GERMANY/HONG KONG JOINT RESEARCH SCHEME
THE PROJECT REPORT
(for Project Completion)

Project Number: G_HK032/11

Title

Ferroelectric Copolymer-Gated Organic Thin Film Transistors for Memory Applications

Particulars

	Hong Kong team	German team
Name of Project Co-ordinator (with title)	Dr. Chi Wah LEUNG	Prof. Bernd PLOSS
Name of Co-Investigator (if any)	Dr. Paddy Kwok Leung CHAN	
Institution or Institutional affiliation	☐ CityU ☐ HKU ☐ CUHK ☐ HKUST ☐ HKBU ☐ LU ☐ HKIEd ☑ PolyU	☑ University of Applied Sciences (FH) Jena ☐ Others:
Other project team members (if any)		

Funding Period

	1st year	2nd year (if applicable)
Start Date	1 Jan 2012	1 Jan 2013
Completion Date	31 Dec 2012	31 Dec 2013

Objective(s) as per original application

1. To prepare organic field-effect transistor-type memory devices based on ferroelectrics copolymer gates and examine their memory performances.
2. To investigate the properties of ferroelectric copolymer films with embedded metal nanoparticles, and study their applications in organic field-effect transistor-type memory devices.
3. To realize field-effect transistor-type memory structure on flexible substrates and investigate their memory behaviour.

Details of Report [Please attach relevant document(s)]

i) Outline of proposed research and results obtained

- **The project is concerned with the preparation and characterization of organic thin film transistors. Much effort was spent on the prevention of leakage currents from the gate dielectric layer, by means of different treatment methods. Eventually organic thin-film transistor (OTFT)-based memory devices were prepared on glass substrates, utilizing a combination of treatments on the Al gate electrodes, annealing processes of the copolymer layer, and the deposition of ultrathin insulating layers. Pentacene and DNTT semicondcutors were used to prepare OTFT memories. Analysis of the hysteretic transfer curve confirmed the memory effect originated from the remanent polarization in the ferroelectric layer and not due to the trapped charges in the semiconductor layer.**
- **Several attempts of doping the copolymer with metal nanoparticles were attempted during the stay in Jena, in hope of providing additional charge traps and lowering the operating voltages of the memories. This was performed by preparing P(VDF-TrFE)/metal/ P(VDF-TrFE) trilayers with ultrathin (~ 65 nm) copolymer layers, where the metal layers are ultrathin (nominally 3 – 5 nm) Ag or Al prepared by thermal evaporation, which tend to form clusters. Unfortunately capacitors prepared with such composite dielectric layers were too leaky, which will not be of use even when prepared into transistor structures.**
- **Due to the efforts spent on the optimization process of the gate dielectric layer, there were no attempts made on the use of flexible transistors.**
-

ii) Significance of research results

- **OTFT memory devices fabricated in this work demonstrated the possibility of memory devices based on organic semi-conductors and gate dielectric materials. This is favourable for the fabrication process, as techniques used for inorganic semiconductors and dielectric may involve high processing temperatures that are not compatible with organic materials. The current research is a step towards the fabrication of all-organic devices, where the metallic electrodes can be replaced by novel materials such as graphene.**
- **The current results provide some strategies for improving the performance of ferroelectric-copolymer gated OTFT memory devices (anodization of surface of Al gate electrodes, use of multiple layers of copolymer with different annealing conditions, use of parylene insulating layers). These considerations are of relevance not just to ferroelectric copolymers, but also to**
- **Although no devices were prepared on flexible substrates, it should be pointed out that part of the team members (CWL and PKLC) have prepared OTFT on flexible substrates, which showed good properties even under repeated bending cycles (J. Mater. Chem. C, 1, 3825 (2013)). It is anticipated that similar device structures can be prepared with ferroelectric copolymer gate dielectric and demonstrate memory behaviour, similar to those prepared on glass substrates in this project.**

iii) Research output

A total of three international conferences were attended as follows:

- **'Thin film transistors with organic active and high-k dielectric layers' in the 8th Asian Meeting on Ferroelectrics (AFM-8), 9 -14 Dec 2012, Pattaya, Thailand.**
- **'Ferroelectric Copolymer as Memory Layer for Organic Thin Film Transistor-based memories' C. Möse, D. von Nordheim, M. Pittner, B.Y. Peng, X.C. Ren, Z.R. Wang, P.K.L. Chan, B. Ploss and C.W. Leung, in The 3rd International Symposium on Next-Generation Electronics (ISNE 2014), 7 – 10 May 2014, Taoyuan, Taiwan.**
- **'Organic Field Effect Transistors With Ferroelectric VDF-TrFE Copolymer Gate Dielectric', D. von Nordheim, C. Möse, B. Peng, X.C. Ren, P.K.L. Chan, C.W. Leung, and B. Ploss, in the 23rd International Symposium on Applications of Ferroelectrics (ISAF)/ International Workshop on Acoustic Transduction Materials and Devices (IWATMD)/ Piezoresponse Force Microscopy Workshop (PFM) (2014 Joint IEEE ISAF-IWATMD-PFM), 12 – 16 May 2014, State College, PA, USA.**

iv) Potential for or impact on further research collaboration

During the period, a number of research opportunities other than that related to thin film transistors were explored between the investigators and the host institutions:

- **Collaboration was established between Prof. Ploss and Dr. Y. Chai of AP, PolyU, on studying the properties of ferroelectric copolymer/ graphene-nanoparticle composite materials.**
- **Another new collaborative initiative between the PIs of the project was on the use of the ferroelectric copolymer for tunable plasmonic structures. P(VDF-TrFE) shows temperature-dependent hysteretic change of dielectric constants, and initial results indicates that a similar behaviour occurs for the refractive index. This implies the potential for bistable thermal tuning of surface plasmon resonance wavelengths. Further investigations are under progress on the potential electrical tuning of the plasmonic resonance behaviour.**