Erasmus Mundus Lectures (December 3rd-6th, 2024):

Scanning electrochemical probe microscopy: Studies of nanomaterials.

The lectures on scanning (electrochemical) probe microscopy (SEPM) covered the basic principles of the most widely used scanning probe technique, atomic force microscopy (AFM), and recently advanced in-situ/operando SEPM techniques such as scanning electrochemical microscopy (SECM) and scanning electrochemical cell microscopy (SECCM), which are highly relevant for the characterization of nanomaterials. Nanomaterials play an important role in science and everyday life, due to their numerous applications in consumer products, medical diagnostics, and energy-related topics. The functionality of nanomaterials is directly related to their size, shape, and structure, which requires analytical methods to provide high-resolution information on the geometric properties and the ability to correlate them with their activity. Scanning probe microscopy techniques are well suited for the characterization of nanomaterials as experiments can be performed in ambient atmosphere, in solution and under in-situ or operando conditions.
After a short introduction and repetition of the fundamental aspects in electrochemistry focusing on micro-and nanoelectrodes, the operating principles of SECM and SECCM were introduced, including the fabrication of nanoelectrodes and nanopipettes. The capabilities of these SEPM techniques were highlighted with selected examples of recent applications to characterize nanoparticles as a function their shape, size and facets. The challenges of such activity measurements with nanoscale resolutions were also discussed.

The lectures were also dedicated to AFM, which is the most used SPM technique in nanotechnology providing qualitative and quantitative 3-D surface information with high resolution along with the physical properties including size, morphology, surface texture, and roughness. After introducing the basic physical principle, the required hardware components and the AFM modes including conductive AFM were explained, before selected applications of nanomaterial characterization were discussed. Finally, hybrid AFM-SECM, which allows direct in-situ correlation of physicochemical properties with electroactivity, was briefly discussed.

The aim of the lectures was to teach the students the principles, advantages and disadvantages of scanning microscopy techniques, especially with regard to the characterization of nanomaterials and the possibility to perform structure-activity analyses. It was a pleasure to teach as the students were really engaged during the lectures. The students' final term paper focused on applications of the techniques in the characterization of nanomaterials.