Resolving Individual Magnetic Domains in Single-Crystal ε-Fe_2O_3 via High-Sensitivity *in vacuo* Magnetic Force Microscopy

SHEET No. 011

Instrument: Hitachi AFM5300E with High-Vacuum and Environmental Control

Introduction

Iron(III) oxide (Fe_2O_3) has four known phases: α-, β-, γ-, and ε-. While α- and γ-Fe_2O_3 exist naturally in minerals, the other two phases (β- and ε-) are typically generated through a synthetic route. In 2004, Prof. Shinichi Ohkoshi, *et al.* from the University of Tokyo reported the novel observation of an extremely large coercive field (20 kOe) comprised of nanometer-sized ε-Fe_2O_3 that was generated via nanoparticle synthesis. This discovery led to extensive investigations on the magnetic properties and domain structures of ε-Fe_2O_3. This application data sheet demonstrates Hitachi's high-sensitivity magnetic force microscopy (MFM) studies of ε-Fe_2O_3 with single-crystal rod morphology.[1)]

(a) (b) (c)

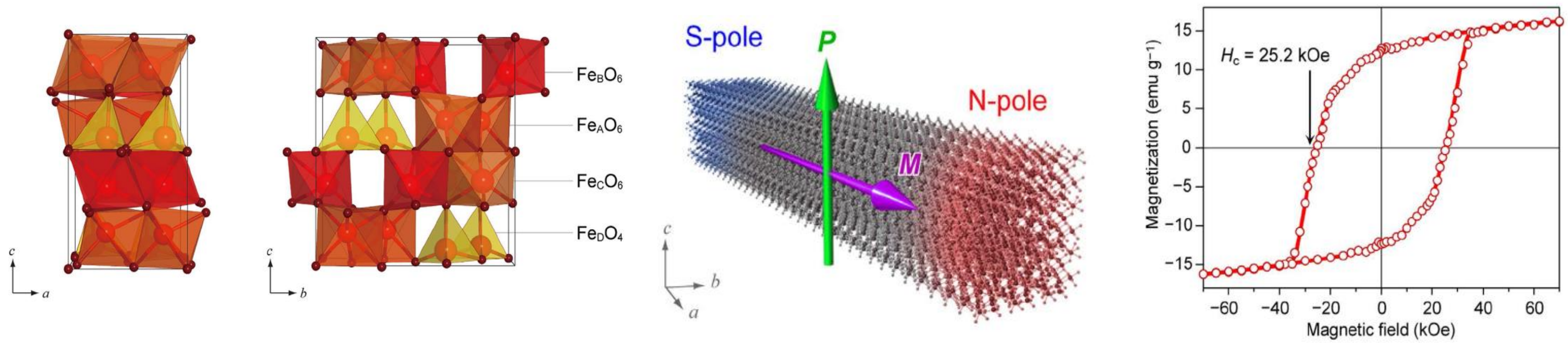

Figure 1: Crystal structure and unique magnetic characteristics of ε-Fe_2O_3. (a) The ε-Fe_2O_3 unit cell viewed along the b-axis (left) and a-axis (right). (b) Schematic image of a bar magnet based on a mesoscopic ε-Fe_2O_3 rod. (c) Magnetization versus external field plot of the ε-Fe_2O_3 rod measured at room temperature along a single in-plane direction.

1) Joint research of The University of Tokyo, University of Tsukuba, and Hitachi High-Tech Science Corporation. S. Ohkoshi *et al.*, Scientific Reports **6**, 27212 (2016).

Results

Figure 2 shows high-sensitivity MFM imaging of a ε-Fe_2O_3 single-crystal ferrite bar magnet in vacuum. Several of these bar magnets are fixed on a common substrate and each bar magnet morphology is that of a single-crystal ε-Fe_2O_3 with its own spontaneous magnetization. The N- and S-pole regions of individual rods as well as overlapping rod complexes were clearly observed with MFM.

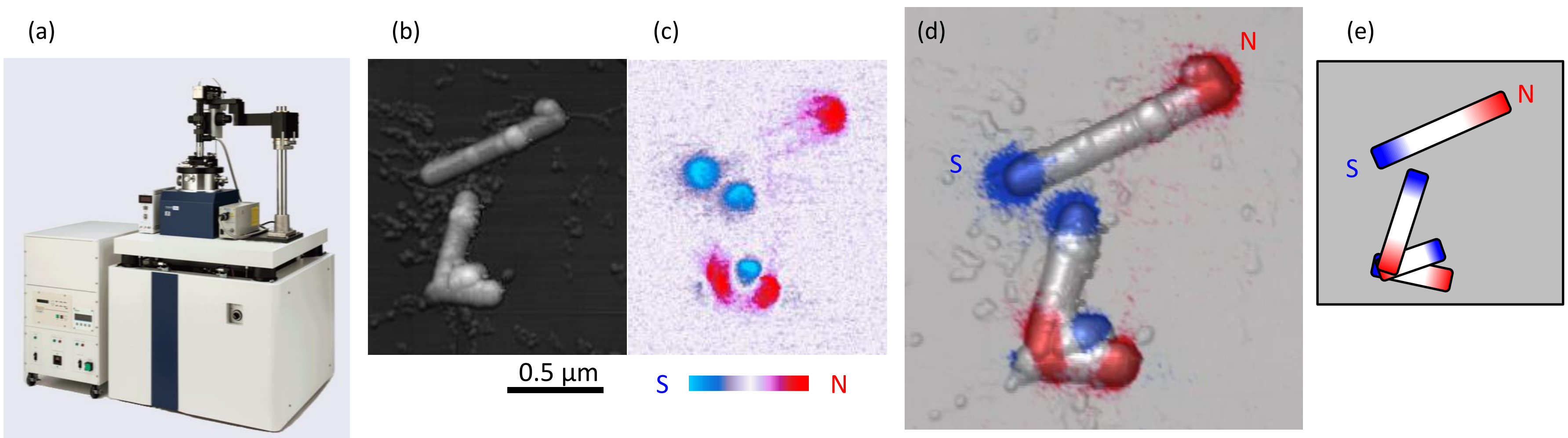

Figure 2: (a) Hitachi high vacuum AFM5300E. (b) Topography and (c) MFM images of an ε-Fe_2O_3 single-crystal ferrite bar magnet. (d) Topography-MFM overlay image. (e) Magnetization arrangement model.

More Applications of ε-Fe_2O_3

Single-crystal ε-Fe_2O_3 exhibits a resonance frequency in response to the magneto-optical effect at the terahertz level (10^{12} Hz). Therefore, one example of utilizing this property could be to serve as a high-frequency microwave-absorbing material in advanced highway safety systems.

Additionally, single-crystal ε-Fe_2O_3, when attached to an AFM cantilever, can be utilized as a high-performance MFM probe due to its high coercivity (Hc).

Author: T. Yamaoka, Analytical Application Engineering Section Tokyo 2, Hitachi High-Tech Science Corporation

Hitachi High-Tech Science Corporation

Headquarters Business Department, 1-24-14, Nishi-Shimbashi, Minato-ku, Tokyo 105-0003 Tel.: +81-3-6280-0062