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New advances in magneto-optical imaging applied to rock magnetism

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We present new advances in the microscopic magneto-optical imaging (MOI) technique applied to rock magnetism. This technique uses the Faraday effect of a thick MO active film. The propagation of linearly polarized light parallel to the direction of magnetization of the film induces a rotation of the polarization direction of the light (Faraday rotation). For small magnetic components B_Z oriented perpendicularly to the film, the Faraday angle of rotation of the polarization of perpendicular incident light is given by $\alpha_F = VB_Zd$, where V is the Verdet constant of the MO material, and d is the thickness of MO active film. Therefore, when the MO film is placed on top of a sample, the MOI technique images the perpendicular component of the magnetic field at the specimen surface. The flux density B_Z is observed through the analyzer of a polarized light microscope. The MO film, or indicator, used in the present study is a bi-doped Yttrium-Iron-Garnet film of thickness 5 μm, deposited on Gadolinium-Gallium Garnet substrate (thickness 500 μm), and covered by a reflecting Al mirror (100 nm). This configuration enables us to observe magnetic fields at the surface of polished samples, such as rocks. In this geometry, light passes through the MO active film twice, and thus the angle of rotation and the sensitivity is doubled ($\alpha_F = 2VBZd$). The contrast of the MO images depends on the relative angular orientation position of polarizer and analyzer. On typically obtains a contrast between bright and dark regions corresponding to field parallel (antiparallel) to the sample normal. Subtraction of images obtained at two different analyzer angles (polarization modulation technique) increases the contrast in image of samples carrying a weak magnetization, such as natural remanent magnetization (NRM).

We will present images obtained on geological samples and meteorites. The MO images show spatial resolution of about 10 μm owing to the thin MO active layer and the close sample-to-layer distance. Besides its good spatial resolution (with respect to magnetic scanning techniques), one of the main advantages is the direct comparison of the magnetic image and the reflected light image taken with the same microscope. For instance, we have successfully imaged internal structures in metallic grains in meteorites carrying SIRM. Even in the NRM state, the MOI technique combined with polarization modulation can reveal small dipole-like features within a metal grain in meteorites.

In conclusion, the MOI technique can image surface magnetic field with 10 μm spatial resolution and appears as a very powerful tool to identify the components responsible for remanence in rock samples.