Visualizing Magnetic domain of Electric Steel using Grating Interferometer at NG6 of NIST

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1. Introduction

As technology advances at high speed, nondestructive imaging has been greatly developed. The Grating Interferometer is one of new imaging techniques provides improved contrast images, Phase Contrast Image and Dark-Field Image, which have never been seen before by conventional radiography. Neutron Dark-Field Imaging (NDFI) suggests new approach for material science providing the scattering image caused by the micro-structure of object. We attracted to the application of NDFI for material science, the electric steel which produce magnetic scattering information especially. In this study, we developed 1 dimensional gratings using gadox filling method to make the Talbot-Lau Interferometer (TLI). The experiment was conducted at cold neutron imaging facility NG6 of National Institute of Standards and Technologies, NIST. We summarize theory of TLI briefly, and it is verified by reporting the result of experiment. In the end of paper, we offer a magnetic domain image of electric steel which is showing a valuable application of NDFI for material science.

2. Methods and Results

2.1 Gratings and Gadox filling method

We prepared set of gratings which have been designed for TLI, π phase shift and neutron wavelength of 4.4Å. One of absorption gratings, source grating, was fabricated using Gadolinium Oxysulfide (Gadox) filling method instead of a deposition method as shown in Fig. 1.

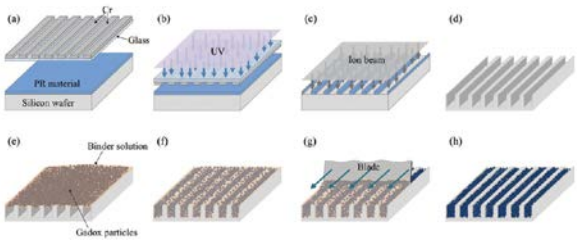

Figure 1. Gadox filling process

The Gadox particles are about 5um, and they are bound between structures of silicon wafer by mixing with texanol and acrylic resin. Table 1 shows information of gratings of TLI.

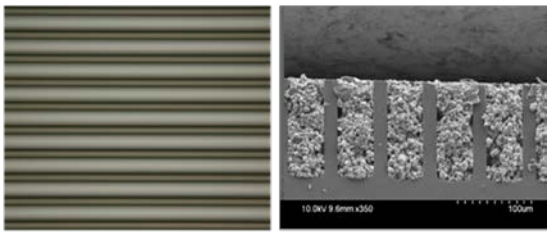

Figure 2. SEM image of Grating

Table 1. Parameters of gratings

	Source grating	Phase grating	Analyzer grating
Period	616.33um	7.95um	4um
Height	400um	34.39um	2.8um
Duty cycle	0.4	0.5	0.25

2.2 Talbot-Lau Interferometer

Grating Interferometer is divided by a lot of configurations about the number and the position of gratings. We are interested in the TLI with long distance in order 3 as shown in Fig. 3. The total length of interferometer from source grating to analyzer grating is 8.352m. Source grating is positioned just before beam source to make neutron beam coherent as a splitter, and analyzer grating is located just ahead of the detector to acquire interferential pattern which is analyzed by phase stepping technique. Phase grating which makes neutrons interfere is located at 5.42cm before analyzer grating.

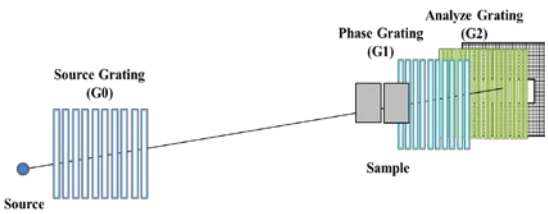

Figure 3. Schematics of Talbot-Lau Interferometer

2.3 Cold Neutron Beamline, NG6

NG6 is new cold neutron beamline at National Institute of Standards and Technologies, NIST. It is specialized at imaging research with Andor SCMOS image sensor that has 2560 x 2160 pixels which are 6.5um. It is attached with 300um thick of LiF scintillator and 20um thick of Gadox scintillator for high-resolution imaging. Monochromatic beam is available by double crystal monochromator which has two of Pyrolytic Graphite (PG) with 0.8 of mosaic spread. It is prepared that aluminum tubes hold the beam intensity from 6% of reduction per each tube. NG6 pursues flexible design for various imaging research, and it is concentrated on grating interferometer, energy selective imaging, microscopic imaging using wolter optics and so on.

2.4 NDFI of Electric steel

Neutrons interact with the magnetic domain wall of electric steel because they have a spin and a magnetic moment. It is related with a magnetic scattering which decreases the amplitude of interferogram obtained by interferometer, and magnetic domain can be visualized by analyze this information. We prepared two types of electric steel that are Grain Oriented (GO) type and Non-Grain Oriented (NGO) type. They were irradiated for NDFI as shown in Fig. 4, and finally the magnetic domains were acquired as shown in Fig. 5.

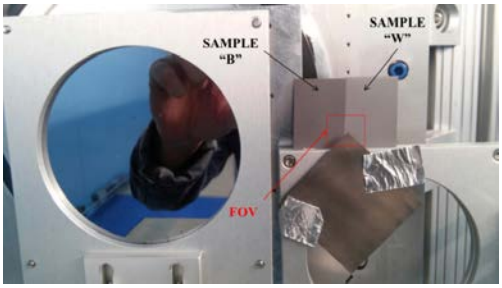

Figure 4. Setup of visualizing magnetic domain of electric steels

Figure 5. Magnetic domain of electric steel

3. Conclusions

We confirmed that the 3 order Talbot-Lau type of neutron grating interferometer which is composed of gratings made by gadox filling method is well operated at cold neutron imaging beamline. NDFI is definitely powerful visualizing tool for material science, especially magnetic materials. In further study, we will research electric steel more in realistic conditions when it is worked as a component of electric motor. Additionally, we are interested in the relationship between magnetic domain and stress condition of thin electric steel, so it is also studied in near future.

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