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INTRODUCTION TO FIB-SEMs

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Dr Michal Urbánek is the Head of the CEITEC Nano Research infrastructure and coordinator of CzechNanoLab – Czech national research infrastructure for nanoscience and nanotechnology with facilities located in Brno and Prague. His main research interests lie in nanofabrication, nanomagnetism, spin waves, and magnetic metamaterials. He pioneered the technique which uses FIB irradiation to locally induce structural (bcc→fcc) and magnetic (paramagnetic→ferromagnetic) phase transformation of metastable Fe78Ni22 thin films grown on Cu(100). This process allows for extended control over magnetic properties of the irradiated areas and enables to create magnetisation landscapes with sub-micron resolution. This technique offers unprecedent possibilities mainly to the field of spintronics, where the magnetisation landscapes can be artificially tailored to the needs of actual spintronic devices. Also, in the last 10 years, he supervised 19 master's and 6 PhD students and he was/is a principal investigator of more than 15 international and national research projects (more than 31 M€ funding).

1. *ABSTRACT*

Nowadays, the systems that allow simultaneous employment of both focussed electron and ion beams are very important tools in the field of micro- and nanotechnology. The focussed ion beam (FIB) operates in a similar manner to the scanning electron microscope (SEM) but scans a beam of Ga^+ (or other types) ions instead of electrons. The FIB column accelerates and focusses ions into a narrow beam that sputter or mill material from the sample surface in controlled patterns. Sputtering occurs due to the mass of the Ga^+-ions that damage the sample surface on impact. Most modern FIB microscopes are attached as an additional column on SEMs allowing the operator to simultaneously observe and control sample milling with the SEM. The combination of the FIB for milling and the SEM for high resolution imaging enables very delicate site specific sample operations to be performed. In addition to the combination with SEM column additional extensions for nanomanipulation, local deposition of materials, mechanical testing, structural and chemical analysis can be combined into a universal multi-purpose nanofabrication/nanoanalytical tool. In the lecture, I will cover the basics of ion-matter interactions, give an overview on the most common types of FIB sources, configurations of different types of FIB-SEM systems including various add-on options and summarise the most common applications of FIB technology, as well as some more exotic ones.

2. *LECTURE OUTLINE*

1. Ion-matter interactions
   a. Electron versus ion
   b. Interaction volume
   c. Consequences of the ion exposure of the material surface

2. FIB instrumentation
   a. History
   b. Ion source types
      i. Liquid metal ion source (LMIS)
      ii. Liquid metal alloy ion source (LMAIS)
      iii. Plasma
      iv. Gas field ion source (GFIS)
      v. Gas cluster ion source (GCIS)

3. FIB-SEM systems
   a. Basic configuration
   b. Analytical extensions
      i. Electron probe (EDX, EBSD, …)
      ii. Ion probe (ToF-SIMS)

c. Additional add-ons and extensions
    i. Gas injection system
    ii. Nanomanipulators
    iii. Cryogenic system
    iv. Inert gas operation
    v. AFM integration

4. FIB Applications
    a. Cross sectioning
    b. TEM lamella preparation
    c. 3D FIB-SEM tomography
    d. Micro-nanopatterning
    e. Nanomanipulation
    f. FIBID 3D prining
    g. Ion-beam irradiation