15B1/2003G003

Magnetostriction Observation by Magnetic Field Symmetry Diffraction Intensity Change at X-ray Resonant Energy Region in Iron

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An X-ray resonant magnetic diffraction was first applied to observe a magnetic field symmetry intensity change in iron. The diffraction usually observes the magnetization asymmetry effect of the anomalous dispersion term of magnetic scattering factor [1,2]. A study on the magnetic field symmetry effect is important to investigate magnetostriction [3].

An X-ray diffractometer method is a direct measurement for determining an internal lattice constant. It is, however, seldom used, because it takes long measurement time except intense synchrotron radiation [4]. X-rays presented only a poor resolution [3]. Ultimate sensitivity was 10^{-5} [3]. The X-ray diffractometer method was applied to obtain the magnetostrictive coefficients, where lattice parameters of magnetized state were measured but lattice parameters of the demagnetized state were calculated [5].

The relative diffraction intensity change is defined as $\delta(H)= (I(H)- \bar{I}(0))/ \bar{I}(0)$, where $I(H)$ is a diffraction intensity at external magnetic field H. $\bar{I}(0)$ is an average diffraction intensity at ascending and descending zero magnetic fields. Two kinds of $\delta(H)$'s are observed as $\delta_a(H)$ and $\delta_d(H)$ at ascending and descending magnetic field, respectively. Subtracting the magnetic field asymmetry effect $<\delta(H)>= (\delta_a(H)-\delta_d(-H))/2$ from $\delta(H)$ gives the magnetic field symmetry effect $\delta(H)-<\delta(H)>$. $<\delta(H)>$ is proportional to a flipping ratio R_a of the magnetic diffraction. $\delta(H)-<\delta(H)>$ is proportional to a Bragg angle change $\Delta\Theta$. As R_a is proportional to the magnetization, R_a divided by its own saturation value evaluates a normalized magnetization M/M_s. The Bragg angle change $\Delta\Theta$ is solved by comparing $\delta(H)-<\delta(H)>$ with the rocking curve at H=0, as $\delta(H)-<\delta(H)>=-(\Delta I(\theta)/\Delta\theta)(\Delta\Theta/I(\theta))$, where θ is an incident angle. Provided to neglect the magnetostrictive volume change, the magnetostrictive coefficient λ_{100} is obtained by $\lambda_{100}=2(\cot \theta_B)\Delta\Theta$, where θ_B is a Bragg angle.

Experiments were performed with the equipments at BL15B1, PF/KEK. An incident X-ray beam was π-polarized with the energy tuned to Fe *K* absorption edge. A specimen was a single crystal of iron, 99.94+% (Monocrystals Co.). The size of the specimen was 6.0 mm diameter and 2.0 mm thick disk. A magnetic field *H* with an electromagnet to the specimen was the perpendicular direction to the scattering plane. The [001] direction of the specimen was parallel to *H*. The surface plane of the specimen was (110), and diffraction observed was 220.

Figure 1 shows the results of the quantitative magnetostrictive coefficient λ_{100} curve of the iron specimen during normalized magnetization M/M_s hysteresis process at room temperature. Solid circles were observed when *H* was ascending. Solid and broken curves are guides to the eye for ascending and descending *H*, respectively.

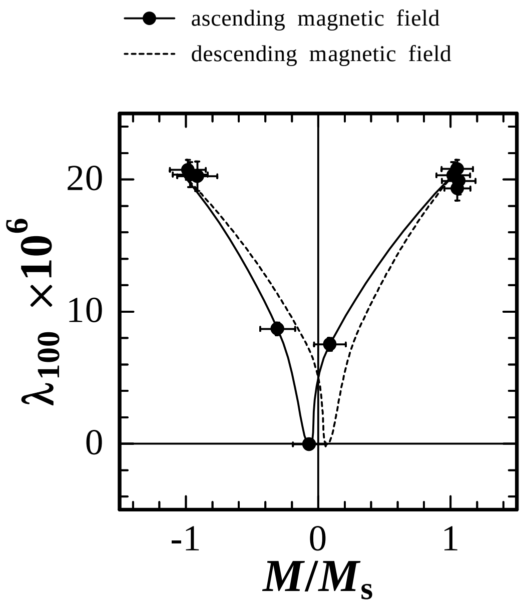

Figure 1 The magnetostriction of iron at room temperature during cyclic magnetization

The iron λ_{100} observed was $(21.0 \pm 0.6)\times10^{-6}$. It should be emphasized that the sensitivity of present method on the magnetostrictive coefficient was 10^{-7}.

We conclude that the observation of the magnetic field symmetry diffraction intensity change would be a new technique to observe the magnetostriction with the magnetization by X-rays.

[1] K. Namikawa, et al., J. Phys. Soc. Jpn. 54 (1985) 4099.
[2] K. Mori, et al., Jpn. J. Appl. Phys. 32 (1992) 323.
[3] E. du Trémolet de Lacheisserie, Magnetostriction: Theory and Applications of Magnetoelasticity, Boca Raton, CRC Press, 1993.
[4] R. Grössinger, et al., 1&2-Dimensional Magnetic Measurement and Testing, Bad Gastein (2000) Paper I-5, 35.
[5] J. Kusz, et al., J. Appl. Cryst., 33 (2000) 213.
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