In recent years, much interest has been focused on hydrogen-based energy systems. The key of this technology is high-density storage of hydrogen, and hydrogen-absorbing (HA) alloy is useful for this purpose. The HA alloy absorbs the hydrogen to form metal hydride. In this process, the hydrogen molecule is dissociated into H atoms and these are stabilized at an interstitial site of the lattice. Detailed understanding of the interstitial H state is thus important for further improvement of HA properties.

We studied the interstitial H state in a material related to the HA alloy using positive muons ($\mu^+$). The $\mu^+$ can be regarded as a light isotope of $^1$H since it possesses charge $+e$ and mass $\sim 1/9 m_n$, where $m_n$ is the mass of a proton. Therefore, chemical properties of the $\mu^+$ in condensed matter are considered to be identical to those of $^1$H except for isotope effects. The $\mu^+$ implanted into materials stops at the interstitial site and decays into a positron and two neutrinos. The positron is preferentially emitted in the direction of the $\mu^+$ spin, which evolves via magnetic interactions with surrounding electron and nuclear spins. Detailed analysis of the time evolution of the $\mu^+$ spin provides us with information on the magnetic environment at the $\mu^+$ site.

We launched this research project with investigation of the interstitial H state in a rare-earth-based intermetallic compound PrPb$_2$, related to the typical HA alloy MnNi$_2$ (Mn: mixture of light rare-earth elements). First, the $\mu^+$ site in PrPb$_2$ was determined to be the midpoint between two Pr ions (Pr') as shown in Fig.6-9, using the $\mu^+$ spin rotation and relaxation method ($\mu^+$SR) in a high magnetic field. $\mu^+$SR measurements in zero magnetic field were also performed, and the characteristic spectrum shown in Fig.6-10 was obtained in the paramagnetic state. This spectrum indicates quantization of the magnitude of a hyperfine field that is generated at each $\mu^+$ site. From detailed analysis, it was clarified that coupling between Pr' and $\mu^+$ spins is anisotropically enhanced as a result of deformation of the $f$-electron state owing to the $\mu^+$ charge. The quantum character of the hyperfine field strongly supports this conclusion.

The present result suggests the importance of the electrostatic interaction between the $f$-electrons and the interstitial H in HA alloys. We plan further $\mu^+$SR studies in HA alloys which have commercial promise, to clarify the relation between this interaction and the HA properties.

Reference