Reduction in Néel Temperature of La_2CuO_4 Nanoparticles

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Recent reports on antiferromagnetic nanoparticles focus on the reduction in Néel temperature (T_N), the emergence of superparamagnetic behavior, and the increase in the band gap value.[1–3] However, there is no unified research on their magnetically ordered state. The cause of T_N reduction has also not been investigated. In order to overcome this situation, a study on the magnetic properties of La_2CuO_4 nanoparticles (LCO NPs) using muon spin relaxation (μSR) and NMR is suggested. La_2CuO_4 is a mother compound of high-T_c cuprate oxides that has been well established by experiments and theoretical methods; thus, a probing nano-sized effect in this LCO system can be achieved.[4]

LCO NPs used in the present study were successfully obtained through the sol-gel method. A detailed explanation about sample preparation has been reported in our previous paper.[5] Zero-field (ZF) μSR on LCO NPs was carried out at RIKEN-RAL Muon Facility in the UK, using a single pulse positive surface muon beam.

ZF-μSR time spectra of LCO NPs with a particle size of 96 nm are shown in Fig. 1. The time spectra were analyzed by using Eq. (1). The first component represents muon spin precession and the second component represents the slow relaxation behavior beyond 1 μs. It is shown that muon spin precession does exist in LCO NPs and it disappears at 100 K. Muon spin precession indicates the formation of the long-range ordered (LRO) state.

$$A(t) = A_1 e^{-\lambda_1 t}\cos(\omega t + \phi) + A_2 e^{-\lambda_2 t} \quad (1)$$

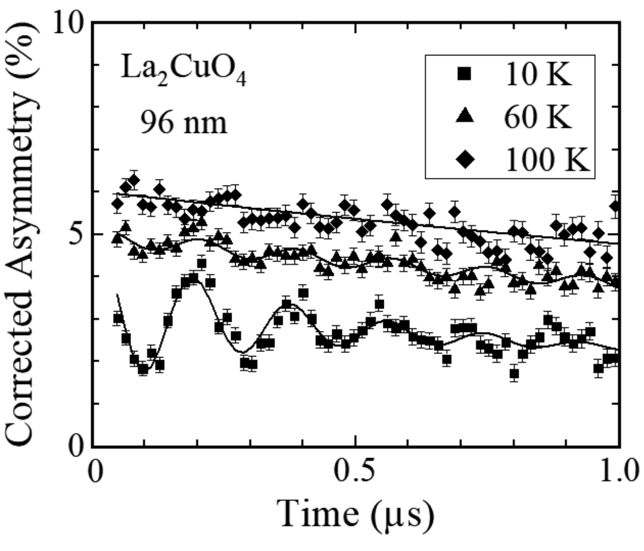

Fig. 1. ZF-μSR time spectra of La_2CuO_4 NPs with a particle size of 96 nm.

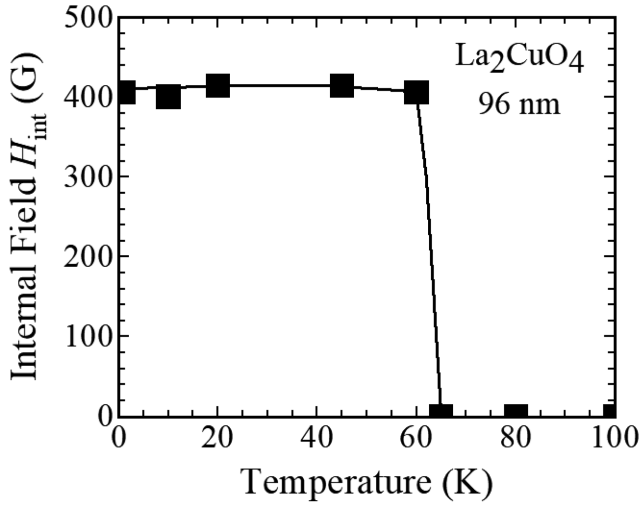

Fig. 2. Temperature dependence of the internal field at the muon site in LCO NPs with a particle size of 96 nm.

Figure 2 depicts the temperature dependence of the internal field at the muon site, H_{int}, of LCO NPs with a particle size of 96 nm. It is shown that H_{int} starts to increase below $\sim$ 60 K, indicating that the T_N of this sample is $\sim$ 60 K; this is strongly suppressed compared to the bulk LCO, which has a T_N of $\sim$ 320 K.[4] H_{int} reaches a saturated value $\approx$ 420 G at low temperatures. This means that LCO NPs have almost the same saturated internal field value as that observed in bulk LCO.[4] It is concluded that the nano-sized effect causes the reduction in T_N but does not affect the internal field at the muon site. These two phenomena are also observed in a hole- doped $La_{2-x}Sr_xCuO_4$ bulk system.[6] However, the resistivity of LCO NPs does not show indication of superconducting behavior. The reduction in the T_N of LCO NPs may be owing to the phase separation into fully antiferromagnetic and paramagnetic regions. Our ^{139}La NMR results also show that phase separation does exist in LCO NPs. Further analysis is required to describe this phase separation so that the cause of the reduction in T_N of LCO NPs can be clearly explained.

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