Simulations of electron holographic observations of magnetic microstructure in exsolved titanomagnetites

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Introduction

Titanomagnetite inclusions in slowly-cooled rocks can contain essential microstructures that consist of closely-spaced ferromagnetic Fe3O4 prisms separated by paramagnetic ultratitanite (Fe2O3) lamellae. Electron holography was used to image the magnetic microstructure of esch that the prisms are mostly magnetically-interacting single domains. Figure 1 shows a set of magnetized prisms, with the orientation of their magnetic field revealed by the projected flux lines in colors (within and outside each element).

The magnetic microstructure depends sensitively on the shapes, spacings and orientations of the prisms, as well as on magnetic history. To understand the observed magnetic microstructures, we have carried out simulations of linear arrays of uniformly-magnetized ferromagnetic prisms by making use of known expressions for demagnetization factors. By varying the size and spacing of the prisms it is possible to chart the magnetic structures of such mineral assemblages in the form of "magnetic microstructure phase diagrams".

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The number of elements in a stack is a sensitive parameter in determining the cross-over critical point. In the figure above (from Ref. [4]), elements are highly anti-parallel if considered alone (the aspect ratio of most elements is between 2 and 4), but we still observe HH-type configurations. Fixing the aspect ratio of each element to 3, we can re-calculate the cross-over point as a function of number of elements in the stack, finding that at least 10 elements are needed to establish the HH state.

References


Fig. 2: A single-domain element of lateral size 20 nm separated by 10 nm is shown to reveal the orientation of the magnetic field, with the orientation of the field revealed by the vector arrows in the images. The cross-over point depends on the thickness of the element 2Lz, a quantity that is not easy to estimate experimentally. It also depends on the larger extent, on the separation distance, a between the elements. This is shown in the plot above, where critical curves (phase boundaries) are drawn as a function of thickness for several values of the separation a. The HH state is expected above the phase boundary, while the AP state is expected below it. The curves refer to prisms of lateral size 2Lz = 200 nm.