Institution: University of the West of Scotland

Unit of Assessment: 13

Title of case study: Thin Films and Advanced Polymer Substrates for Plastic Electronics

1. Summary of the impact (indicative maximum 100 words)

The Thin Film Centre (TFC) group at UWS pioneered thin film materials and processes for plastic electronics with Dupont Teijin Films (DTF) Ltd and Plastic Logic (PL) Ltd over a period of nine years. This work was pivotal to the growth of PL from a start-up position resulting in the first all-polymer e-book reader and was the basis of a world leading position in the supply of specialised substrates for DTF Ltd.

2. Underpinning research (indicative maximum 500 words)

Prof Placido has led TFC for 13 years, specialising in high quality vacuum-deposited thin films of metals and dielectrics. Prof Placido and his team have used their extensive knowledge of plasma processes to develop solutions to coating problems by manipulating thin film properties at the nanoscale, in what can rightly be called atomic engineering. This research spans a very large range of applications in diverse industries, from solar cells and optical filters to corrosion resistant coatings on the inside of pipelines.

Plastic electronics is currently a very hot topic and much of the pioneering work demonstrating the potential was carried out at UWS in a series of EPSRC/DTI(TSB) funded projects.

One major problem to be solved was that while the glass substrates used in conventional electronic display devices are virtually impervious to water vapour and oxygen penetration, polymer substrates pass sufficient water vapour and oxygen to destroy the organic semiconductors used in plastic electronics in a matter of minutes. Prior art involved complex and expensive multilayer coatings that were impractical and too expensive to implement.

In the first EPSRC funded project (2003-2006) with Dupont Teijin Films Ltd, Prof Placido and post-graduate researchers (Sarfaraz Moh, David Lusk and Andrei Voronov) worked on the deposition of ultra-barrier coatings while DTF developed novel planarised and heat stabilised PEN polymer substrates. Our ability to successfully coat large areas of polymer (3000mm x 300mm) allowed statistically significant results to be achieved and repeatability to be demonstrated. The performance of our dense inorganic films as ultra-barrier coatings has yet to be improved upon. This work resulted in several conference papers and a worldwide patent with DTF (Ref 1).

From 2004-2007, Prof Placido and post-doc Dr Shigeng Song worked with Dupont Teijin Films Ltd and Plastic Logic Ltd on a DTI LINK funded project to investigate the feasibility of producing an active matrix backplane on a flexible substrate using semiconducting polymer TFTs. This work led to the first demonstration of a small all-polymer display on PL's prototype facility in Cambridge. In a later EPSRC/LINK project (2007-2010) the same partners worked on the manufacture of a practical A4 size display using Plastic Logic's backplane, Dupont Teijin Films' planarised PET substrate and e-Ink's display medium. Our contribution was to investigate the electrical and mechanical properties of the metallisation layers. Major aspects of this work were the investigation of high work-function coatings based on dielectric and various metal multilayers. A major problem solved in this project was the difficulty of demonstrating good adhesion of these layers to each other and to the polymer substrate. Quantitative methods of measuring adhesion and in-situ optical characterisation methods were developed allowing clear distinction between the wide range of candidate structures. A key finding was that a thin film of aluminium nitride gave excellent adhesion to planarised polymers and also allowed the deposition of a very high quality gold coating with overall excellent adhesion, even after etching to produce 100 micron thick bus-lines. This work is reflected in a patent with Plastic Logic Ltd.

3. References to the research (indicative maximum of six references)

Key outputs from this research include two current patents

1) WO 2006/097733; EP1859490B1; EP1983591A1[1]; US 20080193747: Composite films

suitable for use in opto-electronic and electronic devices. [F. Placido (TFC), W.A. MacDonald and R.W. Eveson, (Dupont-Teijin Films)]

2) WO2010/139802: Electronic devices [F. Placido (TFC), J. Joimel & C. Ramsdale, (Plastic Logic Ltd)]

Related Published papers:-
1) S. Song and F. Placido "In-situ investigation of spontaneous and plasma-enhanced oxidation of AlN film surfaces", Appl. Phys. Lett. 99, 121901 doi:10.1063/1.3640219 (2011)
2) S. Song and F. Placido "In situ investigation of surface oxidation of Ni metal film using single wavelength optical monitoring", 51st Annual Technical Conference, Proceedings of the Society of Vacuum Coaters, Chicago, (2008)
3) S. Song and F. Placido "Gas Release during Microwave Plasma treatment of Polymer Surfaces" 51st Annual Technical Conference, Proceedings of the Society of Vacuum Coaters, Chicago, (2008)
4) A. Voronov, F. Placido, and I. Bain, "In-situ broadband monitoring and characterization of thin films" 51st Annual Technical Conference, Proceedings of the Society of Vacuum Coaters, Chicago, (2008)

Relevant component of grants awarded for work in the development of Plastic Electronics:-

EPSRC/LINK: GR/S28235/01 (Oct 2003 – Sep 2006)
Title: New barrier materials for OLED displays
Awarded to: Prof F. Placido (PI)
Amount: £303,770

DTI LINK Ref: (2004 -207)
Title: Flexible Active Matrix Substrates
Awarded to: Prof F. Placido (PI)
Amount: £320,000

EPSRC/DTI: DT/E010830/1 (Mar 2007 – Feb 2010)
Title: Low Cost Flexible Active Matrix Substrates
Awarded to: Prof F. Placido (PI)
Amount £348,939

4. Details of the impact (indicative maximum 750 words)

In the EPSRC funded project (2003-2006) with Dupont Teijin Films Ltd, Prof Placido and post-graduate researchers (Sarfaraz Moh, David Lusk and Andrei Voronov) developed the first pinhole-free, dielectric ultra-barrier coatings on novel heat-stabilised, planarised PEN substrates. These coatings survived the now standard calcium test for water vapour permeation for 1000 hrs at 99% RH and 50°C. This coating is particularly relevant to organic light emitting diode (OLED) materials but also to other organic semiconductors that require some degree of protection from water vapour.

The 2004-2007 DTI LINK funded project with DTF and Plastic Logic successfully demonstrated the first working all-polymer display, using planarised PET from DTF and prototype backplane facilities at PL .
The same partners later demonstrated the world's first all-polymer A4 size e-book reader.
A significant outcome deriving from Prof Placido's previous work on aluminium nitride thin films was the demonstration that the metallisation layers in the backplane could be reliably fabricated from aluminium nitride and a very thin (50 nm) gold coating. This led to a great simplification in the production process, saving time and cost through the elimination of the usual adhesion promoting layer of titanium, nickel or chromium and also providing a barrier layer against water vapour.

Significant beneficiaries of this research are the companies involved, firstly Dupont Teijin Films Ltd, having acquired a world leading position in the supply of planarised and heat-stabilised polymers for the developing plastic electronics industry. According to the DTF source (submitted letter) “the work in the programme also helped in both the understanding of the property benefits of specialty planarised films; which have formed the basis of DTF’s portfolio of products for the flexible display industry and in forming a view on whether thin film deposition offered an opportunity for DTF”. The same source confirms that the later work with TFC and PL Ltd “has led to significant sales of a planarised film product for DTF”.
Secondly, Plastic Logic Ltd has benefited from very considerable external investment having validated its polymer TFT technology, with the first feasibility study securing >$100M investment and allowing PL Ltd to build in Dresden the first-ever manufacturing facility for flexible displays (Confirmation in submitted letter from CTO, PL Ltd) and in the later EPSRC/LINK project (2007-2010). PL Ltd now has manufacturing facilities in Dresden and also in south Moscow.
In the wider sense, the commercial availability of proven heat-stabilised, planarised polymer substrate material from DTF Ltd is of significant benefit to the world-wide manufacturers of devices based on lightweight, flexible substrates, including displays and solar cells.

5. Sources to corroborate the impact (indicative maximum of 10 references)

The claims presented here can be validated through the published patents, referenced above, which name the co-inventors and from supporting letters supplied by the representatives of Dupont Teijin Films Ltd and Plastic Logic Ltd listed below:

Business Research Associate, Dupont Teijin Films Ltd, Wilton Centre, Redcar, Cleveland, TS10 4RF
Chief Technology Officer, Plastic Logic Ltd, 322 Cambridge Science Park, Cambridge, CB4 0WG