Research Visit to National Institute of Standards and Technology (NIST), Gaithersburg, Maryland, USA

George Dibb - 1st – 12th June 2015

At the WMRIF Workshop for Young Scientists in September 2014 I was awarded financial support for two research visits to national measurements institutes of my choice. The first of those was to NIST in the USA, a visit I was especially excited about making because of the internationally recognised research into organic electronics performed at the institute.

My research at NPL focusses upon organic electronics, particularly organic photovoltaics (OPVs) and their stability. OPVs are known to be highly unstable in air due to the levels of water and oxygen in the atmosphere which lead to the degradation of the device performance, however the exact mechanism of this process is unknown and varies for different systems. At NPL we have developed a novel environmental test chamber in which it is possible to simultaneously expose several devices to environmental stresses such as oxygen or light in a highly controlled environment, whilst experimentally accessing the devices to assess their degradation in situ. Whilst it was not possible to transport the degradation experimental rig to Gaithersburg, it was decided that the main aim of my visit would be to supplement results from degradation tests already performed at NPL with experimental techniques available at NIST.

At NIST I was hosted by the organic electronics group of Dean DeLongchamp and Lee Richter within the polymers division. It was decided prior to my visit that the two particularly useful experimental techniques frequently used and available at NIST that I didn't have access to at NPL were impedance spectroscopy, which uses frequency domain probes of electrical impedance to determine charge carrier behaviour within electronic devices, and Fourier-transform infra-red spectroscopy (FTIR), which uses absorption in the infrared spectrum to determine atomic and molecular bond structures. Both of these techniques would be performed on pristine devices, and devices aged in different conditions, to detect the changes that had occurred during device degradation.

The first step of this process was to fabricate a set of polymer:fullerene devices, as similar as possible to those fabricated at NPL, but made in the NIST lab. In this I had the significant support of Jon Downing who helped me with all stages of the experimental work described here. Two of the devices were then degraded in conditions that as closely as possible approximated tests performed at NPL. The first device was exposed to white light from an AM1.5 solar simulator inside a nitrogen glove-box with low levels of O_2 and H_2O, whilst the second device was also exposed to simulated sunlight, but in air. Both the exposures lasted for 24 hours. The latter test conditions (air plus illumination) is particularly harsh for OPV devices.

Impedance spectroscopy experiments were performed on all three devices (pristine, aged in air and aged in N_2) and significant differences were observed in the

experimental results. These experiments produce large datasets which must undergo significant analysis and fitting to extract relevant conclusions. This process is still ongoing, so at this stage no firm conclusions have yet been reached.

The second experiments performed were FTIR measurements which use optical absorption to probe the molecular bonds within materials. It is commonly proposed that one degradation route for organic semiconductors, particularly under illumination and in oxygen, is the breakdown of the bonds that form the molecules and a subsequent reduction in semiconducting ability and device performance. The FTIR results obtained at NIST show no change in the devices exposed only to illumination, and a small change in devices exposed to air. Together these provide an important insight, as although degradation is often attributed to this mechanism, it can be ruled out in the material system we are studying.

Overall my visit to NIST was a very positive one. I really enjoyed meeting everyone in the organic electronics group and attending seminars, and I have to thank everyone for their hospitality and assistance. Special thanks go to my host Lee Richter who was extremely helpful before, during and after my stay, and Jon Downing who both helped me experimentally and helped me to see plenty of Washington DC! Additionally to Mike Fasolka for all his help arranging the trip and his hospitality during my stay. My time at NIST was very productive experimentally, but I also hope that it can be the beginning of increasing collaboration between the two institutes both pursuing research into the new and exciting area of organic electronics.