Quantitative Magneto-Optical Characterization of Diffusive Reflected Light from Rough Steel Samples

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Abstract

Magneto-Optical Kerr Effect (MOKE) magnetometry, spectroscopy and ellipsometry has been employed to characterize and study magnetic systems with different types of surfaces including rough ones [1-6], where it has been shown that there is an important relation in between surface roughness on one hand and domain size and magnetization reversal on the other [1-2,4]. The study of this kind of surfaces is of great importance to achieve a better understanding of the macroscopic magnetic response that arises from complex surfaces and its application to all types of devices. However, up to now, all magnetic-optical studies have focused on surfaces where two fundamental characterization parameters, namely average roughness R_a and mean peak spacing RS_m, are small in comparison to the wavelength of light [1-6]. To our knowledge, no study has analyzed the magneto-optical response in other roughness regimes, i.e., magnetic surfaces with roughness parameters of the order (or much larger) than the wavelength of light, that makes the reflected light show a diffusely broadened spot. The only exception, being a very special particular case of roughness, is the study of the magneto-optical response of diffracted beams, in which the surface presents periodic variations [7,8]. This lack of studies may be attributed to the fact that diffuse light is not only very difficult to measure but also to interpret for generalized geometries, since the measurements usually depend on the spot size collected at the photo-detector as well as on the different optical and magneto-optical responses that occur at different scattering angles [7,8].

Such an analysis of samples with significant roughness would be useful from an applied and industrial point of view, since it may allow a low-cost non-invasive surface magnetic characterization of industrial samples. The purpose of our study is therefore to explore this possibility. Specifically, we measure here the magneto-optical response of polished industrial samples of varying average roughness R_a, which is of the order of the light wavelength and has a mean peak spacing RS_m that is much larger than the observation wavelength (see figure 1). For this purpose, we performed quantitative MOKE measurements for diffusely scattered light with high signal-to-noise ratio, using a crossed polarizer set-up that is conventionally utilized for MOKE and generalized magneto-optical (GME) ellipsometry. Our study demonstrates that for these specific samples, the magneto-optical activity is monotonously increasing as a function of the scattering angle, while preserving its field dependent shape, i.e. the hysteresis loop shape (see figure 2). We furthermore find that this behavior can be explained by considering the diffused light reflected from a rough surface to be equivalent to the reflection of light from planar surface segments with varying incidence angles. Finally, these results allow for scattering angle dependent integration and therefore, we expect that quantitative magneto-optical characterization of rough surfaces will find wide-spread applications for industrial samples.

References

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Figures

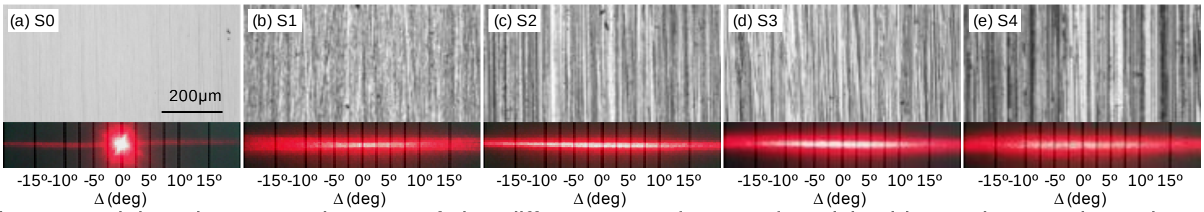

Figure 1. Light microscopy images of the different samples employed in this study. For the sake of roughness comparison, all sample stripes are aligned vertically. The scale shown in (a) applies to all pictures. Below the images, we show the scattered laser spots corresponding to each of the samples. Δ accounts for the difference in between incidence and scattering angles (Δ = 0 for specular reflection).

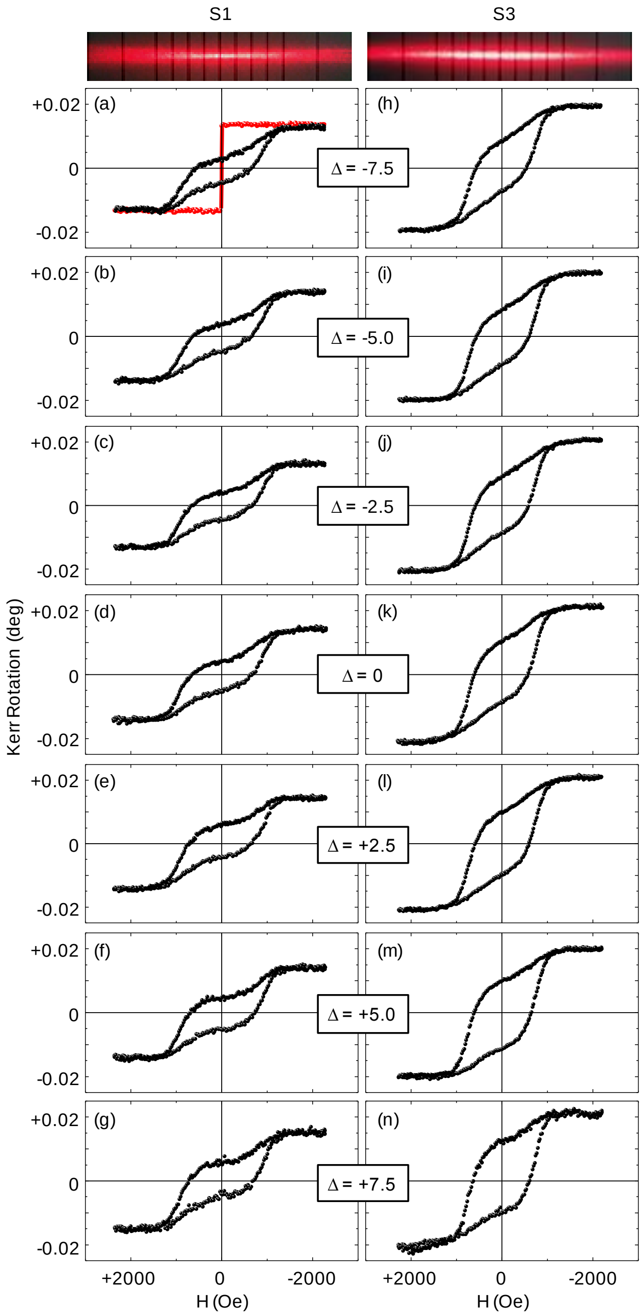

Figure 2. Experimentally determined Kerr rotation hysteresis loops for different scattering angles: (a-g) sample S1 with small roughness; (h-n) sample S3 with larger roughness. For comparison, figure (a) also displays the normalized bulk magnetization response of sample S1 (which is equivalent for all samples in our study) as a function of the applied magnetic field.