Electron spectroscopy and spectromicroscopy with soft X-rays	**Category:** **C. Particle Characterization in- and ex-situ** **Institute:** **Karlsruhe Institute of Technology (KIT)** **Location:** Karlsruhe Institute of Technology (KIT) Institut für Festkörperphysik (IFP) WERA soft X-ray analytics facility Building 348 Hermann-v.-Helmholtz-Platz 1 D-76344 Eggenstein-Leopoldshafen Germany **Contact Details of Technology Experts:** **Name:** S. Schuppler, P. Nagel, M. Merz **Phone:** +49 721 608-24631 **Fax:** +49 721 608-24624 **E-mail:** stefan.schuppler@kit.edu

Short technology description/Overview *(approx 300 words)*:

IFP's soft X-ray analytics facility WERA at ANKA covers the photon energy range 100 – 1500 eV and combines coherently:

- ***electron spectroscopies***
  like XAS / NEXAFS (X-ray absorption, near-edge X-ray absorption fine structure), PES / XPS (photoemission spectroscopy, X-ray photoemission spectroscopy), XMCD / XMLD (X-ray circular and linear magnetic dichroism)
- with ***microscopy*** **and** ***spectromicroscopy***
  in an XPEEM (X-ray photoemission electron microscope).
  XPEEM allows imaging topographic, chemical and magnetic contrast, as well as the parallel detection of local spectra: µ-XAS / µ-NEXAFS; µ-PES / µ-XPS; µ-XMCD.

Associated specialized preparation chambers, including one for pulsed-laser deposition, are interconnected with the experimental endstations via in-vacuo sample transfer.

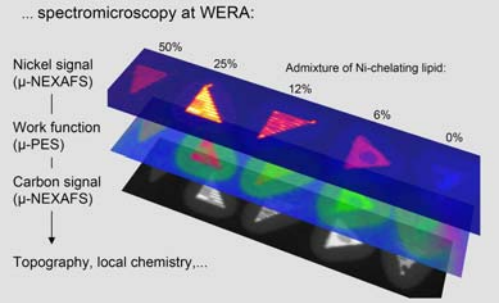
In this way, WERA enables multi-faceted and detailed investigations of many important aspects of chemical, electronic, and magnetic structure, particularly of micro- and nanostructured objects and thin films. The combination of these mutually complementing methods together with high lateral resolution and a variable degree of surface sensitivity allows additional insight.

Main Features (Equipment Capabilities):

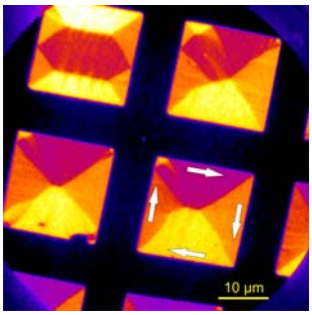
- Photon energies 100 – 1500 eV are well suited for studying the light elements (like oxygen), the 3d transition metals, and the 4f rare-earth elements at their particularly informative K, L, and M edges, respectively. The photon energy resolution $\Delta E/E$ may be chosen as low as 10^{-4}.
- The main instrument for QNano applications will be the ***X-ray photoemission electron microscope (XPEEM)***. Electron optics with great magnification image the lateral distribution of electrons emitted from the illuminated spot on the sample. The lateral resolution in XPEEM can be better than 30 nm (100 nm in spectromicroscopy), and this as well as the variable probing depth of <1 to about 10 nm, depending on technique, is well matched to many nano- and microstructured materials and their typical length scales. Generally, the methods are element-specific. Two main modes are used:

- ***Imaging*** of chemical, electronic, magnetic, and topographic contrast. The field of view can be chosen from 250°µm down to about 20 µm. Using the sample translation stage, a total sample area of up to about 5 mm diameter can be studied.
- ***Spectromicroscopy*** is an especially powerful XPEEM application: By taking stacks of images while tuning the photon energy or the kinetic energy of the detected electrons, laterally resolved sets of X-ray absorption (µ-XAS) and photoemission (µ-PES) spectra are efficiently obtained (see example below). Field of view and accessible sample area are the same as above. The polarization of the synchrotron radiation is a further useful variable: With circular polarization, for instance, ferromagnetic domains become visible ("magnetic dichroism", µ-XMCD), see example, and the associated spectromicroscopy gives element-specific magnetic information such as on spin and orbital magnetic moments. Linear polarization of the incident light makes the experiment sensitive to parameters like molecular and bond orientation.
- In addition, WERA comprises *complementary stations* for XAS, PES, and XMCD. There, the signal is averaged over the illuminated spot on the sample (typically 1 x 0.5 mm^2). This allows higher energy resolution and even greater flexibility in detection methods, polarization, and sampling depth (including fluorescence detection for bulk-sensitive XAS measurements). The sample environment includes temperatures between 15 and 800 K and high magnetic field up to 7°T.
- A number of *sample preparation chambers* and loadlocks are part of WERA. All are interconnected with the experimental chambers by an in-vacuo sample transfer system enabling the combined investigation with methods in different chambers without the need to break the vacuum. The available preparation and characterization methods include pulsed-laser deposition, evaporation (Knudsen cell), sputtering, annealing in vacuum or gases including oxygen, LEED, and RHEED. Compatibility with the NanoLab and the future KNMF laboratory at ANKA is planned and will ensure an even wider range of possibilities for preparation and characterization.

Typical Samples & Images:



Spectromicroscopy of biorelevant micropatterns (phospholipids) written by dip-pen nanolithography.
*The written triangles are 10 µm wide. The increasing admixture of the nickel-chelating lipids (with a **single** Ni atom per lipid macromolecule) to the phospholipid carrier appears in the Ni-sensitive "top sheet" as the increasingly red-yellow colors visible from right to left. The local work function and the carbon signal shown in the lower sheets provide complementary information on the topography. Quantitative analysis reveals that for admixture ratios up to 25%, the Ni content observed in the written patterns directly tracks the nominal values. For the triangle with the highest Ni concentration, however, not the full fraction of the Ni -chelating lipids seems to arrive in the pattern. (Cf. S. Sekula et al., Small (2008)).*



Magnetic domains and possibly defect-related subdomains with various orientation are visible in this magnetic dichroism image of thin-film permalloy squares.

Any further Information: