Study on the electric field-induced lattice deformation in nanocrystalline CuO

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Recently we found that giant thermal expansion was realized in magnetic nanocrystals of CuO(1). CuO, the cupric oxide, is a unique transition metal mono oxide that was previously clarified by us to show strong spin-charge-lattice coupling and ferroelectric properties below its magnetic (antiferromagnetic) transition (2). We had demonstrated that the spin-charge-coupling induced giant dielectric constant and ferroelectric-like spontaneous polarization. Recently, this strong charge-spin-lattice coupling receives intense attention and CuO is grouped to the new category of multiferroic materials (3). As for the reason of the reversed thermal expansion, we suspect that the spontaneous polarization in the dielectric phase causes displacement of the ions on the lattice and therefore the expanding of the lattice. In a number of so-called multiferroic materials electric polarization and magnetic order are coupled, providing a possible direct link between magnetism and NTE for magnetic nanoparticles with low crystal symmetry. With the small number of atoms in the nanoparticles the displacement of ions may substantially influence the lattice equilibrium and hence increase the unit cell volume.

Therefore a neutron diffraction experiment was designed to explore possible electric-magnetic correlation in the nanocrystalline CuO. For this study a thin disc-like pellet (30 mm in diamter and 3 mm thick) was made using nanoparticles of CuO. Gold electric contacts were formed on the two sides of the pellet by cold sputtering. The pellet was then set into a specially designed crystat for the neutron diffraction measurement. The experiment was carried using beamline 4G at JRR-3. In order to investigate the effect of electric field on the lattice a high voltage of 1.4 kV was applied to the pellet sample during the experiment.

A small electric-field-induced lattice change was observed as shown in Fig. 1. As compared with the zero field data, the diffraction peak (111) shifted to slightly higher angles, implying lattice contraction under an electric field.

However, as is seen from this plot, the resolution of the present equipment for neutron diffraction is not sufficient. Further studies may be performed using the synchrotron x-ray facilities.

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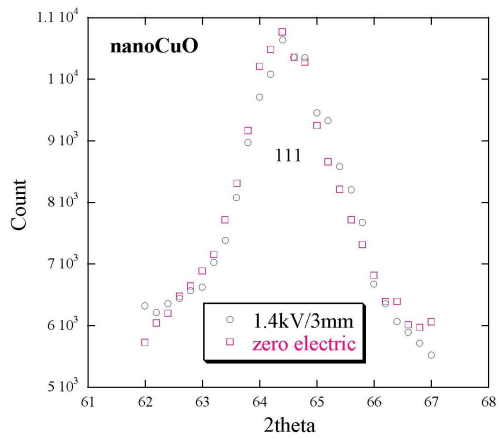

Fig. 1. Fig. 1 Filed-induced change of the (111) peak for nanocrystalline CuO.