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<th>Title</th>
<th>Microscopic Study on Reentrant Spin Glass State of Ternary Alloy Pd$_{1-x-y}$Fe$_x$Mn$_y$ by Mossbauer spectroscopy</th>
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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$_{0.88_1}$Fe$_{0.02_7}$Mn$_{0.09_2}$ (PDFM1) and Pd$_{0.93_0}$Fe$_{0.01_5}$Mn$_{0.05_5}$
(PDFM2): both establish the ferromagnetic order at $T_c$ and reenter into the spin glass state at $T_g$:

$T_c = 15$ K and $T_g_1 = 8\sim 12$ K for PDFM1, and $T_c = 32.6$ K and $T_g_2 = 7$ 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-Rübertschen method. We
evaluated the average hyperfine field $H_{hf}$ using $P(H_{hf})$.

The anomalous increase of $H_{hf}$ is clearly observed for PDFM2 below 7 K which coincides
with $T_g_1$. 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 $T_g_1$
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$_x$Mn$_y$ 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.