Mn-Substitution-Induced Magnetic Phase Transitions in $Sr_3Ru_2O_7$

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The layered perovskite ruthenates $Sr_{n+1}Ru_nO_{3n+1}$ exhibit a variety of ordered states. The number of layer n changes the dimensionality of electronic states. The single-layered Sr_2RuO_4 ($n = 1$) is an unconventional superconductor with spin-triplet pairing. In contrast, $Sr_4Ru_3O_{10}$ ($n = 3$) is an itinerant ferromagnet with Curie temperature of 100 K. The double-layard $Sr_3Ru_2O_7$ ($n = 2$) have an important role because of its intermediate dimensionality between spin-triplet superconductor and itinerant ferromagnet. $Sr_3Ru_2O_7$ is essentially paramagnetic metal. However, a metamagnetic transition is observed in large magnetic fields in $Sr_3Ru_2O_7$ and the relation between metamagnetism and quantum criticality was discussed. Recently, it was reported that Mn substitution causes a drastic phase change in $Sr_3Ru_2O_7$ from the paramagnetic metal to an antiferromagnetic insulator. For $Sr_3(Ru_{0.95}Mn_{0.05})_2O_7$, the antiferromagnetic order and a discontinuous structural change simultaneously occur at ~ 45 K.

We report the results of muon spin relaxation (μSR) measurements on single crystal of $Sr_3(Ru_{0.95}Mn_{0.05})_2O_7$. The oscillation amplitude of μSR spectrum in a week transverse field (WTF) of 30 Oe suddenly decreases at ~ 135 K and almost vanishes below ~ 100 K. The oscillation amplitude represents a volume fraction of the paramagnetic region. This result indicates that a static magnetic order takes place around 135 K and essentially all the volume orders magnetically below 100 K. An enhancement of magnetization is also seen below ~ 135 K, suggesting a ferromagnetic order. The initial asymmetry of WTF-μSR spectrum, which means the asymmetry projected to the beam direction, starts to decrease at ~ 100 K. The projected asymmetry reduces by half at ~ 40 K and maintains half asymmetry below ~ 40 K. Since the magnetic volume fraction is almost 100% below ~ 100 K, this change comes from a variation in the direction of the internal field. In these experiments, the c axis was parallel to the beam direction. Therefore, the internal field is parallel to the c axis above ~ 100 K and inclined at about 45 degrees to the c axis below ~ 40 K. The relaxation rate obtained by fitting the generalized Kubo-Toyabe function to the zero-field μSR spectrum increases rapidly at ~ 40 K. Probably this rapid increase corresponds antiferromagnetic transition. A discontinuous lattice change is observed in neither the Mn concentration dependence up to 5% nor the temperature dependence above 40 K. These results suggest that the parent compound $Sr_3Ru_2O_7$ is a nearly-ferromagnetic paramagnet.