NE3/2001G240

Perovskite related materials studied by nuclear forward scattering of synchrotron radiation

Kiyoshi NOMURA*[1], Alexandre RYKOV[1], Toru. OHKUBO[1] and Xiaowei ZHANG[2]
[1]School of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-8656, Japan
[2]KEK-PF, 1-1 Oho, Tsukuba, Ibaraki, 305-0801 Japan

Introduction

Conducting magnetic systems, consisting of nanometer size magnetic domains dispersed in a non-magnetic conducting matrix have attracted a great deal of research activities in recent years due to associated properties of colossal magnetoresistance (CMR). The method of Nuclear Forward Scattering (NFS) allows resolving the spatial distribution of magnetic inhomogeneities whenever they are on the length scale of the transverse coherence length of synchrotron radiation. The resonance consists in the elastic absorption of the 14.413 keV X-rays, that is a phenomenon known as Mössbauer effect. The time structure of SR is adjusted to the Fe lifetime ($\tau_n \approx 141$ns) in a way to measure effectively the time structure of quanta delayed via the excitation of nuclear level.

Experimental

We employed the monochromatized 14.413 keV SR with the bandwidth of 6 meV. APD detector was used to detect 14.413keV with the time resolution of less than 1 ns. The lengths of pathways from the source elements to the nuclei in the nano-sized domain of the sample determine the distribution of the wave fields at the different sample domains. The SR source at KEK has 2 mm size (D) in holizontal direction, and the typical distances between source and sample (L) are of the order of 25 m. The wavelength of the 14.413 keV radiations, λ_γ, is 0.86Å. This gives transverse coherence lengths $\xi_{tr} = L\lambda_\gamma / 2\pi D$ of about 170 nm. The *effective* transverse coherence lengths:

$$\xi_{tr}^{eff} = \frac{\lambda_\gamma}{2\pi} \frac{1}{\sqrt{(\frac{D}{L})^2 + (\frac{d}{l})^2}} \qquad (1)$$

In the Eq.(1), *d* and *l* are the diameter of the APD detector and the distance between sample and detector, respectively. With the size of the APD detector of 5 mm and the distance between sample and APD of typically 50 cm at our KEK setup, we get

$$\xi_{tr}^{eff} = 1\text{-}2 \text{ nm} \qquad (2)$$

The sample domains which are separated by the distances more than ξ_{tr}^{eff} do not produce any considerable interference.

Results

As shown in Fig.1 (b) and (c), there occur the so-called "quantum beats" due to the interference between the waves from nuclei excited into different quantum sublevels, corresponding to double-site six-line (twelve-line) of the brownmillerite. Fe and Co atoms are intermixed in both tetrahedral and octahedral sites, so that the average Fe-Fe distance is ~0.6 nm.

The oxygen uptake in this A-site (Ca,Sr)-intermixed perovskite is hindered by the chemical pressure exerted by the small-sized Ca-ion.

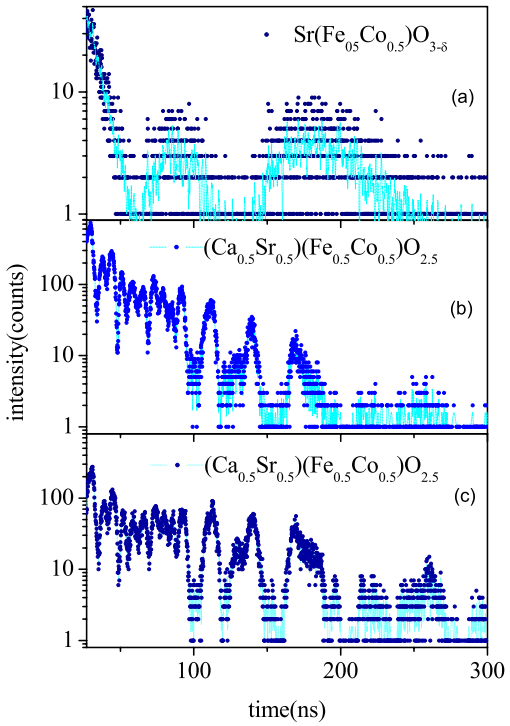

Fig.1 The nuclear forward scattering in the oxygen-deficient perovskite $Sr(Fe_{0.5}Co_{0.5})O_{3-\delta}$ (a), and in brownmillerite $(Ca_{0.5}Sr_{0.5})(Fe_{0.5}Co_{0.5})$ $O_{2.5}$: (b) and (c). The decay is accelerated in (b) compared to (c) due to changes in ξ_{tr}^{eff} and Mossbauer thickness.

In the δ-midway between antiferromagnetic and ferromagnetic structures, the magnetic nanocomposites are created, consisting of the ferromagnetic clusters ordered antiferromagnetically. At room temperature (Fig.1 (a)) the magnetic nanocomposites exhibit, as is expected, only the quadrupolar beats of simple type

$$I(\tau) \propto (\cos\frac{\Delta E_{Q1}\tau}{2} + \cos\frac{\Delta\delta_{IS}\tau}{2}\cos\frac{\Delta E_{Q2}\tau}{2})^2 \qquad (3)$$

Here the beat frequencies ΔE_{Q1} and ΔE_{Q2} are due to two doublets in Mössbauer spectra having the difference of isomer shifts $\Delta\delta_{IS}$.

* k-nomura@t-adm.t.u-tokyo.ac.jp