# $\mu$SR study on $CeRu_2Al_{10}$ under pressure

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$CeT_2Al_{10}$ (T = Fe, Ru, and Os), which has the orthorhombic $YbFe_2Al_{10}$−type structure, can be categorized as a Kondo semiconductor and is of interest because of numerous anomalous electronic behaviors due to the $c-f$ hybridization effect.[1–3] For instance, the antiferromagnetic (AFM) transition temperature ($T_0$) is quite high compared to that usually expected for Ce-based intermetallic compounds,[2] and the spin alignment in the AFM ordered state is $m_{\rm AF} \parallel c$, although the easy magnetization axis is the $a$-axis with the large magnetic anisotropy $a \gg c \gg b$.[4,5] In addition, the magnetic structure is easily changed from $m_{\rm AF} \parallel c$ to $m_{\rm AF} \parallel b$ or $m_{\rm AF} \parallel b$ to $m_{\rm AF} \parallel c$ by application of non-magnetic La doping, magnetic field, or external pressure.[6] Furthermore, tiny $d$-electron doping, such as Rh($4d^8$)-doping in Ru($4d^7$), easily breaks the $m_{\rm AF} \parallel c$ ordering, and $m_{\rm AF} \parallel a$ ordering is realized instead.[7] These results indicate that the magnetic structure of $CeRu_2Al_{10}$ is not robust and is easily tuned by such perturbations.

Regarding the effect of pressure on $CeRu_2Al_{10}$, $T_0$ is enhanced up to about $P$ = 2 GPa, beyond which it exhibits a slight decrease; at approximately $P_c$ = 4 GPa, $CeRu_2Al_{10}$ exhibits a first-order-like transition from the AFM Kondo semiconducting state to the non-magnetic Fermi liquid state.[2] Since $T_0$ is enhanced at low pressures, the bulk magnetization is expected to also be enhanced by pressure. However, the magnetization is strongly suppressed by pressure.[8] At $P$ = 1 GPa, the magnetization becomes nearly half of that at ambient pressure. That is, the pressure enhances $T_0$ but suppresses the magnetization. These results seem to contradict each other. In order to verify whether $m_{\rm AF}$ is suppressed on applying pressure, we performed $\mu$SR experiments on $CeRu_2Al_{10}$ under pressures up to about $P$ = 0.6 GPa. From the $\mu$SR experiment, the pressure dependence of $m_{\rm AF}$ can be clarified through the change in the internal magnetic field at the muon site. To our knowledge, this is the first attempt at investigating the effect of pressure on the $m_{\rm AF}$ in $CeT_2Al_{10}$ (T = Ru, Os).

Figure 1 shows the temperature dependence of the initial asymmetry of $CeRu_2Al_{10}$ at ambient pressure and at $P$ = 0.6 GPa. The initial asymmetry is extracted from the transverse field (TF) measurement. The decrease in the initial asymmetry below $T_0$ is a good indicator of the appearance of a magnetically ordered state. We clarified that $T_0$ is enhanced by pressure by observing bulk properties. The temperature dependence of the initial asymmetry at ambient pressure is consistent with our previous $\mu$SR experiment.[7] As seen below for $T$ =10 K, the temperature dependence of the asymmetry is different between the data at ambient pressure and at those $P$ = 0.6 GPa, indicating that the evolution of the $m_{\rm AF}$ is different between these two cases. This would be attributed to a change in the hyperfine process through the Fermi contact field caused by pressure.[7] We aimed to clarify a change in the magnitude of $m_{\rm AF}$ under pressure. However, owing to the fraction of stopping muons in the sample being less and the strong restriction of the time resolution of the double-pulsed muon beam, we could not observe the muon spin precession, and thus, from the zero field measurement, no quantitative information on $H_{\rm int}$ could be achieved directly under ambient or high pressure. In order to obtain detailed information on $m_{\rm AF}$, further studies are needed.

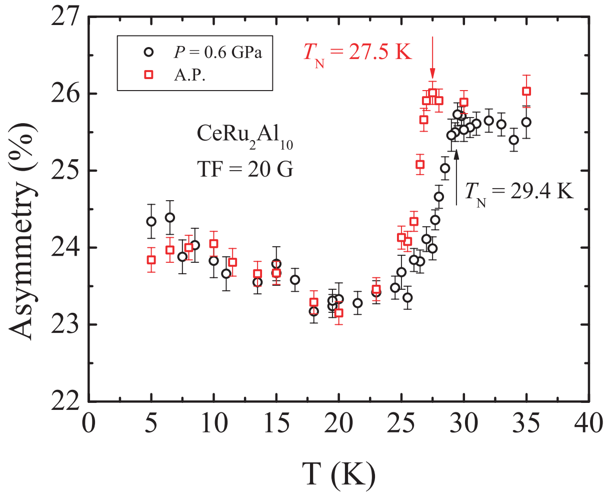


Fig. 1. Temperature dependence of the initial asymmetry of $CeRu_2Al_{10}$ at ambient pressure and at $P$ = 0.6 GPa. The initial asymmetry is extracted from transverse field (TF) measurements.

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