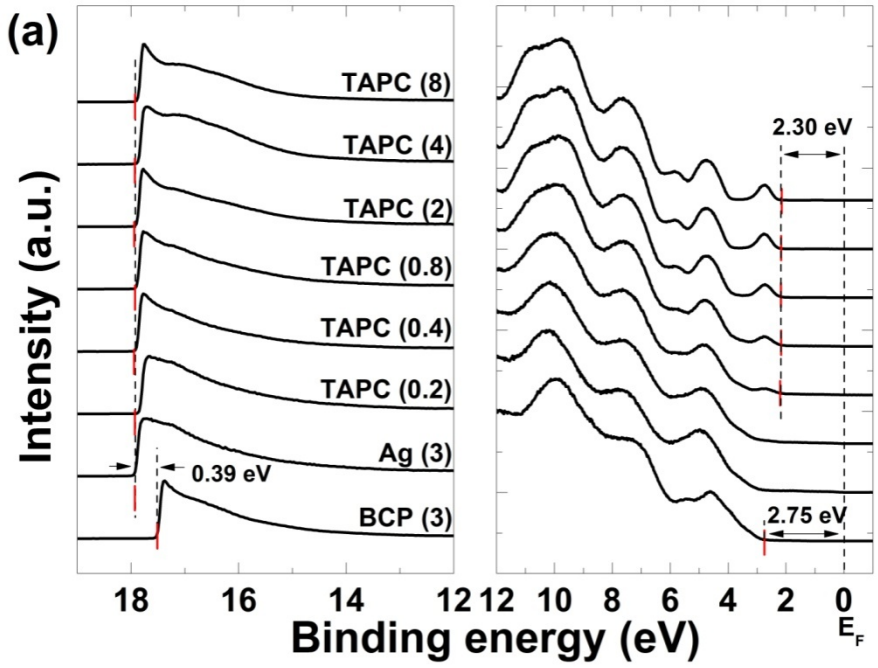
Correlation of the electronic structure of an interconnection unit with the device performance of tandem organic solar cells

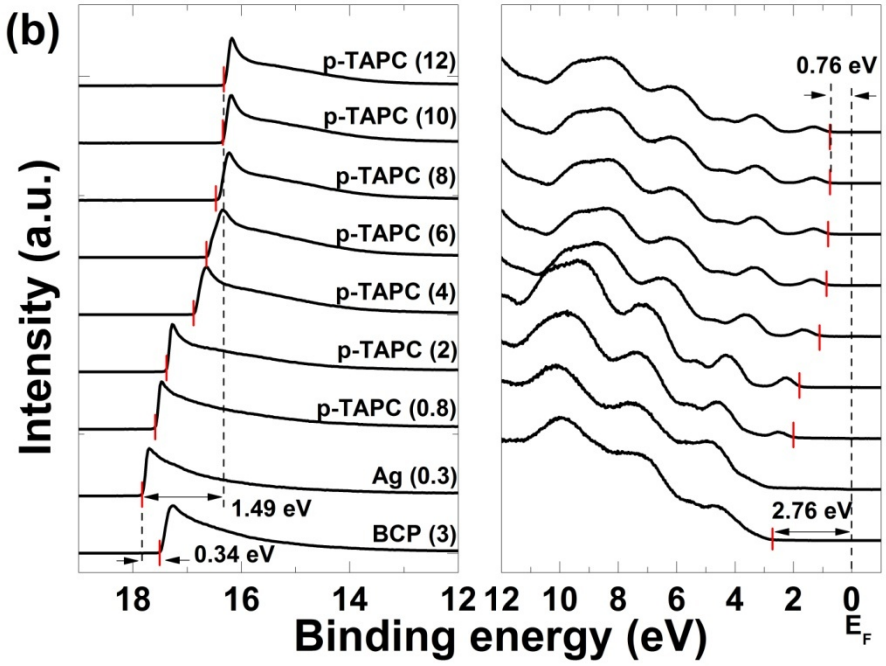
Hyun-Sub Shim[a], Jung-Hung Chang[b], Seung-Jun Yoo[a], Chih-I Wu[b] and Jang-Joo Kim[a,*]

[a] Department of Materials Science and Engineering and the Center for Organic Light Emitting Diode, Seoul National University, Seoul 151-74, South Korea. Fax: 82 889 8702; Tel: 82 2 880 7893; E-mail: jjkim@snu.ac.kr

[b] Department of Electrical Engineering and Graduate Institute of Photonics and Optoelectronics, National Taiwan University, Taipei, Taiwan 10617, ROC

Figure S1 shows the evolution of the UPS spectra near the onset (left side) and the valence band region (right side) as a function of the thickness for different doping concentrations. All binding energies are referenced to the Fermi level (E_F) of ITO. The vacuum level (E_{VAC}) shift, depletion width (W_D) of the *p*-HTL and the positions of the HOMO levels are analyzed with increasing layer thickness and the results are indicated using the vertical lines in the figures. The vacuum level and the HOMO level positions are determined by interpolating the shoulder of each signal and the background of the spectra.[1, 2] The vacuum level shift between BCP and Ag is in the range of 0.34 eV~0.4 eV, and the E_F-HOMO level of BCP is around 2.78 eV for all the doping concentrations. When the undoped layer is used, there is no vacuum level shift at the Ag/TAPC interface (Figure S1a). Interestingly, the onset and the HOMO level positions move toward lower binding energies when the *p*-HTL is introduced, which become larger as the doping concentration increases (Figure S1b-d). Moreover, the saturation thickness of the *p*-HTL becomes narrower with increasing doping concentration. With a doping concentration of 5 mol.%, the UPS data was not obtained due to the low carrier density in the doped layer.


(a)
Intensity (a.u.)
TAPC (8)
TAPC (4)
TAPC (2)
TAPC (0.8)
TAPC (0.4)
TAPC (0.2)
Ag (3)
BCP (3)
0.39 eV
2.30 eV
2.75 eV
18
16
14
12
12
10
8
6
4
2
0
E_F
Binding energy (eV)


(b)
Intensity (a.u.)
p-TAPC (12)
p-TAPC (10)
p-TAPC (8)
p-TAPC (6)
p-TAPC (4)
p-TAPC (2)
p-TAPC (0.8)
Ag (0.3)
BCP (3)
1.49 eV
0.34 eV
0.76 eV
2.76 eV
18
16
14
12
12
10
8
6
4
2
0
E_F
Binding energy (eV)

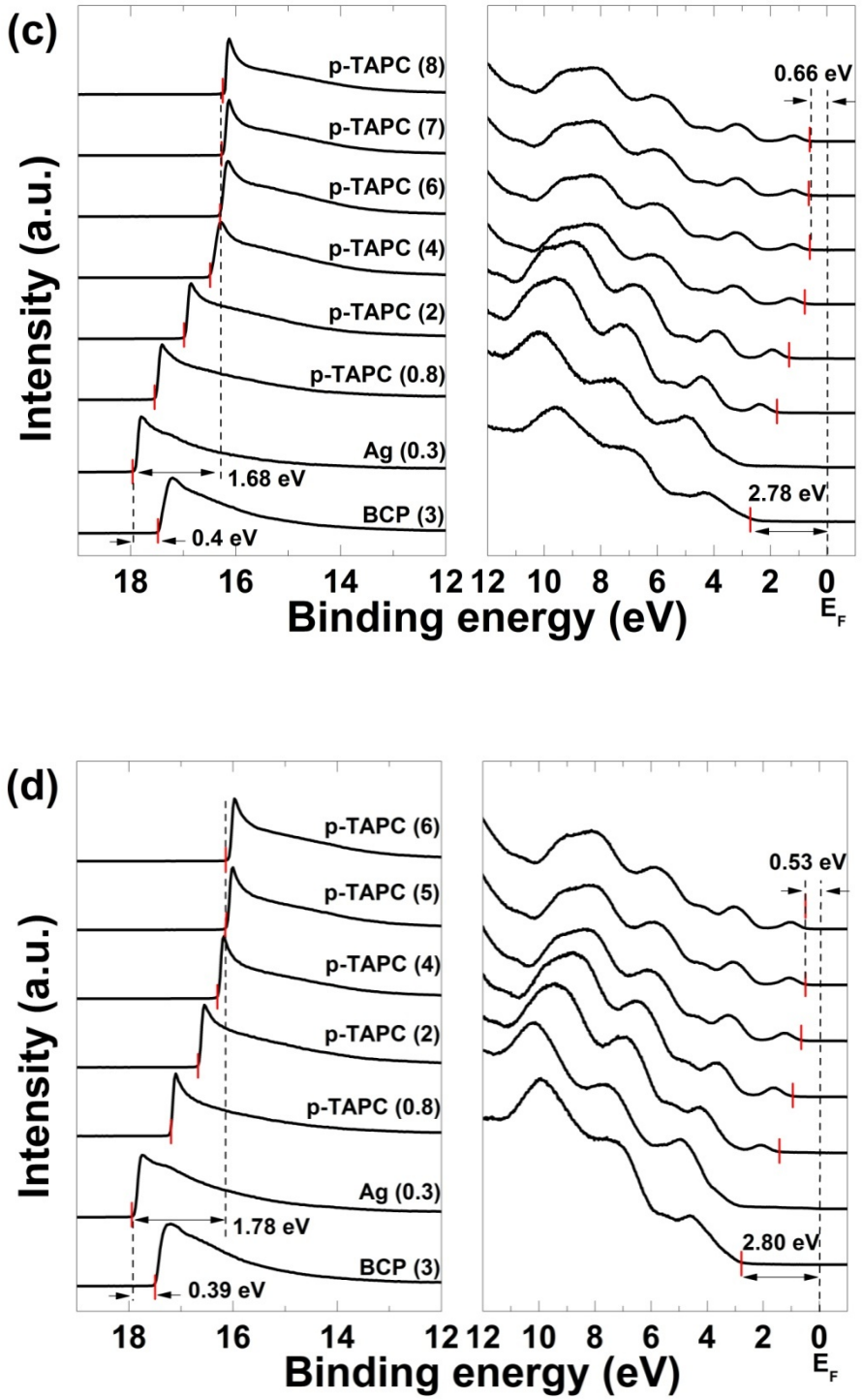


Figure S1. UPS measurements of BCP(3 nm)/Ag(0.3 nm)/*p*-TAPC with different doping concentrations of (a) 0 mol.%, (b) 11 mol.%, (c) 18 mol.% and (d) 25 mol.%. The vertical lines represent the changes in the vacuum level and the HOMO level.The thickness of each layer is indicated in the brackets with a nm scale.

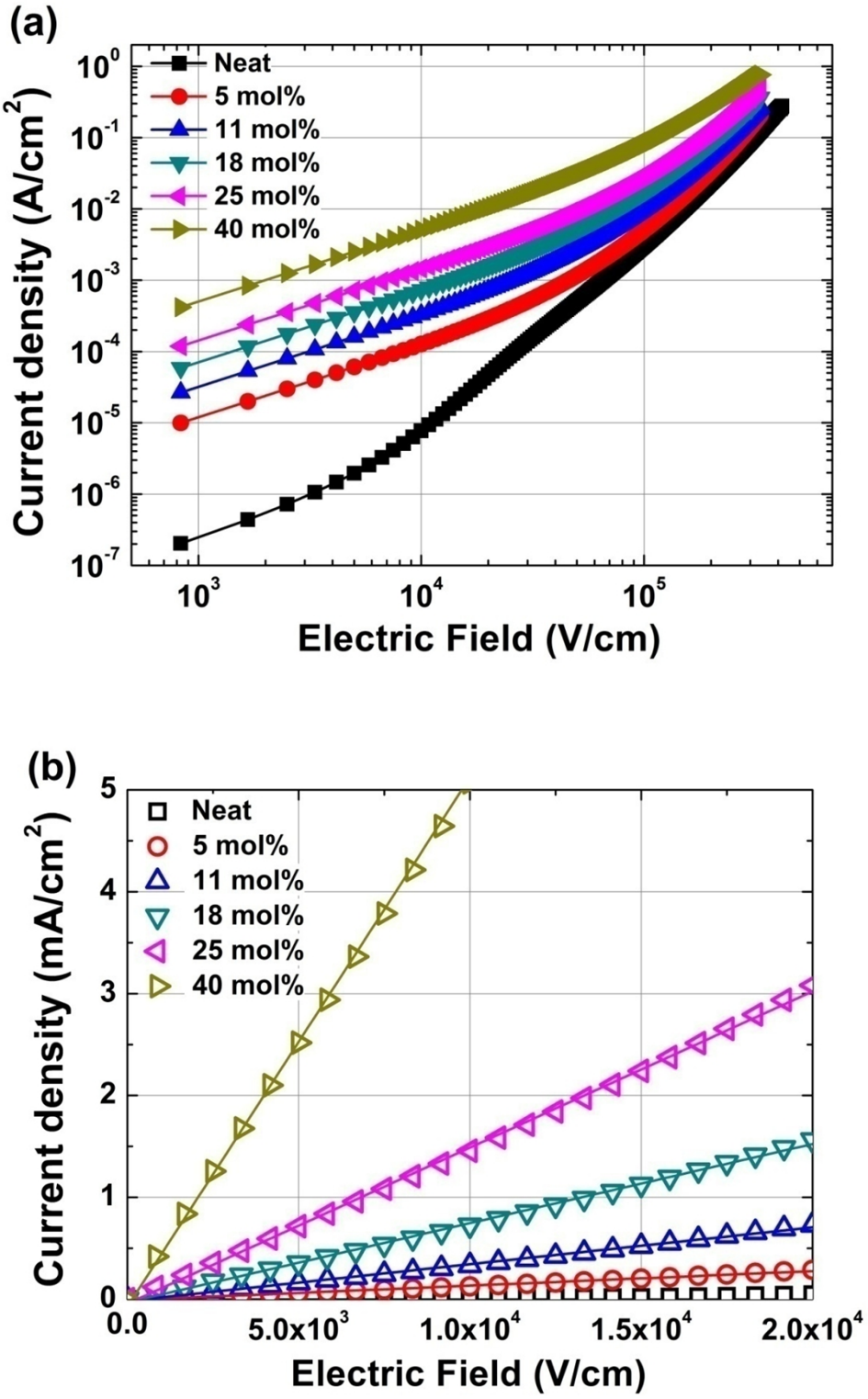


Figure S2. (a) The *J-F* characteristics of $Mp^{++}p^{+}p^{++}M$ devices with different doping concentrations of *p*-TAPC in the full scale and (b) linear *J-F* characteristics with different

doping concentrations in the ohmic region. The open symbols represent measured values and the solid lines indicate linear fits.

1. J.-H. Lee, P.-S. Wang, H.-D. Park, C.-I. Wu, J.-J. Kim, *Org. Electron.* **2011**, 12, 1763.

2. I.-W. Wu, Y.-H. Chen, P.-S. Wang, C.-G. Wang, S.-H. Hsu, C.-I. Wu, *Appl. Phys. Lett*. **2010**, 96, 013 301.