Exploiting the Acceleration Voltage Dependence of EMCD

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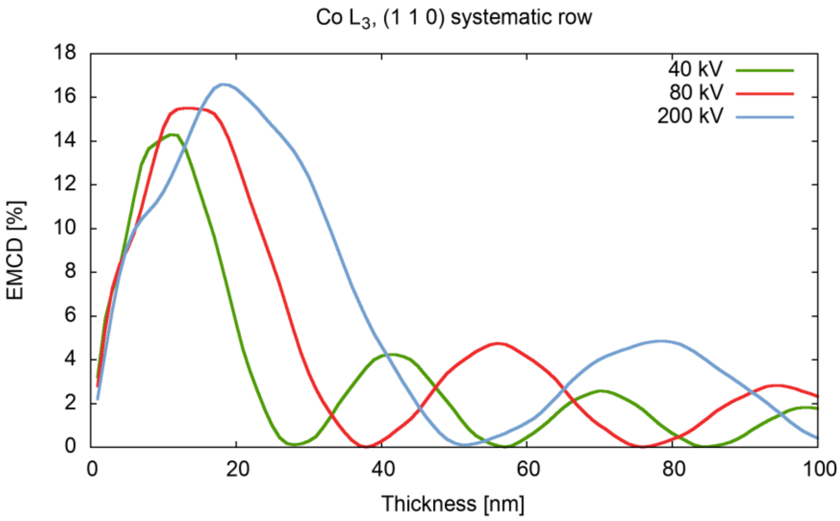
Energy-loss magnetic chiral dichroism (EMCD) [1] is a versatile tool for studying magnetic properties on a wide range of length scales in the TEM using EELS. It is based on the fact that in core-loss excitations in spin-polarized materials, vortex beams are created. These vortex beams are characterized by their unique phase structure, which can be measured by interferometry. To that end, the crystalline sample acts as a beam splitter. The resulting interference fringes can be measured in the diffraction plane on the Thales circle between the diffraction spots [1]. The relative difference between the constructive and the destructive interference fringe is exactly the EMCD effect. There is one downside to using the sample as a beam splitter, however: the electrons' phases oscillate due to elastic scattering as they propagate through the sample - this is the well-known *pendellösung*. This phase oscillation causes a thickness- and orientation-dependence of the EMCD signal and can suppress the measurable EMCD signal well below the experimental noise level [2,3]. In principle, this could be solved by additional sample preparation, but in many situations, that may not be feasible (as this may introduce artifacts, increase the contributions from the surfaces, reduce the overall inelastically scattered intensity, or cause nanoparticles to be removed from the surrounding matrix).

Here, we present an alternative approach to modify the thickness-dependence of the EMCD signal. As the frequency of the phase oscillation is related to the extinction length, which is inversely proportional to the wavelength. Hence, changing the acceleration voltage and with it the electron wavelength allows to tune the relative phases of the undiffracted and the diffracted vortices, thereby changing the EMCD effect. The figure below shows the calculated EMCD thickness dependence for the Co L_3 edge when tilting the sample into a (1 1 0) systematic row condition [4]. It is apparent that for, e.g., a 50 nm thick sample, measurements at 200 kV would yield no signal, whereas measurements at 80 kV would give an appreciable signal of ca. 5%. In addition to an increasing the signal, lowering the acceleration voltage may have many other benefits, such as reducing beam damage. Moreover, acquiring an acceleration voltage series may allow for a kind of tomographic reconstruction in the future by using the fact that the areas contributing strongly to the EMCD signal differ with beam energy.



[1] Schattschneider et al., Nature 441 (2006) 486

[2] Thersleff et al., PRB 94 (2016) 134430

[3] Löffler & Hetaba, Microscopy (2018) DOI: 10.1093/jmicro/dfx129

[4] Löffler & Schattschneider, UM 110 (2010) 831