Investigation of successive magnetic transition in $Sm_2Ru_2O_7$ via muon spin relaxation (μSR)

M. A. Syakuur,[*1] U. Widyaiswari,[*1] and I. Watanabe[*1]

In recent decades, frustrated magnetic systems have become a prominent area of study. Frustration arises when a system cannot achieve the lowest possible energy state.[1)] Geometrical frustration, in particular, results from the lattice geometry of the crystal structure. Examples of lattice geometries causing frustration include trigonal and tetragonal arrangements. Pyrochlore oxide, with its tetrahedral sublattice, is an example of a geometrically frustrated system. Its general formula is $A_2B_2O_7$, where A represents a trivalent rare-earth ion and B is a tetravalent transition metal ion.[1–4)]

Pyrochlore ruthenates, $A_2Ru_2O_7$ (where A is a rare-earth ion), exemplify a Mott system.[2)] The Ru 4d electrons exhibit both on-site Coulomb repulsion (U) and spin-orbit coupling (SOC) effects.[2)] As the ionic radius of A increases from Yb to Pr, the magnetic transition temperature rises from ∼80 K to ∼160 K.[1)] Notably, Mauws *et al.*[5)] identified $Sm_2Ti_2O_7$ as a potential candidate for magnetic fragmentation in Sm-based systems. $Sm_2Ru_2O_7$, with its non-Kramers A-site behavior and the presence of Ru 4d electrons, is also a promising candidate, as suggested by Taira *et al.*[2)] Although this compound was synthesized long ago,[1)] its magnetic and electrical properties are not yet fully understood. We investigated the magnetic behavior of $Sm_2Ru_2O_7$ using muon spin relaxation (μSR) to explore the possibility of magnetic fragmentation within its magnetically ordered states.

Polycrystalline $Sm_2Ru_2O_7$ samples were synthesized using a solid-state reaction. Stoichiometric amounts of Sm_2O_3 (99.99%) and RuO_2 (99.9%) were mixed for 96 hours in a ball mill and then sintered in air at 1100°C for 12 hours. The crystal structure was analyzed using X-ray diffraction (XRD). Zero-field (ZF) μSR measurements were performed in the temperature range of 5 K to 300 K.

Figure 1(a) presents the X-ray diffraction (XRD) patterns of $Sm_2Ru_2O_7$ recorded at room temperature. The analysis of the diffraction data confirms that the compound crystallizes in a face-centered cubic structure, which belongs to the space group $Fd\bar{3}m$. This structural symmetry is characteristic of pyrochlore oxides, and it aligns well with previous studies on similar compounds. Detailed examination of the diffraction peaks revealed a lattice parameter of 10.28 Å, indicating the periodic arrangement and precise geometric dimensions of the crystal lattice. Furthermore, all observed peaks in the diffraction pattern were successfully indexed, confirming the phase purity of the synthesized sample and the absence of significant impurities or secondary phases. This structural information provides a solid foundation for further exploration of this material.

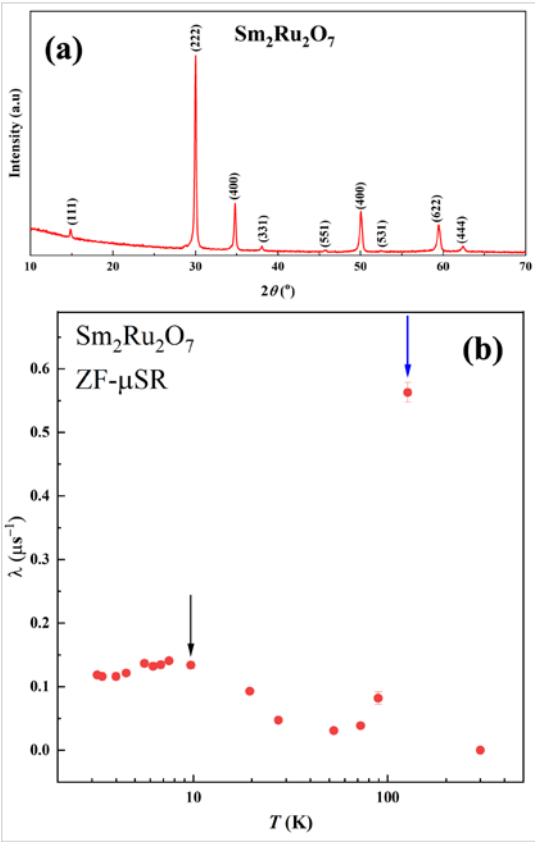

Fig. 1. (a) X-ray diffraction patterns of $Sm_2Ru_2O_7$. (b) Temperature dependence of muon spin relaxation rate, λ, of $Sm_2Ru_2O_7$.

Figure 1(b) illustrates the temperature dependence of the relaxation rate (λ). At approximately 127 K, λ shows a pronounced increase (indicated by blue arrows), associated with the critical slowing of Ru spins[2)] and magnetic ordering. Below 90 K, λ remains constant, but it gradually increases again below 30 K. A smaller, broader peak appears around 10 K (indicated by black arrows), potentially reflecting additional magnetic instabilities in Sm spins. This suggests changes in the static and dynamic properties of Ru and/or Sm spins, as Ru spin properties appear stable below 90 K, consistent with previous findings.[2,6)] Our study employed pulsed muons with a time resolution suitable for internal fields exceeding ∼500 G. Future studies using continuous muon sources, available at TRIUMF

*1 RIKEN Nishina Center

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in Canada and PSI in Switzerland, could provide further insights.

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