Magnetic high-field studies of nanostructures in natural and synthetic ilmenite-hematite solid solutions

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Abstract: Nanostructures in quenched hematite-ilmenite solid solutions or exsolved hemo-ilmenite or ilmeno-hematite can exhibit strong exchange bias, self-reversed thermoremanent magnetization, and extremely high coercivity. Even magnetic fields up to 7T commonly are completely insufficient for magnetic saturation of such materials. To obtain a better physical understanding of these phenomena, the magnetization of a series of synthetic quenched and annealed metastable ferri-ilmenite solid solutions and several naturally exsolved samples, showing lamellar magnetism, were measured in fields up to 60T in the Dresden High Magnetic Field Laboratory (HLD). Magnetization change is measured by integrating the voltage induced in a secondary coil during the primary field pulse lasting 6 ms, and then subtracting a corresponding background signal from a pulse with an empty holder. The voltage signal is individually calibrated by comparison to PPMS/MPMS measurements on the same samples. In the synthetic samples, saturation field and critical exponent of the approach-to-saturation law depend primarily on the degree of order Q as inferred from Bloch's law, or a mean-field model of M_s *(T)* curves. Details of the approach-to-saturation curves relate to the nanoscale microstructure of antiphase domains evolved during incremental ordering. The metamagnetic transition of ilmenite is visible in natural ilmenite and in a ferri-ilmenite solid solution containing 97% ilmenite. Most remarkably, it also occurs in natural exsolved titanohematite samples, which show exchange bias at low temperature. This provides additional evidence for the crucial

role of nanoscale ilmenite lamellae for the unusual magnetic properties of these minerals.

Keywords: hematit-ilmenite, metamagnetic transition, self-reversal, exchange bias

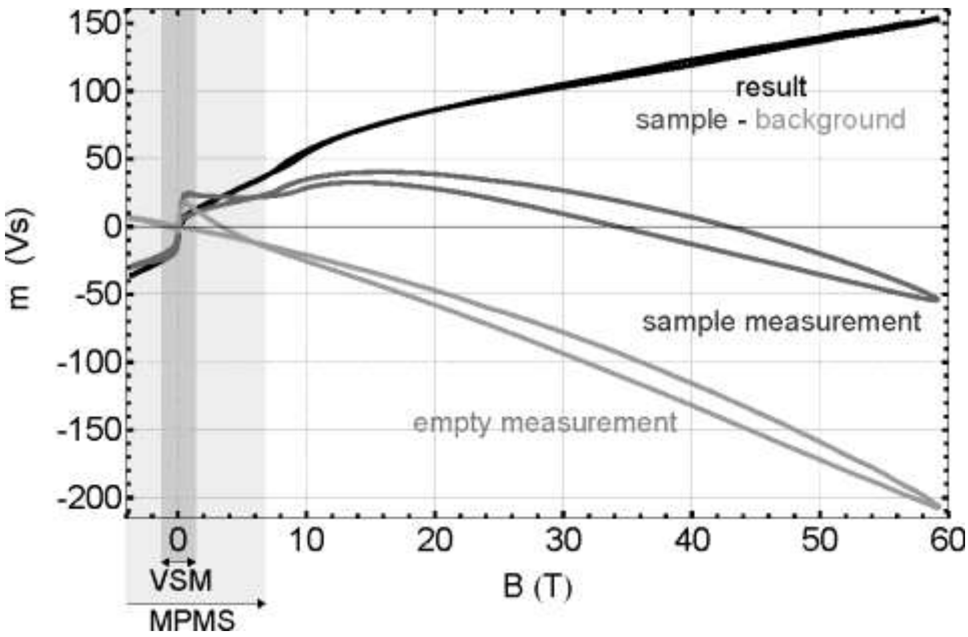

Figure 1: Evaluation of an magnetization measurement at the High-Field Laboratory Dresden (HLD) . The sample's magnetization curve at 6.1 K is obtained from the difference between sample and empty magnetization measurements, represented by integrated induced voltages within a secondary coil during a 6 ms current pulse through the primary coil. Note the metamagnetic transition near 8 T that proves the presence of ilmenite in this natural sample, and explains a previous observation of upward bended hysteresis loops in 7 T MPMS measurements at 5 K.