Application Note
nanoARPES or k-Microscope

In nanotechnology and nanoscience the objects are in the order of 10^{-9} m. The properties are known to be different for a material in the nano-meter size compared to bulk. An important factor to understand and control these property changes is to gain insight in the electronic properties of the material, not only with high resolution in energy, angle and reciprocal space, but also with high lateral resolution. Photoelectron spectroscopy is a perfect tool for electron property studies; with x-ray photoelectron spectroscopy (XPS) it is possible to study the core levels of a material and acquire element specific chemical information and with angular resolved photoelectron spectroscopy (ARPES) it is possible to map the band structure of a material. In order to make use of XPS and ARPES in nanoscience Maria Carmen Asensio et al. have developed a new technique where the light is focused down to nanometre size – defining the area studied with photoelectron spectroscopy (PES) to be in the nano meter size.

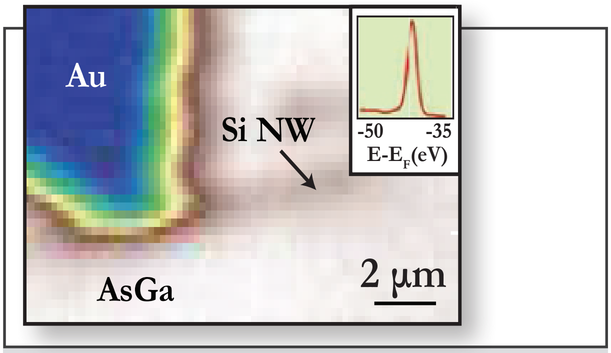

Figure 1: nanoscale-resolved As 3d XPS of a Si nano wire connected to a gold leg on a GaAs-sputtered substrate. Insert: As 3d XPS spectrum.

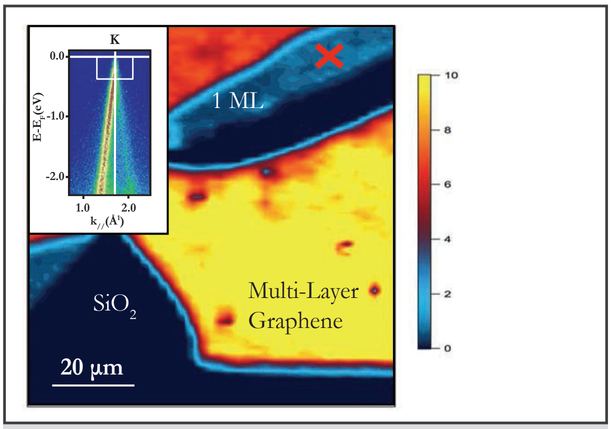

Figure 2: Nano-resolved ARPES real space image of exfoliated graphene on silicon oxide. The inset shows a nanoARPES spectrum at the k-point of graphene., recorded at X. The real space map is constructed out of the intensity variations of the k-selected electronic states enclosed in the white box of the insert.

The setup is located at the ANTARES beamline at SOLEIL synchrotron, France. It is an undulator beamline with a set of pre-focusing mirrors to collimate the undulator beam, a plane grating monochromator and a second set of mirrors, so called pseudo Wolter post-focalization mirrors, that refocus the beam to the pin hole (or sample) for nanometer (micro meter) spot size, respectively. In order to get nanometer spot size on the sample the light is further passing through a zone plate located in the end station of the beamline. A R4000 WAL analyser detects the emitted electrons. The setup is further described in Avila et al., Synchrotron Radiation News 27:2 (2014) 24 and references therein.
With this setup it is possible to study the valence and core level electrons and their electronic states. The valence electrons are directly responsible for the chemical bonds reactivity, electron transport and thermal, magnetic, and mechanical properties of matter whereas the core level states can be used for element specificity and chemical state information.

With the ANTARES nanoARPES setup it is possible to study devices with a spatial resolution better than 100 nm. Figure 1 shows an example of a nanoscale resolved element specific real space map of silicon nano-wires (NW) connected to gold legs on a GaAs-patterned substrate. The image show the tip of a gold leg with a silicon NW attached to it. Figure 2 illustrate the capabilities to produce real space maps originating from a set of nanometre excited ARPES spectra of k-selected electronic states close to the Fermi level. The sample is exfoliated graphene transferred to silicon oxide. Using ARPES it is possible to monitor the number of mono layers (ML) deposited and the quality and robustness of the Dirac relativistic-like electronic spectrum as a function of size, shape and orientation of the single crystal grains, which is expected to have great importance in graphene device fabrication.

This application note is written in collaboration with Maria Asensio. For more information please see Avila et al., Synchrotron Radiation News 27:2 (2014) 24 or contact asensio@synchrotron-soleil.fr.