MULTIfuncTional organic electronics throUgh nanoscale controlleD bottom-up tailoring of interfacES: an Intra-European Fellowship for career development

Sprawozdania

Informacje na temat projektu

MULTITUDES

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Final Report Summary - MULTITUDES (MULTIfuncTional organic electronics throUgh nanoscale controlleD bottom-up tailoring of interfacES: an Intra-European Fellowship for career development.)

Organic electronics is now a commercial technology, but despite a huge and successful effort in developing novel organic semiconductor materials over the past years, much of their potential has not been fully realised. Improvements in functionality (e.g. the fabrication of multifunctional devices), performance, durability and compatibility with existing technologies are needed to fully exploit the advantages of organic electronics over conventional electronic devices. Given the leading role played by Europe in the science and in particular industrial market in the field of plastic (opto)electronics it is most important to extend such a leading role also to the development of a nanoscale technology based on organic semiconductors. MULTITUDES provides an important contribution to the European effort in this field by supporting the research activity of a most promising young researcher in a multidisciplinary area at the interface between chemistry and materials science.
By merging a bottom-up and top-down approach to nanoscience, the research in MULTITUDES has developed functionalised electrodes through a simple, cheap, tuneable and up scalable approach. This was achieved for both organic electronic and multifunctional organic electronic devices.
These electrodes have both the purpose of improving (opto)electronic properties of devices and allowing the fabrication of planar devices that can be investigated by surface sensitive techniques, such as scanning probe microscopies, so as to better understand their nanoscale physical processes. The extremely versatile approach developed in MULTITUDES involves the functionalisation of the electrodes to allow deposition of different SAMs on the electrodes.
To reach these goals, a detailed understanding of the dynamic processes of SAM formation was developed, being already itself one among the greatest challenges in chemisorbed SAMs and more generally in surface science. Furthermore, MULTITUDES developed new multifunctional SAMs, conferring their properties new multifunctional devices with potential for sensor applications or multifunctional logic.

First main objective: Top-quality research training and transfer of knowledge (ToK) in an interdisciplinary, intersectorial and emerging field.
Second main objective: Development of asymmetrically functionalised electrodes for planar organic electronic devices with improved performance and/or increased functionality.

Work performed:

To achieve success, this project focused on building up understanding of our systems from the molecular to the ensemble and device level. In this context, a number of SAM molecules were identified for the properties they would confer to the gold electrode surface. These included molecules which would raise or lower the electrode work function, but also molecules which would confer additional functionality to the electrodes. Some of these molecules were commercially available and but many new molecules were developed in this project in partnership with synthetic chemist collaborators.
Self-assembled monolayers of these molecules were studied at the nanometer scale by scanning tunnelling microscopy, using the unit cell dimensions as the basis for computational modelling.
Macroscopic properties of the electrodes relevant to devices such as work function, surface energy and tunnelling barriers were characterised using a wide range of experimental techniques such as Kelvin probe, photoelectron spectroscopies and water contact angle. The comparison between modelling and experiment allowed a deep insight into the origin of the tuning of electrode properties by SAMs that will provide a basis for development of new families of SAM molecules in the future.

In these studies, the researcher also developed understanding of the instrumentation involved including measuring the hitherto unknown depth sensitivity of photoelectron spectroscopy in air and also characterising the cantilever capacitance artefact in Kelvin probe force microscopy. These findings will be of great assistance to the relevant research communities.
This solid understanding of SAM formation allowed the development of robust procedures to fabricate electrodes with SAMs able to confer desired properties into devices, namely transistors and diodes. In particular this project achieved pairs of gold electrodes with a remarkable 1.4 eV difference in work function conferred to the electrodes functionalisation. In a further extension of this concept, multifunctionality was conferred to the device through the properties of SAMs formed at the electrodes. As such this project takes electrodes from being passive components, to being the source of multifunctionality, opening up new concepts in the design of organic sensors and logic.
These results have resulted in two publications in peer-reviewed journals (so far):
[1] O. Fenwick et al., Modulating the charge injection in organic field-effect transistors: fluorinated oligophenyl self-assembled monolayers for high work function electrodes, J. Mater. Chem. C, 3 (13), 3007–3015 (2015).
[2] A. M. Masillamani et al., Light-induced reversible modification of the work function of a new perfluorinated biphenyl azobenzene chemisorbed on Au (111), Nanoscale, 6 (15), 8969–8977 (2014).
A further 6 publications are in preparation, and two posters have been presented at conferences.
The results will be presented as invited talks at two international conferences in 2015.

Impact:

By merging the bottom-up to the top-down approach, the knowledge acquired in MULTITUDES is central both to the optimisation of organic opto-electronic devices, and to the development of new multifunctional devices. Moreover, the use of SAM functionalised electrodes as multifunctional components paves the way towards novel inexpensive products with new sets of properties being tailored at the molecular level. Furthermore it demonstrates a way to increase integration density of functional devices.
The fellow has received multidisciplinary training in a range of experimental techniques, built new academic and industrial collaborations and has worked in world-class laboratories.
In this context, MULTITUDES strengthens the position of Europe as the leading force in organic electronics in the world.

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