Monoclinic c-axis selection at the Verwey transition: new insights from off-axis electron holography and the delta-ratio magnetosome detection method

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Given their stable single domain (SSD) configuration at room temperature and world-wide occurrence, magnetosomes produced by magnetotactic bacteria are potentially an important source for stable (post) depositional remanence. One way to detect their presence is by the so-called low-temperature delta-ratio test proposed by Moskowitz et al. [1993]. When magnetite is cooled through the Verwey transition at ~120K (Tv) it transforms from cubic to monoclinic symmetry. Associated with this crystallographic transition is the selection of a new magnetic easy axis along the c-axis in the monoclinic phase, which corresponds to one of the three original cubic [100] directions. The selection of the new c-axis is at least a function of the presence or absence of an external field during cooling. In fact, this cooling field dependence forms the basis for the delta-ratio test for detecting chains of magnetite magnetosomes. In essence, the application of the external field biases the c-axis selection and effectively produces an assemblage of partially aligned SD particles below Tv. Whereas samples containing high concentrations of magnetite magnetosomes chains are known to yield high delta ratios (>2.0), the details remain unclear. For instance, we do not know how physical deformation of the chain structure may modify the c-axis selection. Nor do we have

a good understanding of how partial oxidation or magnetic relaxation affects the reorientation of magnetic easy axes on warming remanences. Here we attempt to duplicate the delta- ratio test inside a transmission electron microscope while monitoring the magnetic microstructures within magnetite magnetosome chains using off-axis electron holography. Our results will shed light on the c-axis selection process and the possible reasons for elevated delta ratios in magnetite magnetosomes.