Thin Films
Room: Makai - Session TF-MoE

Electronics and Displays on Flexible and Hard Substrates
Moderator: Lain-Jong Li, King Abdullah University of Science and Technology

5:40pm **TF-MoE1 Organic Thin Film Transistors: Materials, Device Interfaces and Performances**, ***Yunqi Liu***, Institute of Chemistry, CAS, China **INVITED**

Organic/polymer thin-film transistors (O/PTFTs) are of great interest for practical applications in active-matrix displays, radiofrequency identification tags, biosensors, and integrated circuits owing to their advantages of low cost, light weight, and mechanical flexibility. In this presentation, I will report a few results on O/PTFTs from my research group,[1–10] including materials, device interfaces and performances.

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6:20pm **TF-MoE3 Investigation of Strain Sensors Based on Thin Graphite Wires**, ***Takanari Saito***, *M. Matayoshi, J. Shirakashi*, Tokyo University of Agriculture & Technology, Japan

Among the flexible electronic devices, the strain sensors have attracted a great deal of interest due to its wide range of utility in real life, for example, the detection of human motion, monitoring personal health and therapeutics. Previously, we have reported that thin graphite wires are simply and easily fabricated from pyrolytic graphite sheet (PGS) [1] which is commercially available from Panasonic Corporation and have potential applications in microheaters [2]. In this report, we focus on the thin graphite wires fabricated on sticky tapes as flexible devices and investigate the electrical properties of the thin graphite wires for strain sensors.

The experimental procedures are as follows. First, graphite wires with the length of 45 mm and the width of 1 mm were cut off from PGS. Then, we prepared thin graphite wires with thickness down to about 3 µm using mechanical exfoliation. The electrical properties of the thin graphite wires were studied by applying a tensile bending stress with the radius of curvature from 5 to 25 mm. When applying tensile strains by bending the graphite wires, resistance of the graphite wires could show increasing response. The relative change in resistance ($\Delta R/R_0$) under a bending radius of 5 mm was 48 %, where R_0 is the resistance under zero strain; R is the resistnace under strain; and $\Delta R=R-R_0$. It has been proposed that resistance of graphite-based strain sensors under the bending stress changes due to variations in length and cross-sectional area as well as the distance between conductive particles [3]. Hence, the resistance changes of our thin graphite wires are caused by similar mechanism. Therefore, it is suggested that thin graphite wires simply and easily fabricated from PGS can be used as strain sensors.

References

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6:40pm **TF-MoE4 Photovoltaic Devices, Sensor and Electrostatic Self-Assembly Based on Conjugated Polymers**, ***Chang-Lyoul Lee***, Advanced Photonics Research Institute (APRI), Gwangju Institute of Science and Technology (GIST), Republic of Korea, *N.C. Greenham,* Cavendish Laboratory, University of Cambridge, UK, *S.-H. Han,* Mokpo National Maritime University, Republic of Korea, *W.-E. Lee,* Advanced Photonics Research Institute (APRI), Gwangju Institute of Science and Technology (GIST), Republic of Korea, *G. Kwak*, Kyungpook National University, Republic of Korea **INVITED**

In this talk, I will introduce two topics. One is polymer photovoltaic devices and the other is sensor for detecting biomolecules (or heavy metal ions) and pattering application of conjugated polyelectolyte through *in-situ* electrostatic self-assembly.

The roll of triplet states in photovoltaic devices (PV) is less studied than in PLEDs. Recent studies show that utilization of triplet excitons in conjugated polymer improves PV device performance. The triplet exciton dynamics of conjugated polymer in phosphorescent dye blended polymer PV device was investigated by photo-induced absorption (PIA) spectroscopy. From the low temperature PIA experiments of phosphorescent dye blended conjugated polymer films, the origin of the enhancement of triplet exciton population of conjugated polymer was revealed. And also, the PIA and PV response studies of phosphorescent dye blended conjugated polymer : fullerene bulk heterojuction PV device as well as phosphorescent dye blended conjugated polymer : fullerene bilayer PV device reveal the photo-physical interaction among the conjugated polymer, phosphorescent dye and fullerene and effects of triplet excitons to the PV device performance. (*Adv. Funct. Mater.,***20**, 2945, 2010).

The second section of this talk is senor and pattering application of conjugated polyelectolyte (CPE). Conjugated polyelectrolyte (CPE) with new signal transduction mechanism, based on sulfonated poly(diphenylacetylene), was developed. The CPE showed relatively weak FL emission in water due to a highly dense stack degree of side phenyl rings, while the stack structure was consistently relaxed by being combined with proteins, showing a great PL amplification. Consequently, the CPE was highly responsive to even a little amount of proteins because each of numerous side phenyl rings act as FL probes. (*Chem. Commun.,* **49**, 9857, 2013).

A new method for patterning conjugated polymer (CP) by *in-situ* electrostatic self-assembly (ESA) of conjugated polyelectrolyte (CPE) with surfactants in a film was reported. The *in-situ* ESA was simply realized by contacting the film to appropriate surfactant solutions. The contacting parts on the CPE film have completely different solubility from the non-contacting parts; the polymer chains in the contacted part also undergo supramolecular rearrangement, consequently resulting in dramatic PL emission enhancement. The optical and structural properties of the contacted part were regulated by varying the alkyl tail length of the surfactants employed. Highly resolved CP patterns can be readily obtained through this *in-situ* ESA approach. (*unpublished results*)

7:40pm **TF-MoE7 Substrate Dependant Film Growth Mechanism for the Production of Highly Durable Multi-Layer Plastic Mirrors**, ***Colin Hall***, *K. Zuber, E. Downey, E. Charrault, D. Evans, P. Murphy*, University of South Australia

The use of polymers to replace traditional materials in the automotive, aerospace and other industries is continuing at a high pace. Polymers offer distinct advantages over glass and metals, such as weight, impact strength, and the ability to be formed into complex shapes. To ensure long service life, however, in some applications the polymers must be coated to provide protection from damage due to mechanical abrasion or chemical attack. This coating can also enhance the plastic's functionality, such as changing its optical, electrical or surface properties.

One such example of this is the development of a highly durable plastic mirror through the deposition of a physical vapour deposition (PVD) multi-layer stack.[1,2] The growth of sputtered layers on plastic substrates requires the use of a relatively thick "hardcoating" (some 3 to 8 µm thick). This hardcoating is used in the ophthalmic and automotive industries and is typically a thermal cured organosilicone nanocomposite resin. Subsequently, a silica and chromium PVD multilayer was deposited to form the durable mirror coating. In developing this coating system to meet automotive glass mirror performance, it was found that there were substrate dependant effects on the sputtered layers characteristics. That is, the type of hardcoating had a direct influence on the growth of the sputtered layers. Interestingly, it was found that the mechanical properties of this hardcoating correlated with changes in optical, electrical and mechanical properties of the grown multi-layer stack.

The understanding developed has aided in the successful commercialisation of the plastic mirror, as the spotter mirror in the Ford F250 truck. However, as the plastic/hardcoat/PVD architecture is used extensively elsewhere (ophthalmic and decorative coatings) the phenomenon is of wide interest.

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8:00pm **TF-MoE8 Investigation of Peculiar Spin Electronic States Induced by Spin-Orbit Interaction Using High-Resolution Spin-Resolved Photoemission**, ***Taichi Okuda***, Hiroshima University, Japan **INVITED**

Spin-orbit-interaction induced spin polarized surface states such as Rashba spin split states or topological surface states(TSS) are the new class of quantum mutter and getting much attention as the key materials for the realization of spintronic devices. Spin polarization reversal in the surface state bands with respect to time reversal symmetry point in these materials expects to suppress backscattering by nonmagnetic impurities and to realize dissipationless spin transport.

In case of Rashba systems, however, the possible back scattering to the spin split pair band having opposite spin polarization hampers the complete suppression of backscattering. In addition, some quasi particle interference pattern of STM measurements show the existence of the scattering path even in the topological insulators. Furthermore, for the real application one should also consider to protect the surface states from the contamination. It has been reported that small amount of gas adsorption can produce the band bending in the topological insulators and changes the property of the TSS dramatically. Thus, in order to use the spin-polarized surface states and realize the spintronic devices one should eliminate these problems.

Here I present some recent results of spin- and angle-resolved photoelectron spectroscopy (SARPES) that show the hints to solve these problems. The first example is a Rashba system on one-dimensional surface states. High-resolution SARPES of Au induced chain structure on vicinal Si(111) surface shows clearly one-dimensional Rashba spin-split states. Interestingly the spin polarization vector is not in-plane but points perpendicular to the surface deviating from the normal Rashba spin-split states. This out-of-plane spin polarization and the one-dimensional band structure will help to reduce the scattering probability of the electron in the system.

Bi film on vicinal Si(111) surface also shows interesting spin structure having out-of-plane spin polarization. Unlike the Bi film on normal Si(111) surface that has (111) orientation, the film on the Si(557) surface shows LEED pattern and surface band structures similar to those of Bi(110) surface. Because of the lower symmetry (C_{1h}) of the sample structure not only in-plane but also significant out-of-plane spin polarization has been observed.

As the other examples, the investigation of lead based topological insulator $PbBi_4Te_7$ will be presented. Surface and bulk sensitive SARPES measurement proved the existence of spin-polarized topological surface states protected physically under the quintuple layer. This protected TSS will open the pathway to utilize the spin-split electrons in the future.

8:40pm **TF-MoE10 Spin Current at Surfaces of Strong Spin-Orbit Coupling Materials**, ***Shuji Hasegawa***, *N. Fukui*, *R. Hobara*, University of Tokyo, Japan, *T. Hirahara,* Tokyo Institute of Technology, Japan, *A. Takayama*, University of Tokyo, Japan

Recent studies have shown that the surface states exhibit spin-split and spin helical structures when spin-orbit coupling is strong enough. This is due to break down of space-inversion symmetry at crystal surfaces. Surface Rashba systems and topological insulators (TI) are the typical examples. This causes interesting phenomena relating to flow of spins, such as spin-polarized current [1] and spin current (without charge current) at crystal surfaces and edges of thin atomic layers of such materials. Such spin current may be useful for future spintronics devices because spin current causes no energy dissipation.

"Spin Hall Effect" (SHE) is one of such phenomena, which produces spin current perpendicular to the charge current. Due to bending of electron flow in opposite directions depending on the spin orientation, caused by strong spin-orbit coupling, a flow of spin is produced in the direction perpendicular to the charge current. Its time-reversal process also occurs (inverse SHE) in which the spin current produces charge current, by which we can detect he effects.

By using a H-shaped pattern of thin Bi_2Se_3 film, one of the topological insulators, we have tried to detect the SHE. The pattern was fabricated in a UHV-FIB (Focused Ion Beam) combined with a four-tip STM and MBE chambers [2]. In order to verify the SHE, we measured the nonlocal voltage drop caused by SHE and inverse SHE. All the processes including the film growth, patterning and measurements were done *in situ* in UHV to protect the surface states with a four-tip STM equipped with FIB [2]. The nonlocal voltage drop obtained was mainly explained by the classical Ohm's law, with small deviation. The deviation is explained by the SHE. From the data fitting we could deduced the spin-Hall angle and spin relaxation length.

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Authors Index

Bold page numbers indicate the presenter