

Investigation of organic thermovoltaic devices by utilizing a layered structure of pentacene and fullerene thin films

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1. Introduction

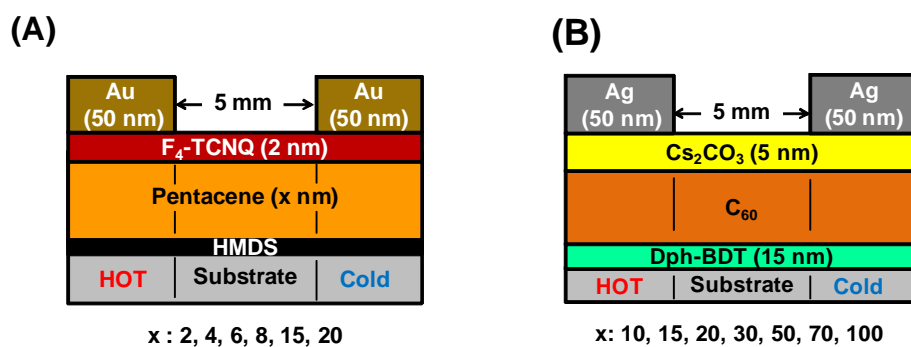
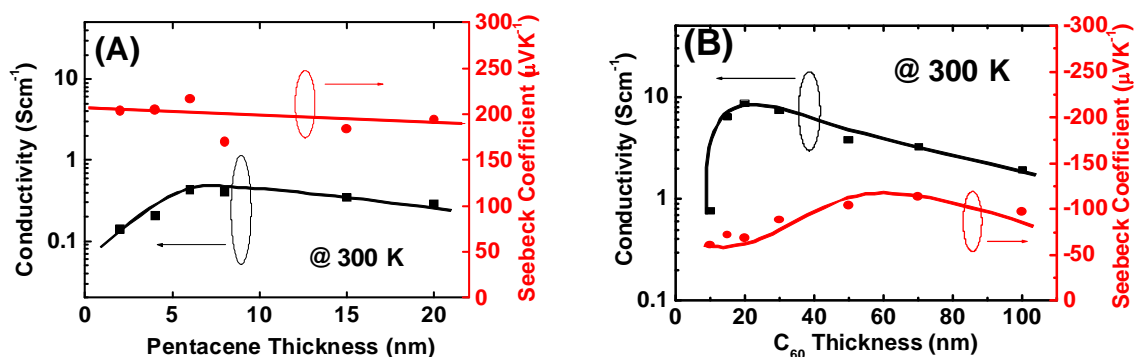
Organic semiconductors have been attracting considerable attention on account of their potential for flexible, low-cost, and large-area applications such as light-emitting diodes, solar cells, and thin-film transistors.^[1] The spectacular progress in organic optoelectronics leads us to expect possibility for a thermoelectric application utilizing organic thin films, which may comprise of different scheme from that of conventional inorganic devices. However, a thermoelectric performance of organic materials is significantly lower than that of inorganic materials due to a small number of studies with organic thermoelectric devices.^{[2], [3]} In this study, we have improved thermoelectric performance of small molecule-based organic semiconductors by utilizing a novel device structure which is alternative to conventional doping method.

2. Result and Discussion

We utilized pentacene and C₆₀ as a *p*- and a *n*-type active layers, respectively, due to their high carrier mobilities. Moreover, we chose 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F₄-TCNQ) and cesium carbonate (Cs₂CO₃) as acceptor and donor materials, respectively. We deposited these materials on hexamethyldisilazane (HMDS) modified glass substrates in *p*-type devices and 2,6-diphenylbenzo[1,2-b:4,5-b']dithienophene (DPh-BDT) modified glass substrates in *n*-type devices, and fabricated a bilayer structure composed of *p*- or *n*-type active layers capped with dopant layers as shown in Fig. 1(A) and (B). For evaluating thermoelectric performances, we measured the electrical conductivity and Seebeck coefficient of these devices, and calculated the power factor.

Figure 2(A) and (B) show the electrical conductivity and the Seebeck coefficient of *p*- and *n*-type devices as a function of the active layer thickness. We successfully obtain high power factors for both *p*- and *n*-type samples, respectively: The power factor of *p*-type pentacene was 2.0 $\mu\text{Wm}^{-1}\text{K}^{-2}$;^[4] the power factor of *n*-type C₆₀ was 5.6 $\mu\text{Wm}^{-1}\text{K}^{-2}$. These power factors are ten times higher than that of conventionally prepared doped films.

In case of the doped devices, the more doping concentration increases, the more a carrier mobility of the device decreases due to impurity scattering. On the other hand, with the bilayer configuration, charge carriers are generated at the charge transfer (CT) interface between the active layer and the donor layer. The carrier transport in the intrinsic active layers within the bilayer configuration is supposed to be free from impurity scattering, which should lead to an improved mobility and hence a high electrical conductivity.

Fig. 1 The cross-sectional views of (A) *p*-type and (B) *n*-type bilayer structuresFig. 2 Thermoelectric performance of (A) *p*-type and (B) *n*-type bilayer devices as a function of an active layer thickness.

3. References

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4. Acknowledgement

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