○お茶の水女子大学理学研究科物理学専攻

1. Study on a non-diluted insulating spin glass $Fe_XMn_{1-X}TiO_3$: Susceptibility

（濃厚絶縁体スピングラス $Fe_xMn_{1-x}TiO_3$ の帯磁率測定による研究）

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ABSTRACT

Since the pioneering studies by Cannella and Mydosh, and by Edwards and Anderson, many experimental and theoretical investigations have been done on spin glasses which are formed in spin systems in which ferromagnetic and antiferromagnetic exchange interactions are randomly distributed. Experimentally the low field susceptibility shows a sharp cusp at a low temperature T_g, indicating that the local spins are frozen randomly in direction. On the other hand, the specific heat does not exhibit any evidence for a phase transition at T_g, and no long-range order has been observed by neutron scattering measurement. These features have been observed widely in dilute magnetic alloys in which the long-range RKKY interaction dominates and also in insulating compounds in which the nearest-neighbor exchange interaction does.

The most fundamental question in properties of spin glasses is whether

the spin glass freezing is a thermodynamic phase transition, or not. Many theoretical investigations have been done on Ising spin systems by using the mean-field approximation, on the assumption that the freezing is a phase transition. But the magnetic behavior of spin glasses experimentally examined does not always agree with that obtained by the mean-field approximation. The competition between exchange interactions in metallic spin glasses or diluted insulating ones is rather complex. In order to understand the physics of spin glasses, a non-diluted insulating spin glass is more suitable to be investigated, because the nature of the exchange interaction is well-known in it. But in such spin glasses ever examined, there exists not only the competition between the exchange interactions but also the other competition, such as that between the spin anisotropies.

A non-diluted insulating compound $Fe_xMn_{1-x}TiO_3$ is expected to be an ideal Ising spin glass in which only the competition between the exchange interactions exists. Both $FeTiO_3$ and $MnTiO_3$ are antiferromagnets having easy-axis aisotropy along the hexagonal c-axis. Within the c-layer, spins are ferromagnetically coupled in $FeTiO_3$, and antiferromagnetically in $MnTiO_3$. In the mixture $Fe_xMn_{1-x}TiO_3$, therefore, the ferromagnetic and antiferromagnetic interactions compete with each other within the c-layer, and the spin glass behavior is expected to appear at low temperatures.

Single crystals of $Fe_xMn_{1-x}TiO_3$ were investigated by magnetization and ac susceptibility measurements. As a result, in $Fe_{0.50}Mn_{0.50}TiO_3$ Ising-like spin glass behavior appears below T_g=21.1K, and we report experimental results about $Fe_{0.50}Mn_{0.50}TiO_3$.

The zero-field cooled magnetization M_{ZFC}, which is measured in magnetic field of 20e along the c-axis (H//c) after zero-field cooling, shows a sharp cusp at T_g=21.1K. While the field cooled magnetization M_{FC} is nearly independent of temperature below T_g. Comparing the temperature dependence of magnetization measured in H//c with that done in H⊥c, $Fe_{0.50}Mn_{0.50}TiO_3$ is considered as an Ising-like spin glass.

With increasing applied field H, the cusp is broadened, and the

temperature $T_g(H)$, where the irreversibility appears between M_{ZFC} and M_{FC}, decreases. The H dependence of $T_g(H)$ is described by

$$H = A\,[1 - T_g(H)/T_g(0)]^{\alpha} = 4.26 \times 10^4\,[1 - T_g(H)/T_g(0)]^{1.49} \qquad (1)$$

This relation coinsides with the de Almeida-Thouless line (α=1.5) calculated by using the mean-field approximation.

Below T_g, the long-time relaxation phenomenon was observed. The time dependences of the thermoremanent magnetization M_{TRM} and the growth of the isothermal remanent magnetization M_{IRM} in applied field were investigated. It is found that M_{TRM} and M_{IRM} obey the power law quite well,

$$M_{TRM}(t) = At^{-n} \qquad (2)$$

$$M_{IRM}(t) = M_0 - At^{-n} \qquad (3)$$

where M_0 is an adjustable parameter. Eq.(3) indicates that the value of M_{IRM} reaches M_0 after infinit time, that is, M_0 is the value of M_{IRM} in the thermodynamic equilibrium state. The value of M_0 agrees with that of M_{FC} within experimental accuracy. This result suggests that the field cooled state is close to the thermodynamic equilibrium state. This conclusion is obtained, for the first time, from the relaxation measurement. The exponent n and the prefactor A of Eqs.(2) and (3), depend on both temperature and applied field. As temperatures increase, n increases exponentially, while A decreases linearly and is extrapolated to zero at near $T_g(H)$. The temperature dependences of n and A for another spin glass $Rb_2(Mn,Cr)Cl_4$ for which the relaxation is fitted to the power law decay, are similar to those for $Fe_{0.50}Mn_{0.50}TiO_3$, though the authors have not touched upon them. Therefore, our findings about the temperature dependences of n and A are considered to be common at least for non-diluted insulating spin glasses.

The ac susceptibility has been measured in a frequency range between 20Hz and 66.5kHz. The temperature $T_g(f)$ showing cusp increases with increasing frequency f, which indicates that there exists wide distribution in relaxation times $\tau=f^{-1}$. The f dependence of $T_g(f)$ is described by both the Fulcher law and the power law within this frequency range. Even if we take into account the result of the Mossbauer measurement ($T_g(f\simeq10^7\text{Hz})\simeq28\text{K}$),

still both laws are equally well fitted. In order to determine which law is better, measurements by other technique with large f is required.

2. Study on Melting Process of DNA Double Helix by 5-pass Brillouin Spectroscopy

（ブリュアン散乱によるDNA二重らせんの融解現象の研究）

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ABSTRACT

It has been of great interest to clarify the dynamical mechanism of the melting process in the DNA double helix, because the melting phenomena have been found to relate closely with the basic molecular biological process, such as the replication and the transcription of genetic information. The melting phenomena can be caused not only by the interaction with enzymes but also by increasing the temperature. Numerous investigations on the melting phenomena of the DNA double helix in dilute solution have been carried out by means of absorption spectroscopy, circular dichroism and other methods with increasing temperature. But there have been only a few studies on the dynamical mechanism of the melting process in the condensed state.

In the present work it has been found that the dynamical structure of the primary hydration shell around the DNA double helix in the condensed state changes drastically during the melting process, which is observed by means of the Brillouin scattering spectroscopy using a 5-pass Fabry-Perot interferometer.

The lyophillized calf-thymus DNA was made into the gel state in the thin glass capilary by adding distilled water. It has been known that the 30 w/w% DNA gel has both the primary hydration shell and the secondary hydration shell as the hydrated water, but has no bulk water.