Organic EL television was commercialized last year. Next target of organic electronics is organic solar cell. Our group accomplished the world record conversion efficiency of 5.3% based on the fundamental research on the organic semiconductors such as ultra-high purification, nanostructure design. Moreover, 1000 h (42 days) operation of organic solar cell without degradation was accomplished.

1. Efficient Organic p-i-n Solar Cells
Having 1 µm-Thick Codeposited i-Layer Incorporating Seven-Nine (7N) Purified Fullerene

In 1991, we proposed p-i-n organic solar cells in which the i-interlayer is a codeposited film composed of p- and n-type organic semiconductors. Since i-interlayer acts as an efficient photocarrier generation layer, if this codeposited i-interlayer could be thick enough to be able to absorb entire irradiated solar light, organic p-i-n cells would show the magnitude of photocurrent density comparable to inorganic solar cells.

Unfortunately, i-interlayer has been inevitably very thin. For example, we have reported p-i-n organic solar cells in which the i-interlayer is nanostructure-optimized codeposited film composed of fullerene and metal-free phthalocyanine (C₆₀:H₂Pc). At that time, thickness of C₆₀:H₂Pc i-interlayer was limited below 180 nm since the fill factor (FF) was seriously decreased for thicker i-interlayer due to the increase of internal resistance of i-layer.

On the analogy of the case of Si which is usually purified to eleven-nine (11N), we convinced that the purity of organic semiconductors should be reached to ppm level at least in order to draw out their essential nature.

In this study, we performed the single-crystal formed sublimation under N₂ gas of 1 atm (Figure 1). Due to the gas convection, in the case of C₆₀, single crystals of the maximum size of 2 mm × 2 mm were obtained (Figure 2). C₆₀ purity was determined by the secondary ion mass spectroscopy (SIMS), which has been used for the analysis of dopants in Si wafer. Purity of C₆₀ crystals purified three times was more than 0.1 ppm, i.e., seven-nine (7N). On the other hand, purity of H₂Pc sample purified four times was five-nine (5N).

p-i-n cell structure is shown in Figure 4. p-type layer of H₂Pc, codeposited i-interlayer composed of C₆₀ and H₂Pc, and n-type layer of NTCDA, which also acts as a transparent protection layer, were successively deposited by vacuum evaporation on ITO glass substrate. Codeposited films were fabricated by the coevaporation from two separately controlled sources on the substrate heated at +80 °C.

Figure 3(a) shows the dependence of fill factor (FF) on i-interlayer thicknesses (X). Surprisingly, FF hardly decreased...
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2. Long-Term Operation for 42 Days

The conversion efficiency of organic solar cells is expected to exceed the practical level (10%) within few years. However, few studies have been made on their durability.5)

In this study, we performed the long-term operation tests reaching 1000 h in high vacuum (10^-7 Torr). White light (100 mWcm^-2) was continuously irradiated under the short-circuit condition. Gradual degradation within 100 h was observed for p-i-n cells having the structure of Figure 4. Detailed investigation revealed that the photodegradation of NTCDA, which acts as the transparent n-type layer, occurred.

Therefore, we replaced NTCDA with Al-doped ZnO (AZO) fabricated by electron beam evaporation on organic film (Figure 6). Fabricated AZO was transparent and showed the conductivity of 10^3 Scm^-1, which is comparable to ITO. Little decrease of $J_{sc}$ and efficiency after 1000 h operation was confirmed (Figure 6). This is good news for the practical application of organic solar cells.

References


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