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Magnetostriction Curve of Iron Observed with X-ray Diffraction

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As sensitivity on a magnetostriction measurement with an X-ray diffraction technique has been improved [1], an observation on the magnetostriction and a relative magnetization simultaneously at specimen coextensive volumes has made getting an exact magnetostriction curve possible [2]. The magnetostriction curve shows a magnetization dependency of the magnetostriction as a parameter of a magnetic field. The magnetostriction curve contains information on behaviors of magnetic domains in a magnetization process, which has not been able to be determined with a hysteresis curve of the magnetization as a function of the magnetic field. Though it has been said so far that no hysteresis features of the magnetostriction curve are shown [3], recently, hysteresis of the magnetostriction curve of laminated SiFe alloys were reported [4]. The magnetostriction curves along typical directions for single crystal specimens would little show the hysteresis. With the X-ray diffraction technique, we studied the hysteresis of the magnetostriction curve in a single crystal specimen of iron which was magnetized along a special direction [5].

For iron, [100] is one of the magnetization easy axes, and [111] is one of the magnetization hard axes. λ_{100} and λ_{111} are magnetostrictive coefficients for them. If we apply the magnetic field, H, along [$\bar{1}$12], an estimated magnetostriction observed along [110] with X-ray diffraction is

$$\lambda_{\perp} = -\frac{1}{4}\lambda_{100} - \frac{1}{4}\lambda_{111}, \qquad (1)$$

where $\lambda_{\perp}$ is a perpendicular component of the magnetostriction to the magnetization. Note that two factors, −1/4, in front of both λ_{100} and λ_{111} terms in (1) are equal. Absolute values of λ_{100} and λ_{111} of iron are almost same but their signs are opposite [5]. This configuration is one kind of the null method, when one investigates the hysteresis of the magnetostriction curve of iron [5]. The $\lambda_{\perp}(H)$ profile to be observed at a certain process during the cyclic magnetization, $M(H)$, as a parameter of H would show which contribution of either λ_{100} term or λ_{111} term was dominant. This configuration would be sensitive to the magnetostrictive behavior [5].

An experiment was performed on beamline BL15B1 of PF, KEK. X-ray beams from a bending magnet were monochromatized by a Si(331) channel cut crystal monochromator. The incident beam was π-polarization. The photon energy was tuned to Fe K absorption edge, 7.111 keV, 1.744 Å. A specimen was a single crystal iron disk of 6.0 mm diameter and 2.0 mm thick in size, 99.94+% (Monocrystals Co.). The flat surface side used was (110). It was exposed under atmosphere during the measurement. An X-ray beam irradiated area was 2 mm horizontal and 2 mm vertical. The specimen [$\bar{1}$12] was oriented vertically, in-plane to the specimen flat surface, along which the magnetic field with an electromagnet of maximum 4.7 kOe was applied, and perpendicular to the scattering plane. At room temperature, 220 diffraction intensity was counted with an SSD on a 2θ-θ axes goniometer.

Fig. 1 represented the magnetostriction curve during the cyclic magnetization which was averaged among the curves observed at six different incident angles of lower and higher angle sides than the rocking curve center. Measurement time for whole data in Fig. 1 was approximately two days, which included the photon counting time and magnetic field applying time [5].

Scatters of Fig. 1 were not small, but one could see a flat region and different heights of two positive peaks [5].

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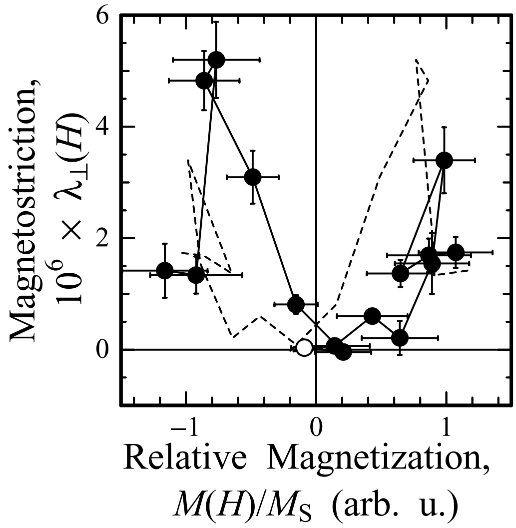

Fig. 1. Magnetostrictive behaviour of iron (110) specimen surface during cyclic magnetization at room temperature. Circle marks were plotted while H was ascending. An open circle of them indicated the point that was measured at H = 0. Solid curve was a guide to the eye for ascending H. Broken curve for descending H was simply obtained from reversing the solid curve at H = 0. After [5], modified.

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