9.2 Bottom-up chemical approach for engineering thin films of organic electronic materials for field-effect transistors

Aiman Rahmanudin¹, Raymundo Marcial-Hernandez¹, Suresh Garlapati², Krishna C. Persaud², Michael Turner¹

¹ Organic Materials Innovation Centre, School of Chemistry, University of Manchester, Oxford Road, Manchester, M13 9PL, UK
² School of Chemical Engineering and Analytical Science, University of Manchester, M13 9PL, UK

The need to engineer stable thin films and develop sustainable solution processing methods has great technological importance in the performance and progress towards commercialization of organic electronic materials into relevant devices such as organic field-effect transistors (OFETs). Herein, we will highlight the development of two bottom-up chemical approaches that address stable low-voltage OFET chemical sensors and a unique direct aqueous processing method of high performance thin films of polymer semiconductors.

1) OFETs have shown great promise for use as chemical sensors for applications that range from the monitoring of food spoilage to the determination of air quality and the diagnosis of disease. However, for these devices to be truly useful they must deliver reliable, stable low-voltage operation over extended timescales. An important element to address this challenge is the development of a high-capacitance gate dielectric that delivers excellent insulation with robust chemical resistance against the solution processing of organic semiconductors (OSC). We report the development of a bilayer gate dielectric containing a high-κ fluoropolymer relaxor ferroelectric layer modified at the OSC/dielectric interface with a chemically resistant low-κ methacrylate-based copolymer buffer layer. Bottom-gate OFET chemical sensors using this bilayer dielectric operate at low-voltage, with exceptional operational stability. They deliver reliable sensing performance over multiple cycles of ammonia exposure (2 to 50 ppm) with an estimated limit-of-detection below 1 ppm. We will briefly mention the use of this polymer gate dielectric as a platform for other OFET gas sensing applications.

2) In conventional organic electronic devices, thin films of polymer semiconductors are solution-processed from toxic chlorinated solvents that are arguably harmful to the environment, while aqueous processing has major advantages as a sustainable and eco-friendly process. A promising method is the use of conjugated polymer nanoparticles (CPNs) as colloidal aqueous inks to process thin films of polymer semiconductors. Typically, CPNs are prepared via emulsification of pre-synthesized polymer semiconductors that are dispersed in a continuous aqueous phase kept stable as colloid by a surfactant. We proposed a method that combines the synthesis and processability of the CPNs into OFETs through direct aqueous thin film processing of CPNs synthesized via miniemulsion polymerisation. It shortens the route from synthesis to devices, adding more value for a “greener” solution processing method of functional high-performance polymer semiconducting thin films for OFETs.

References