Atomic Force Microscopy for Nanoscale Morphological and Electrical Characterisation of Semiconductors

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Atomic force microscopy (AFM) is an indispensable tool in the development of next-generation semiconducting materials and devices since it is able to elucidate their morphology and electrical properties on the nanoscale, enabling refinement of processing conditions and detailed failure analysis. In this talk, we will explore several emerging applications of atomic force microscopy in semiconductor research with a particular focus on how hardware and software automation improves both throughput and reproducibility.

The first example we will explore is the use of piezo response force microscopy (PFM) and Kelvin probe force microscopy (KPFM) to study electronic devices with memristive functionality imparted via ferroelectricity. We will see how the use of more sophisticated detection mechanisms such as dual-frequency resonance tracking (DFRT-) PFM and heterodyne (HD-) KPFM are advantageous in measuring ferroelectric materials that can also be switched using the AFM probe. The second example will look at the use of scanning capacitance microscopy (SCM) and scanning microwave impedance microscopy (SMIM) to spatially map dopant concentrations and carrier type in semiconducting devices. The third example will examine ways in which nanoscale electrical characterization can be extended to the detection and characterization of buried features. Taking the example of hBN encapsulated single layer graphene, we will show how both SMIM and second-eigenmode amplitude modulated KPFM can be used to map buried layers, even revealing variations due to interfacial contaminants. The final part of the talk will introduce nano-IR spectroscopy as a robust method to obtain chemical information with nanoscale resolution and examine its promise in surface specific vibrational characterisation of semiconducting materials, resists used in their processing and organic contaminants that affect their performance.