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1. Microscopic Study on Reentrant Spin Glass State of Ternary Alloy $Pd_{1-x-y}Fe_xMn_y$ by Mössbauer spectroscopy

（リエントラント・スピングラス3元合金 $Pd_{1-x-y}Fe_xMn_y$ のメスバウアー分光による微視的研究）

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Abstract

Randomized systems near the critical concentration where long range order develops have been the focus of considerable attention in recent years because of the rich variety of physical phenomena these systems exhibit. Among these systems magnetic dilute alloys with competing exchange interactions (so called spin glass) are attractive. In these systems, frustration occurs that can lead to complicated magnetic behavior as a function of temperature. The theory formulated by Sherrington and Kirkpatrick indicates that under suitable conditions a paramagnetic to ferromagnetic transition can occur near the percolation threshold for long range order to develop, followed at lower temperature by a transition to a spin glass state. It has been still controversial whether this spin glass state is a true thermodynamic phase or is a non-equilibrium state in which freezing of spins proceeds with widespread relaxation times. Experimentally, on the other hand, many studies have been made on the systems which undergo a magnetic double transition: a transition from paramagnetic to ferromagnetic state at T_c and that from ferromagnetic to a spin-glass-like state at lower temperature T_g;

the magnetic system with this kind of magnetic double transition has been called "reentrant spin glass". Most of the studies ever made are concerned with the macroscopic properties of the systems.

In order to study these phenomena from the microscopic point of view, we applied Mössbauer spectroscopy to the ternary alloys $Pd_{0.881}Fe_{0.027}Mn_{0.092}$ (PDFM1) and $Pd_{0.930}Fe_{0.015}Mn_{0.055}$ (PDFM2): both establish the ferromagnetic order at T_c and reenter into the spin glass state at T_g: T_c=15 K and T_{g2}=8~12 K for PDFM1, and T_c=32.6 K and T_{g1}=7 K for PDFM2, which were determined by the magnetic measurements. Observations were made at temperatures between 1.7 K and R. T. under magnetic fields up to 6.0 kOe. The distribution of hyperfine field $P(H_{hf})$ is obtained from analyses of the Mössbauer spectra by Window method and Hesse-Rübartsch method. We evaluated the average hyperfine field $\bar{H}_{hf}$ using $P(H_{hf})$.

The anomolous increase of $\bar{H}_{hf}$ is clearly observed for PDFM2 below 7 K which coincides with T_{g1}. This can be explained as freezing of the transverse spin component. The variation of the Mössbauer absorption intensities with applied magnetic field supports this interpretation. Furthermore, the variation of the intensities demonstrates that Fe spins behave partly ferromagnetic and partly like a spin glass. We consider that this fact is an evidence for the coexistence of the spin glass and ferromagnetic orderings. The reentrant spin glass state with this coexistence realized below T_{g1} may correspond to the mixed state M_1 theoretically predicted by Gabay and Toulouse. In PDFM1, on the other hand, there is no clear evidence for the coexistence of spin glass and ferromagnetic orderings. It should be noted that in PDFM1 the dynamical effect is clearly observed in the spectra taken above 8 K and is still noticed even above T_c.

The problems associated with reentrant spin glass state in $Pd_{1-x-y}Fe_xMn_y$ are rather complex. Further investigation of the samples with other concentrations is required to clarify whether the coexistence of ferromagnetic and spin glass orderings in the reentrant spin glass state is a general property or not.