STUDIES ON SPINTRONICS-RELATED THIN FILMS USING SYNCHROTRON-RADIATION-BASED MÖSSBAUER SPECTROSCOPY

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Mössbauer spectroscopy, which can detect local electronic states around nuclei, has been used to study magnetism of thin films, including surface and interface magnetism, in these decades. The role of this experimental method becomes larger in phase with the recent development of “spintronics”, where spins of electrons are actively used for electronic devices.

When Mössbauer spectroscopy is applied to thin films or nanostructures prepared on thick substrates, conversion electron Mössbauer spectroscopy with a radioactive source is usually used in laboratories. With this method, however, it is relatively difficult to perform measurements at special sample conditions, such as at very low temperatures and in magnetic fields. Besides, more and more sensitivity has been required for very thin films and patterned nanostructures prepared on substrates. Synchrotron-radiation-based Mössbauer spectroscopy is a promising method to overcome these problems and make Mössbauer spectroscopy more attractive for researchers in industrial applications of magnetic thin films and nanostructures.

When the synchrotron radiation, which is basically a “white” light source, is used for Mössbauer spectroscopy, special ideas and setups are required. The method which has mainly been used so far for thin film experiments is "time domain" measurements, where interference patterns of pulsed X-rays resonantly scattered by nuclei are detected as a function of time [1]. By analyzing the time spectra, the size and direction of magnetic hyperfine field can be obtained. This method is quite time-effective and the validity for the determination of the direction of magnetization in thin film systems has been well-demonstrated so far [2, 3]. However, magnetic materials for industrial use often have inhomogeneity in the nuclear environments, so that the analysis of time spectra becomes complicated [4]. Therefore, "energy domain" measurements are desirable for industrial applications.

In this presentation, examples of synchrotron-radiation-based Mössbauer spectroscopy in energy domain on thin films performed by our group are introduced. Two methods have been developed and optimized for experiments on magnetic thin films. One is to use a standard absorber to create an energy dip in neV order in the light source [5] (Fig. 1(a)). The other is to use a nuclear Bragg monochromater to monochromatize the light source into neV order [6] (Fig. 1(b)). The dip energy (in the former case) or the peak energy (in the latter case) is modulated by the Doppler shift. The X-rays resonantly scattered by the sample are detected synchronized with the Doppler velocity to obtain Mössbauer spectra in energy domain.

The measured samples are spintronics-related thin films, which include layered Fe/Cr films, where giant magnetoresistance effect was first observed [7, 8], Co_2MnSn Heusler alloy films, where high conduction-electron spin polarization is expected [9], Fe_4N films, where negative anisotropic magnetoresistance was observed [10], and layered Fe/Fe_3O_4 films, where strong antiparallel magnetic coupling is observed [11]. The validity and limitation of the energy-domain methods for industrial application will be discussed.

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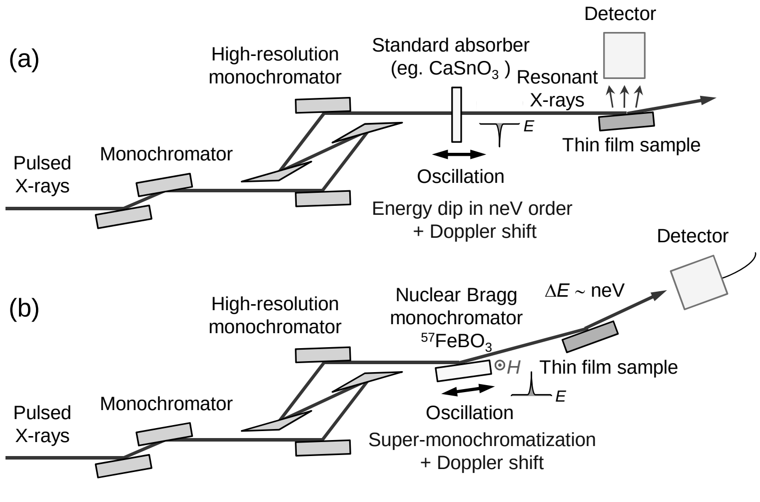

Fig. 1 Typical setups for synchrotron-radiation-based Mössbauer spectroscopy in energy domain for the investigations on thin-film magnetism.