Sample synthesis of $Nd_2Ru_2O_7$ for researches by using quantum beams

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The pyrochlore system, $A_2B_2O_7$, is a frustrated magnet with corner-sharing crystal structure.[1] Frustrated is defined as a condition where a system cannot minimize its total energy.[1] Frustration caused by the lattice geometry in the crystal structure is classified as geometrical frustration.

There are a series of $A_2B_2O_7$ shows a variety of unique electronic states. Among them, an interesting example but not yet well studied is $Nd_2Ru_2O_7$, which shows a magnetic fragmentation state with a monopole or multipole state at the A site.[2] This system has the Kramer's ion Nd at the A site and the 4*d* element Ru with a magnetic moment at the B site. The Ru magnetic moment shows a magnetic ordering below 145 K and the Nd magnetic moment indicates an ordered state as well below 2 K.[2] An anomaly in the temperature dependence of the magnetic susceptibility was reported to be approximately 25 K. The origin of this anomaly was not clear and show the sample dependence.[3]

Mother materials of Nd_2O_3 and RuO_2 were used to synthesize $Nd_2Ru_2O_7$. Hence the chemical reaction efficiency between Nd and Ru is not so good and the vaporization temperature of those elements is different, it is not so easy to obtain a single-phase sample even for a powder one.

Furthermore, a single crystal is necessary to investigate the magnetic fragmentation and the monopole/multipole states. This has not yet been achieved yet until now due to those difficulties of the sample synthesis. We are now trying to develop the sample synthesis method to get a single-phase powder sample which is necessary for the single crystal growth.

We mixed the mother powder samples as much as possible by using a ball mill and adjusted the sintering temperature and atmospheric gases, and we confirmed that the anomaly observed around 25 K was due to Nd_3RuO_7 which showed a ferromagnetic ordering.[3]

Figure 1(a), the results of the X-ray diffraction measurement show that there is no other phase besides $Nd_2Ru_2O_7$ for a mixing time of 12 hours. While the mixing time using a ball mill for 6, 24, or 96 hours gives rise to other phases besides $Nd_2Ru_2O_7$.

Figure 1(b), the temperature dependence of susceptibility graph, χ, shows a transition at 145 K which corresponds to the magnetic transition of Ru^{4+} moments of $Nd_2Ru_2O_7$ as reported in previous studies.[2–5] This magnetic transition temperature decreases, with increasing ball mill time which is not good to maintain a single phase sample. In this 12 hours ball mill sample, we confirmed that there is no anomaly peak around 25 K which corresponds to other phases, namely Nd_3RuO_7.[3]

By using this single phase sample, a single crystal synthesis process will then be carried out using the floating zone method, Bridgman technique, and the complete sealed sample cell with high temperature synthesis for researches by using quantum beams such as neutron and muon spin relaxation (μSR).

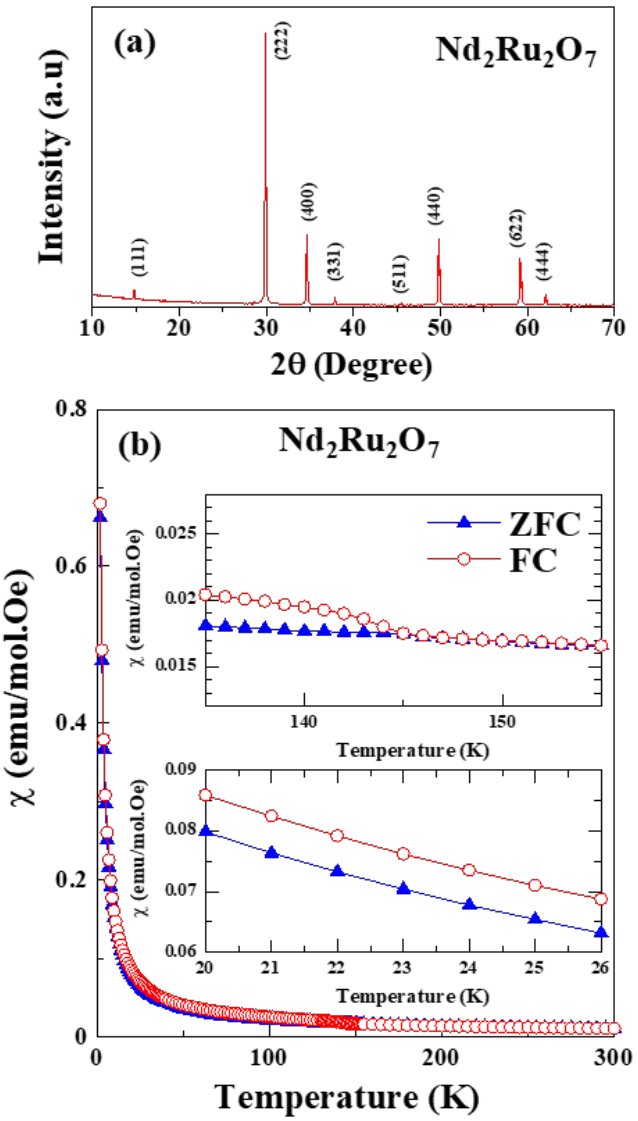

Fig. 1. (a) X-ray diffraction patterns of $Nd_2Ru_2O_7$. (b) Temperature dependence of the magnetic susceptibility, χ, measured from 2 to 300 K at $H = 0.1$ kOe.

References

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