Energy level shift at organic semiconductor interface by gold nanoparticles

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Interface states or charges trapped at interface play an important role in semiconductor device mechanism. Organic semiconductors have closed shell structure and therefore, no dangling bonds, which cause large interface state density in inorganic semiconductors. It has been reported that the gold nanoparticles deposited sparsely at an electrode/organic semiconductor interface can lower the carrier injection barrier drastically due to the charged nanoparticles. The nanoparticles embedded in between a front cell and a back cell of tandem organic photovoltaics can increase the open circuit voltage (V_{oc}). In the present study, the technique to control the number density (d_n) and particle size (l) of the gold nanoparticles at organic semiconductor interface by arc plasma gun (APG) was established. And it was investigated how the particle size and number density affect the V_{oc}.

Based on our experiment results, the V_{oc} of tandem cell (d_n: 6×10^{16} m^{-2}, l: 1.6 nm) is 0.86V, which is almost doubled compared with the reference single cell. The stacked cell without gold nanoparticles showed almost identical V_{oc} of single cell. The d_n and l of the gold nanoparticles deposited by APG can be changed with the pulse voltage, pulse number and pulse time interval. As shown in Fig.1, the Voc showed abrupt increase around $4\sim5\times10^{16}$ m^{-2} and reached plateau at 7×10^{16} m^{-2} area. To discuss the particle size dependence, the V_{oc} vs Au particle size was analyzed when the number density was $4\sim6\times10^{16}$ m^{-2}. It was observed that the V_{oc} decreased as the Au size increased (Fig.2). In order to find out which factor can result to this dependence, the work function of CuPc was measured by photoelectron yield spectroscopy (PYS). The work function difference (ΔWF) on the particle size deposited onto the CuPc by APG was plotted in Fig.3. The result showed that ΔWF decreased as the particle size increased. And this is contributed to the electrical bilayer formed on the metal/organic interface, and this local electric field could shift the vacuum level. In this research, we also try to calculate the relation between particle size and Voc to analyze the dependence accurately.

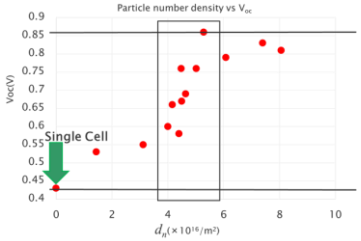

Figure1 V_{oc} and Au number density

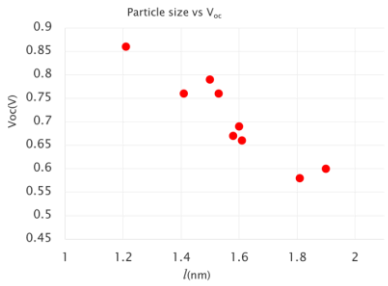

Figure2 V_{oc} and Au particle size (number density 4-6×10^{16} m^{-2})

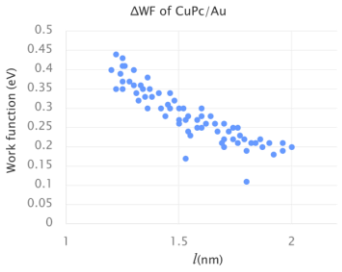

Figure3 ΔWF and Au particle size