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**Electron Spectroscopy of Organic Thin Film FET Structures**Toshihiro Shimada<sup>1</sup> and Atsushi Koma<sup>2</sup><sup>1</sup> PREST, Japan Science and Technology Corporation (JST) and The University of Tokyo, Department of Chemistry  
Phone:+81-3-5841-7595 Fax:+81-3-5689-0654 E-mail: [shimada@chem.s.u-tokyo.ac.jp](mailto:shimada@chem.s.u-tokyo.ac.jp)

Bunkyo-ku, Tokyo 113-0033, JAPAN

<sup>2</sup> The University of Tokyo, Department of Chemistry

Phone:+81-3-5841-4353 Fax:+81-3-5689-0653

Bunkyo-ku, Tokyo 113-0033, JAPAN

**1. Introduction**

Novel physical properties of organic field effect transistors (FETs) are gathering much attention recently[1]. However, the electronic structures showing characteristic properties have not been studied because the nanometer-scale interfaces exhibiting those properties are buried under the gate metals and insulators and are not approachable with ordinary techniques probing the electronic structures. This difficulty can be overcome if we use thin film FET architecture (Fig.1) with thin enough organic layers. In this paper, we describe our results of the measurement of the electronic structure of the gate biased C<sub>60</sub> thin film FETs by surface sensitive electron spectroscopy techniques. It was found that the measurement induces irreversible change in the electronic structure of C<sub>60</sub>.

**2. Experimental**

Thin film FET samples were prepared by depositing C<sub>60</sub> molecules onto a interdigital line (10 $\mu$ m) and space (50 $\mu$ m) electrode pattern formed on SiO<sub>2</sub> / Si under ultrahigh vacuum. The pre-patterned substrate was mounted on a sample cartridge with three shielded electric connectors (for source, drain and gate) and was introduced to the deposition chamber. The thickness of the C<sub>60</sub> films was monitored by quartz crystal microbalance. After the deposition, the sample was transferred to the analysis chamber where the ultraviolet photoelectron spectroscopy (UPS) and electron energy loss spectroscopy (EELS) were measured. The photon source was He discharge lamp and the electron spectrometer was an angle resolved ADES-500 (Vacuum Generators). EELS was taken using EG-5 electron gun (VSW).

**3. Results and Discussions**

For the measurement of electron spectroscopies it is important to have electrically continuous organic films on the FET electrode substrate. Figure 2 shows an example of a discontinuous film (thickness 10 monolayer equivalent(ML)). The UPS spectrum changed its

position when applied gate bias voltage was altered. The amount of shift is proportional to the gate voltage, which shows the Fermi level reference in the film is gate voltage and no change in the physical properties is expected.

By improving the surface treatment of the substrate prior to the thin film growth, it was possible to obtain electrically continuous films of C<sub>60</sub>. It was found that different UPS spectra was obtained when the gate bias was changed. Figure 3 shows a result of a sequential scan (from bottom to top) increasing the absolute value of gate bias voltage (V<sub>G</sub>). A peak appears at binding energy (E<sub>B</sub>) 2 eV and the peak intensity of E<sub>B</sub> = 4eV is decreased. It seems that the change is accelerated when |V<sub>G</sub>|  $\geq$  100V. However, it was found that this change was irreversible, i.e., the initial spectrum at zero bias was not recovered once the spectrum had been changed by measuring UPS with high bias voltages. Since intermolecular electronic interaction of C<sub>60</sub> is not sensitive to the molecular arrangement, we consider the present result suggest that C<sub>60</sub> molecules are chemically changed by irradiating ultraviolet photons with high bias voltages. It should be noted that no change in the UPS spectra was observed without applying the bias voltages.

In order to study the nature of the change, EELS were measured from the films after the change (Fig. 4). The valence plasmon energy was changed from 28 eV [2] of C<sub>60</sub> to 25.5 eV. Since it is established that the valence plasmon energy of C<sub>60</sub> is higher than other carbon materials because of the isolated spherical shell shape of the molecule [2], our result suggest that the isolated spherical shape is destructed by the measurement. Since polymerization is observed by ultraviolet irradiation [3] or by charge transfer from dopants [4], it is possible that the irreversible change of the C<sub>60</sub> is due to the polymerization.

It is still unclear that which of the field effect or possible small leak current is responsible for the irreversible change. Precise measurements of gate current and FET characteristics are under way. Results on other organic molecules will also be presented.

#### 4. Conclusions

We have measured UPS and EELS of  $C_{60}$  thin film FET structures. Irreversible change in the electronic structure of  $C_{60}$  was observed. It seems that the UV irradiation accompanied with the absolute value of the bias voltage larger than 100V is essential for the change. From the decrease of valence plasmon energy, it seems that the isolated shell structure of  $C_{60}$  molecules is destructed, which may mean the polymerization of the molecules.

#### References

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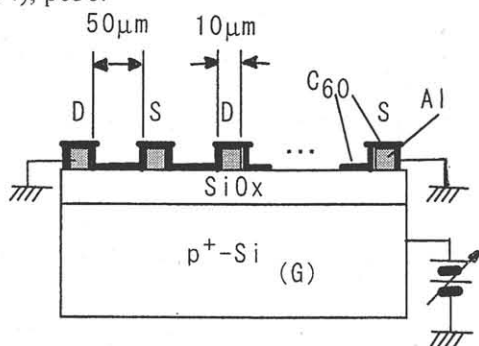


Fig.1 Structure of a FET sample

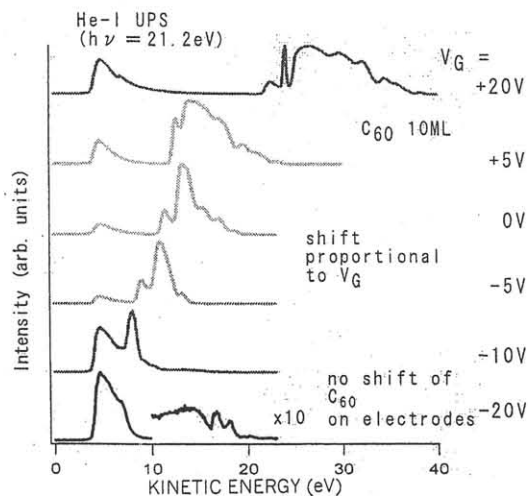


Fig.2 UPS of discontinuous thin film FET structure

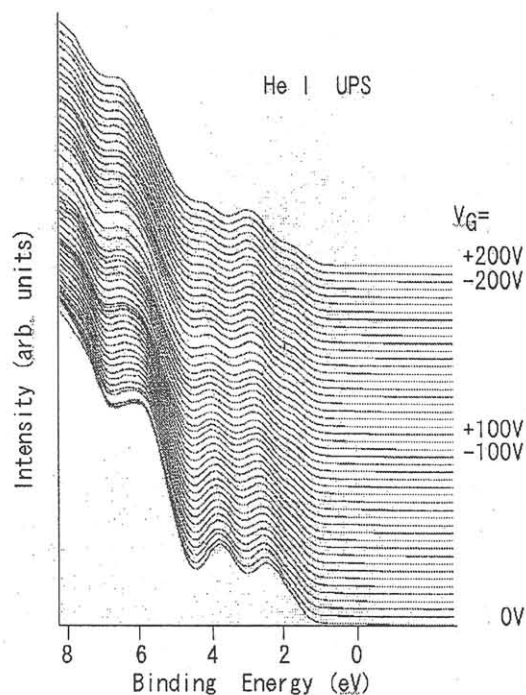


Fig.3 Change of UPS during the measurement

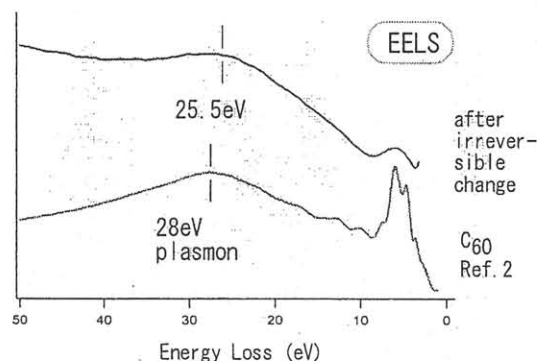


Fig.4 EELS after the irreversible change