Achievements and perspectives of magnetic soft X- ray transmission microscopy

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A fundamental understanding of magnetism on the nm length and sub-ns time scale is currently the focus of both basic and applied solid state physics research. The origin of interlayer exchange coupling, perpendicular magnetic anisotropies, unusual magneto resistance effects, precessional and relaxation phenomena are just a few examples. Laterally patterned magnetic systems are also promising candidates in future magnetic storage and sensor technologies, where both the miniaturisation and the speeding up of switching processes are crucial.

The X-ray magnetic circular dichroism (X-MCD) effect, in which the absorption coefficient of right and left handed circularly polarized x-rays is dependent on the magnetization state of the sample, has stimulated the development of numerous powerful analysis techniques to investigate the magnetism of solids, surfaces and thin films with inherent energy tuneable element-specificity. The combination of a high-resolution full field transmission soft X-ray microscope with lateral resolution, demonstrated down to 15nm, provided by Fresnel zone plate optical elements, with X-MCD which provides a large and element specific contrast mechanism creates a ideal instrument to study the magnetic behaviour in low dimensional magnetic systems in detail, e.g. layer resolved magnetisation reversal and nucleation processes on an granular length scale. Moreover, the complexity of an elliptically polarized undulator is not required for this technique; the off-axis radiation of a simple bending magnet produces elliptically polarized x-rays either above or below the electron orbital plane. The environment of the sample, which can be at atmospheric pressure, can be controlled by the application of external fields and temperature conditioning.

In addition to high spatial resolution, the inherent sub-ns time structure of current synchrotron radiation facilities can be used in a stroboscopic pump-and-probe experimental arrangement to image the fast magnetization dynamics in microstructured elements. An electronic pulse launched into a microcoil or stripline (pump) excites the magnetization in the sample under test, which is imaged at a variable delay time by the flash of the synchtrotron pulse (probe) [2]. Hence local spin dynamics, e.g. vortex motions on a ns time scale can be addressed.

We will review the current status of the full-field soft X-ray microscopy endstation XM-1 at the ALS in Berkeley CA with respect to technical improvements [3]. Recent experimental results to study the microscopic origin of magnetization reversal will be reported providing detailed insight into the reproducibility and stochasticity of local switching phenomena [4]. Perspectives of MTXM aiming at ultrafast (ps) magnetization dynamics will be discussed.

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