The Magnetic Properties of S = 21/2 Frustrated Ferromagnetic Trimer $Gd_3Os_4Al_{12}$

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Geometrical frustration has been one of the most interesting themes in magnetism, which often induces unique magnetic phenomena such as a quantum spin liquid state, *etc*. Especially, the system in which frustrated localized spins and itinerant electrons coexist have been vigorously investigated to explore the unusual magnetoelectric phenomena. Intermetallic $Gd_3Ru_4Al_{12}$ is one of such compounds [1]. In $Gd_3Ru_4Al_{12}$, localized Gd 4*f* electrons (S = 7/2) are responsible for magnetism on a breathing kagome network in which the triangles with strong J_1 and weak J_2 interactions connect alternately with sharing ether vertices. Previous study revealed that both J_1 and J_2 are ferromagnetic, however, J_1 is about 5 times larger than J_2 due to the difference in distance between Gd ions. Therefore, the three Gd ions coupled by strong J_1 form S = 21/2 ferromagnetic trimer at low temperature. With the formation of the trimer, the system effectively becomes a triangular lattice of S = 21/2 Gd trimers, and the predominant antiferromagnetic RKKY interaction between the trimers causes magnetic frustration. Furthermore, $Gd_3Ru_4Al_{12}$ has attracted new attention such as the formation of the spiral order of trimeric spins [2], topological Hall effect, and the observation of the skyrmion [3].

We tried to search for related compounds to elucidate the magnetic properties of the $Ln_3TM_4Al_{12}$ system and to develop new magnetoelectric physical properties. We succeeded to grow the single crystal of $Gd_3Os_4Al_{12}$ in which Ru was replaced with Os. Single-crystal X-ray analysis revealed that it was isostructural to $Gd_3Ru_4Al_{12}$ ($P6_3/mmc$), and its lattice constants were a = 8.8104 Å and c = 9.5287 Å. The magnetic susceptibility obeys the Curie-Weiss law at high temperature, and this compound has a net ferromagnetic interaction with a Weiss temperature Θ_W = 46.8 K, and effective Bohr magneton p_{eff} = 8.02 indicates that a localized moment of Gd ion is S = 7/2. A broad peak is observed around 30 K in the magnetic specific heat, which can be explained by the ferromagnetic Gd trimer formation with $J/k_B \approx 4.2$ K. Sequential magnetic transitions were observed at lower temperature with complex magnetic field dependence. The electrical conductivity of this compound shows metallic behavior and decreases slightly at the magnetic order.

In the presentation, we will report the synthesis, crystal structure, magnetization, electrical resistivity, and specific heat measurements, and discuss the magnetic nature of the compound.

REFERENCES

[1] S. Nakamura *et al.*, PRB, **98** (2018) 054410.
[2] T. Matsumura *et al*., JPSJ, **88** (2019) 023704.
[3] M. Hirschberger *et al*., Nat. Commun., **10** (2019) 5831.

FIGURES

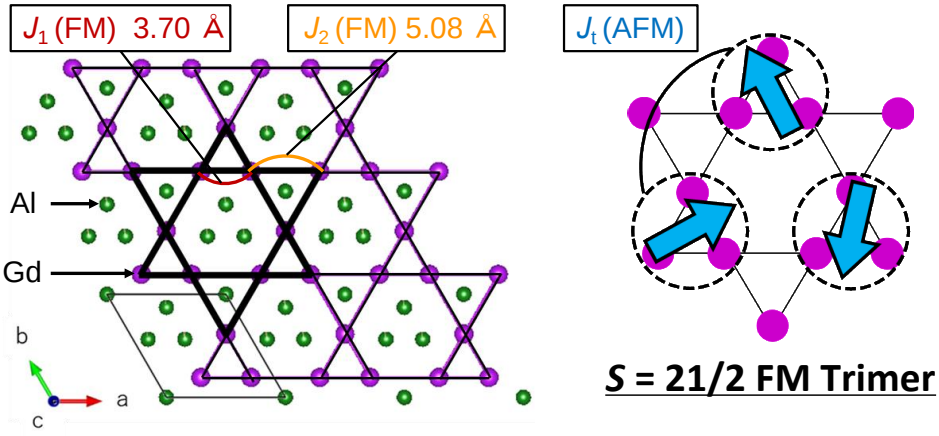

Figure 1: Gd ions are responsible for magnetism on breathing Kagome network on GdAl layer of $Gd_3Os_4Al_{12}$. They form S = 21/2 FM trimers with small triangles.