Metal-organic interfaces at the nanoscale

C. Troadec, D. Jie, L. Kunardi, S. O'Shea and N Chandrasekhar
Institute of Materials Research and Engineering
3 Research Link, Singapore 117602
n-chandra@imre.a-star.edu.sg

Metal organic interfaces have been attracting intense scrutiny over the past few years The motivation for this research is to understand the basic physical phenomena that occur at such interfaces, with the objective of improving devices based on organics and polymeric materials. Such interfaces have been studied extensively by spectroscopy, which averages over large areas. A nanoscale characterization of such interfaces is currently lacking.

In this work, we present the results on ballistic hole emission spectroscopy (BHES) and imaging of metal-organic interfaces. Ballistic hole microscopy is a variation of ballistic electron emission microscopy (BEEM). BEEM is a relatively new technique, based on the scanning-tunneling microscope, to study potential steps at interfaces with a lateral resolution in the nanometer scale. Up to now, BEEM has mainly been applied to metal/semiconductor interfaces. Ballistic hole spectroscopy investigates the transport or injection of holes across a metal-semiconductor interface.

In our experiments, a thin layer of metal, such as Ag, typically <10 nm is evaporated on a previously evaporated PPP film of 100 nm thickness. The PPP itself was deposited on a Au film (100 nm thick) on a glass substrate. BHES studies were done in a home built UHV low temperature STM system. The Ag film is grounded, and the STM tip is used to collect a hole current from the PPP, so that the tip has a fairly large bias.

An application of the Schottky-Mott rule to this interface yields an interface injection barrier of 0.9 eV. This rule ignores the possibility of dipoles at the metal-organic interfaces. Evidence for the existence of interfacial dipoles comes from various experiments, including UPS and Kelvin probe.

Figures 1 to 3 show our results. Fig. 1 is a plot of the BHES current, measured at the bottom Au film, which also serves as the BHES electrode. Fig. 2 is the derivative spectrum of the data in fig. 1. The data indicate that the injection barrier is not a unique quantity, as is common in the case of metal-inorganic semiconductor interfaces. Variations in the injection barrier can occur due to conformational changes in the organic. Possible reasons for multiple thresholds, effects of charge traps (known to be present at metal-organic interfaces) as well as the existence of interface dipoles, will be discussed in the presentation.

Fig. 3 shows STM and ballistic hole current images. The STM image in the top panel indicates the surface morphology of the silver film. This image is taken at a constant tunnel current of 1 nA. The bottom panel shows the ballistic hole current and its variation with position, over a 50 nm square area. The image clearly indicates non-uniformity of the injection barrier over the region scanned by the STM. This image is taken at a STM tip bias of -0.7 V.

We will also present our attempts to characterize cross-bar type devices made from organics using this technique, and discuss the implications of our observations on device characteristics.

References

1. M Prietsch, Phys. Rep., 253 (1995) 163-233.
2. V Narayanamurti and M Kozhevnikov, Phys. Rep., 349 (2001) 447-514.

Figures

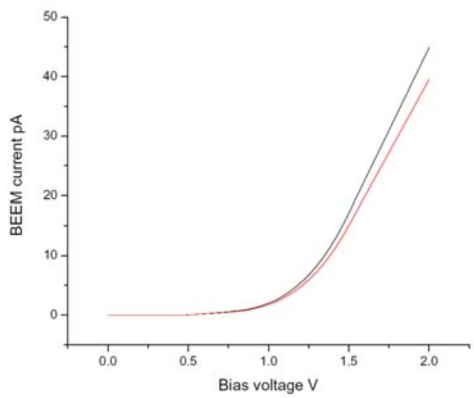

Figure 1 BHES spectra of the Ag-PPP interface

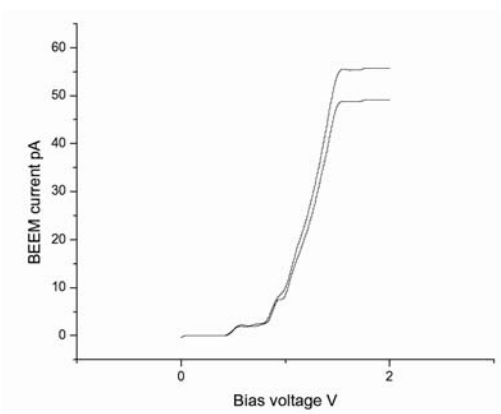

Figure 2 dI/dV of the BHES spectrum shown in fig. 1.

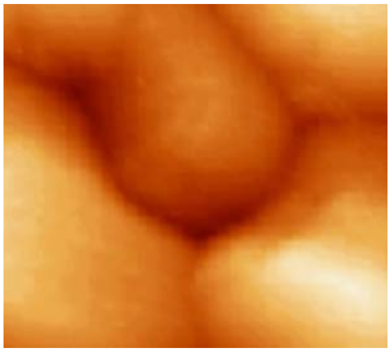

Figure 3 STM and BHES images.