Magnetic short-range order in a hyperkagome lattice alloy Mn_3CoSi

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We found a magnetic short-range order (SRO) in a hyperkagome lattice alloy of Mn_3RhSi up to 720 K.[1] The onset temperature is the highest among any magnets, to our knowledge. Because of the historical record, the magnetic cluster may be topologically protected in a paramagnetic state. To reveal the possible mechanism, we have studied Mn_3TX (T: Co, Rh, and Ir, X: Si and Ge) family alloys by μSR, where the cubic lattice parameter varies together with the electronic bandwidth. The lattice parameter of Mn_3CoSi is close to that of β-Mn, which is known as a non-Fermi liquid and spin-liquid candidate compound.[2,3] The β-Mn is also the heavy electron metal (γ = 70 mJ/Mn K^2).[3] Mn_3CoSi with the smallest cubic lattice parameter (a = 6.26 Å) locates near the quantum critical point, then with increasing the cubic lattice parameter, the magnetic transition temperature increases, and the electronic specific heat γ decreases in the Mn_3TX system. In the case of Mn_3RhSi with a lattice parameter of $a = 6.45$ Å, the Néel temperature T_N becomes 190 K and γ decreases to 12.1 mJ/Mn K^2. Our magnetic pair distribution function analysis revealed that the magnetic SRO originated from the other magnetic structure different from the long-range order (LRO) magnetic structure.[4] In addition, a similar magnetic SRO is recently discovered in a skyrmion alloy $Co_7Zn_7Mn_6$ with the same β-Mn structure.[5]

Here, we report the μSR result of the single crystal Mn_3CoSi measured at M20 of TRIUMF (M2201) and ARGUS of ISIS (2070006). The transverse field (TF) time spectra of Mn_3CoSi were analyzed using a Gaussian damped oscillation function. The temperature dependence in Fig. 1 clearly shows the drop in the initial asymmetry. The onset temperature is about 240 K. Figure 2 shows the phase diagram of the Mn_3TSi system. The result suggests that SRO and LRO temperatures decrease to a quantum critical point. In addition, the initial asymmetry drop also decreases to the quantum critical point. The ratios were about 20% and 1% for Mn_3RhSi and Mn_3CoSi, respectively.

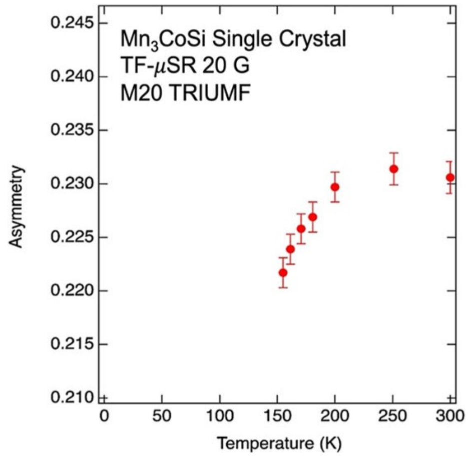

Fig. 1. Initial asymmetry obtained from the Mn_3RhSi single crystal under a transverse magnetic field of 20 G.

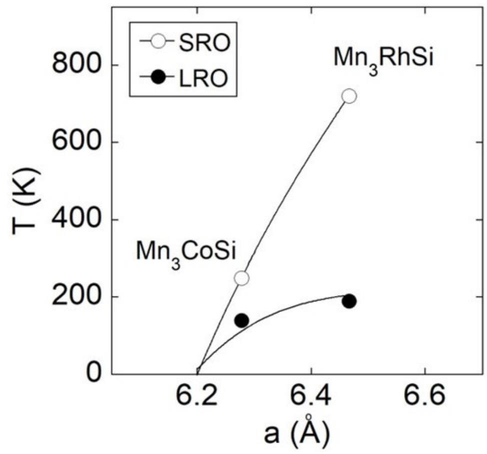

Fig. 2. Tentative phase diagram of Mn_3TSi system.

In summary, we have studied Mn_3CoSi crystal by μSR. The SRO and LRO temperatures depend on the lattice parameter, suggesting the bandwidth effect. To further explore the magnetic SRO, it is necessary for us to study Mn_3IrSi with a lattice parameter of $a = 6.50$ Å by μSR. These alloys have spiral structures of Mn triangular units, resulting in the noncentrosymmetric space group. Neutron scattering measurements may be required to study further the magnetic SRO related to a topological magnetic cluster by using single crystals. We acknowledge the present μSR measurements at M20 of TRIUMF (M2201) in 2022 and ARGUS of ISIS (2070006) in 2020.

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References

1) H. Yamauchi *et al.*, Commun. Math. Phys. **1**, 43 (2020).
2) J. R. Stewart *et al.*, Phys. Rev. Lett. **89**, 186403 (2002).
3) H. Nakamura *et al.*, J. Phys. Condens. Matt. **9**, 4701 (1997).
4) K. Kodama *et al.*, J. Phys. Soc. Jpn. **90**, 074710 (2021).
5) V. Ukleev *et al.*, npj Quantum Mater. **6**, 40 (2021).