# Same Area Observation of the Nano-Structure, Composition and Properties of Crystals and Grain Boundaries

SHEET No. 004

～Ion Milling-SEM-AFM of a Nd-Fe-B Permanent Magnet～

Instruments: Environment control AFM AFM5300E, Hybrid Ion Milling IM4000 Plus
Shottky FE-SEM SU5000

## Introduction

The increasing demand for high quality Nd-Fe-B magnets used in electric vehicle motors requires their exact control, observation and evaluation of the nano-structure, composition and magnetic properties at crystal grain size level. This data sheet presents the observation results of a hot-deformed Nd-Fe-B permanent magnet. The nano-structure, composition and properties of its crystals and grain boundaries were observed with SEM and magnetic force microscopy (MFM) after the flatmilling® process.

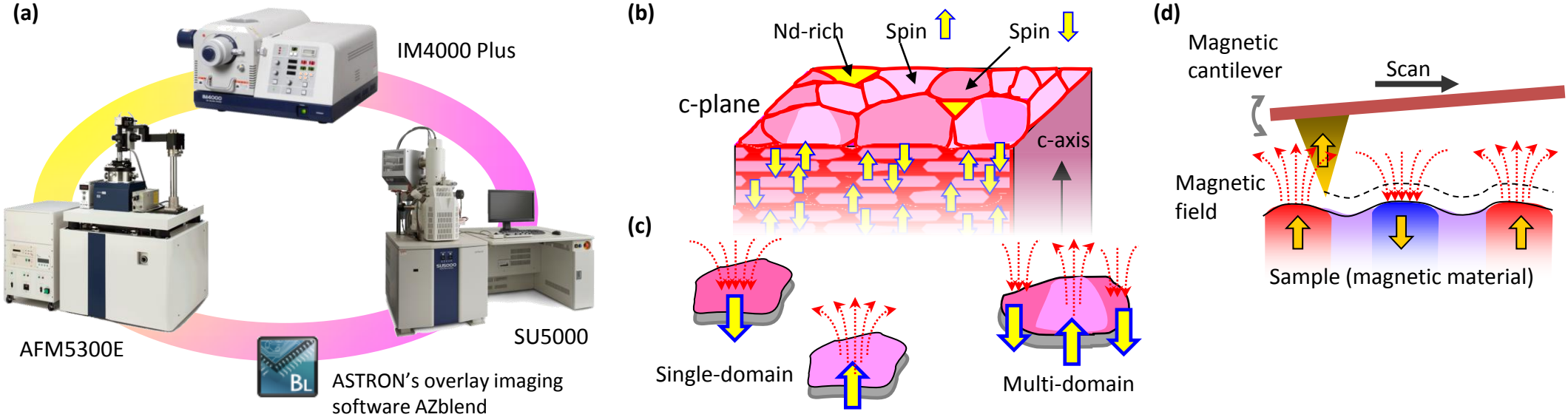


Figure 1: (a) Ion milling for flatmilling® and SEM-AFM for the observation of a hot-deformed Nd-Fe-B magnet (b) Model of the crystal structure of the magnet and its magnetization at the thermally demagnetized state (c) Single-domain and multi-domain grain models (d) MFM (magnetic force microscopy) principle

※ The flat crystals of a hot-deformed Nd-Fe-B permanent magnet, being 300 nm large and 50 nm thick, are oriented in c-axis direction. The spin direction of the crystals is upwards or downwards and can be divided into single-domain grains with only one magnetization and multi-domain grains showing multiple magnetic domains. At a completely thermally demagnetized state, the amount of upwards and downwards spins of the whole sample are equal.

## Results

Figure 2 shows the overlay images of SE (secondary electron) and BSE (back-scattered electron) images with AFM and MFM images of the crystal grain boundaries of a hot-deformed magnet that became visible after the flatmilling® with the ion milling. The MFM/SE image shows very clearly the correlation of structure and magnetism so that each crystal grain can be identified as single-domain or multi-domain grain. From the MFM/BSE image, the non-magnetic Nd-rich grains observed as white crystal grains by BSE reveal in the MFM image a weaker contrast. [1)]

By the correlative analysis of SEM and MFM observation results, plenty of sample surface information could be obtained that could not have been acquired by only analysing the SEM image or the MFM image.

1) Yamaoka, Tsujikawa, Ando, Hasumura, IEEJ Technical Meeting on Magnetics (invited), MAG-15-161, IEEEJapan, pp.39-43, 2015.

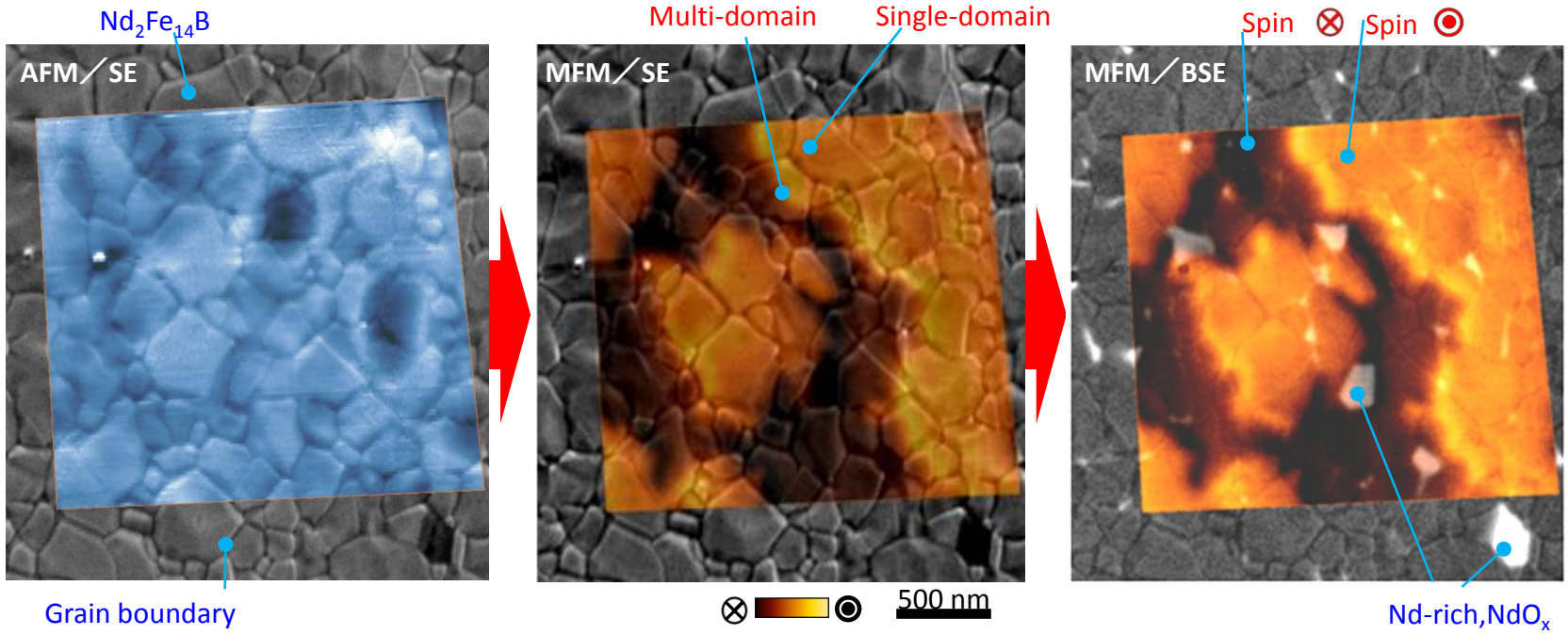


Figure 2: SEM-MFM Observation results of a hot-deformed Nd-Fe-B magnet, overlay images made by AZblend (Sample courtesy: Daido Steel Co., Ltd.)

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