences the lifetime of organic photovoltaic cells

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Organic solar cells using Ca/Ag as cathode can reach operational lifetimes of 2400h under one sun illumination, at 25°C, in a controlled atmosphere.

Recent progress in the field of organic solar cells\(^1\) suggests that industrially viable systems for small handheld devices and large-scale power generation are conceivable.\(^2\) Photovoltaic cells based on flexible, lightweight plastics promise both low production costs and large conformable devices.\(^3,4\) Although improved performance of polymer solar cells is essential to validate the field, lifetime is still the key obstacle to commercialization. Accordingly, lifetime studies are needed to develop efficient organic photovoltaics.\(^5\) We report such studies incorporating varying cathode composition and thickness conducted at the Atomic Energy Commission National Institute for Solar Energy in France (CEA–INES).

The bulk heterojunction solar cells we describe consist of a blend of methanofullerene[6,6]-phenyl C61 butyric acid methylester (PCBM) and poly(3-hexylthiophene) (P3HT) sandwiched between two electrodes. The anode was transparent indium tin oxide, and the cathode was either LiF/Al or Ca/metal. The best power conversion efficiencies were obtained for cells based on the (1:1, w/w) P3HT:PCBM ratio, with LiF/Al cathodes (0.28cm\(^2\) area) and post-production thermal annealing. Following calibration using a monocrystalline silicon solar cell, this setup yielded power conversion of 4.1% for AM1.5 (the standard spectrum of sunlight at the earth’s surface), 100mW/cm\(^2\). The short-circuit current density, \(J_{sc}\), was 10.9mA/cm\(^2\), and the fill factor (FF) reached 0.64.

One method of studying and predicting the lifetime of polymer solar cells is accelerated lifetime measurement,\(^3\) which assesses device performance at elevated temperature but otherwise normal conditions. Using this method, we studied the influence of the cathode on the aging and stability of solar cells.

![Figure 1. This graph presents efficiency data on up to 150h of aging for P3HT:PCBM solar cells using three types of cathodes—Al (squares), LiF/Al (circles), and Ca/Ag (stars)—under AM1.5, 100mW/cm\(^2\) illumination, at 70°C.](image)

The study was carried out under an inert atmosphere and at a temperature of 70°C imposed by the illumination. During the degradation process, all of the parameters that can be extracted from an \(I(V)\) curve were recorded, including \(J_{sc}\), FF, open circuit voltage (\(V_{oc}\)), efficiency (\(\eta\)), serial resistance (\(R_s\)), and shunt resistance (\(R_m\)). We focus here on \(J_{sc}\) as a key parameter in degradation.

We monitored the degradation processes of solar cells with different cathodes for more than 600h. We extracted and recorded all photovoltaic parameters from \(I(V)\) curves every hour. The cells were kept in short circuit during the experiment, even when no \(I(V)\) curve was recorded. Figure 1 shows the variation in the four photovoltaic parameters.

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Three types of cells were tested for aging: one with a simple Al cathode, one with a LiF/Al cathode known to enhance solar cell performance, and one with a Ca/Ag cathode. As we did not observe any change in the absorption spectra of the P3HT:PCBM films, i.e., the polymer did not visibly degrade, we assume that the nature of the cathode plays a preponderant role in the long lifetime of organic solar cells. The cells used for this experiment purposely represent average power conversion efficiency. Initially, the cells performed similarly, regardless of cathode composition. When exposed to AM1.5, 100 mW/cm² illumination at 70°C, however, the behavior of the cells began to differ dramatically. As shown in Figure 1, the Ca/Ag-based cathode is more stable than the Al-based cathodes, even when LiF is introduced between the polymer and the metal. At 65°C, the efficiency of the Ca/Ag cathode solar cells is still greater than 1% after 600h of continuous work. From t=1h to 600h of illumination at 70°C, V_oc dropped to less than 15% and J_sc to less than 10%; FF was still greater than 30% (see Figure 2).

Using the thermal acceleration factor of 4 between 25 and 70°C, obtained from recent publications, we can estimate an operational lifetime of 2400h for a Ca/Ag cathode solar cell under one sun illumination at 25°C if we remove all traces of oxygen and water by encapsulation.

This study shows that cathode composition affects the stability of polymer solar cells. The aging process appears to consist in cathode aging followed by polymer aging. Accelerated lifetime measurements on different cathodes indicate the work that must be done to fully understand the aging process of organic solar cells.

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References