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SOFT X-RAY PHOTOELECTRON EMISSION MICROSCOPY (X-PEEM)

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1. A "NANOSCALE" INTRODUCTION

Surface and nanoscale aspects are becoming more and more important in modern technology. The ongoing trend for smaller and yet more powerful devices in microelectronics and data storage technology pushes the relevant lateral dimensions far into the sub-micrometer regime. In microelectronics, for example, the smallest lateral dimension of elements in a Random Access Memory (RAM) cell are currently reaching down to about 100 nm and the 65 nm technology node is projected to come within reach in the year 2007 [1]. The bit size in commercially available magnetic data storage has decreased to about 100×500 nm [2], and yet higher storage densities resulting in smaller bit sizes are demonstrated in various research labs throughout the world. At the same time, the relevant vertical dimensions have dropped to the nanometer regime. In order to observe single electron tunnelling phenomena in nonmagnetic or spin-dependent transport effects in magnetic systems, extremely thin films of 1 - 2 nm thickness must be prepared. Paired with these technological developments is a strong scientific activity in the fields of surface physics, surface chemistry, and materials science, which also concerns the creation of a wide variety of nanoscale physical systems.

2. VISUALIZING MICRO- AND NANOSTRUCTURES

It is obvious that this situation asks for high-resolution imaging techniques, in order to visualize the system itself and to investigate its underlying physical and

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chemical properties on a small lateral scale. In addition, these techniques must have a certain surface sensitivity, if studies of surface-related effects or thin film systems are concerned. With respect to the experimental realization, two principal imaging approaches may be distinguished. In *scanning probe techniques* a finely focussed electron beam (Scanning Electron Microscopy) [4] or a tip with nanometer tip radius (Scanning Tunnelling Microscopy) [5] is scanned across the sample surface and the information is collected sequentially on a point-by-point basis. These scanning techniques are well established in surface physics and have been constantly improved in lateral resolution. They have been specialized with respect to the contrast mechanisms to meet various needs. In some cases, even studies of dynamic processes have been carried out. Also dedicated variations of these techniques for the investigation of magnetic surfaces have been developed. These are, for example, Scanning Electron Microscopy with Spin Polarization Analysis (SEMPA) [3], Magnetic Force Microscopy (MFM) [6], or Spin-Polarized Scanning Tunneling Microscopy (ST-STM) [7].

The second imaging approach involves the parallel acquisition scheme well known from conventional light-optical microscopy. The surface is illuminated by a wide beam of electrons or photons and the surface area within the field of view of the microscope is imaged simultaneously, for example, by means of a photo or video camera. In order to combine high spatial resolution with surface sensitivity, the image is formed by the electrons reflected at or emitted from the surface. Technical realizations of this approach, for example, are Low Energy Electron Microscopy (LEEM) [8] and Photoelectron Emission Microscopy (PEEM) [1] for the case of electron and photon beam illumination, respectively. By exploiting specific magnetic contrast mechanisms, both techniques can also be used to study magnetic phenomena at surfaces. This is particularly true for the PEEM technique, which recently became rather popular due to the increasing availability of highly brilliant synchrotron radiation from third generation storage ring facilities. The excitation with polarized soft X-rays (X-PEEM) offers a unique combination of surface sensitivity, element selectivity, and magnetic contrast, as will be discussed in more detail in the following.

1. More precisely this approach is a *photoexcitation* electron emission microscopy. The majority of PEEM experiments generates images with secondary electrons rather than (direct) photoelectrons.