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THE RECORD OF LEARNING AND FORGETTING THE PROCESS OF MAGNETIZATION

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The development of spontaneous magnetization in a weak ferromagnet (Mn formate $2H_2O$) was studied in detail around T_N (3.686K) under very weak external magnetic field H_{ex} lower than 10mOe by the use of SQUID magnetometer. The rather complicated but reproducible signals were found in the course of sweeping the temperature down and up through T_N. It was revealed that the memory of magnetization process was learnt in ordered region below T_N and kept even for two hours in some higher temperatures ($\varepsilon \simeq 1\times10^{-2}$) than T_N. The memory was lost when the sample warmed up to $=5\times10^{-2}$.

1. Introduction – Development of spontaneous magnetization

We studied in detail the development of spontaneous magnetization M_s under very weak external field H_{ex} by the use of SQUID magnetometer. The crystal we investigated, is Mn formate $2H_2O$ which is an antiferromagnet with very weak canting ferromagnetic moment.

When the external field was reduced to lower than 10mOe, Ishizuka detected the development of M_s with irregular fluctuation just around T_N at 3.686K, as shown in Fig. 1, in the course of sweep from higher to lower temperature across T_N. The phenomena might be attributed to the development of ferromagnetic clusters under nearly zero external field. We guess the analogy of the phenomena with the development of the droplets in zero gravitational space.

We studied the phenomena with very precise control of temperature and external field, and tried to detect any reproducibility in the course of cooling down and warming up, even though how irregular it is.

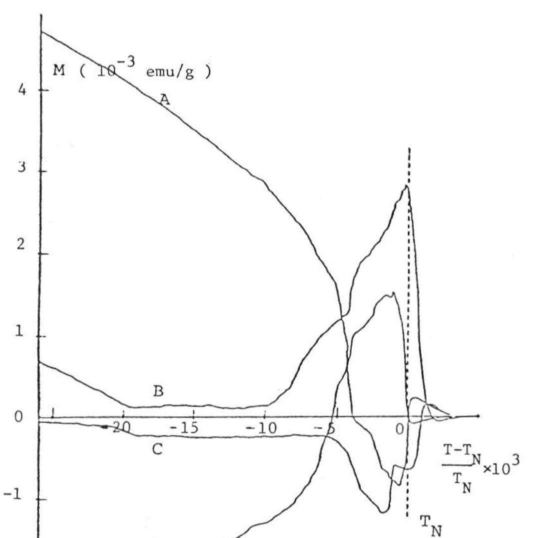


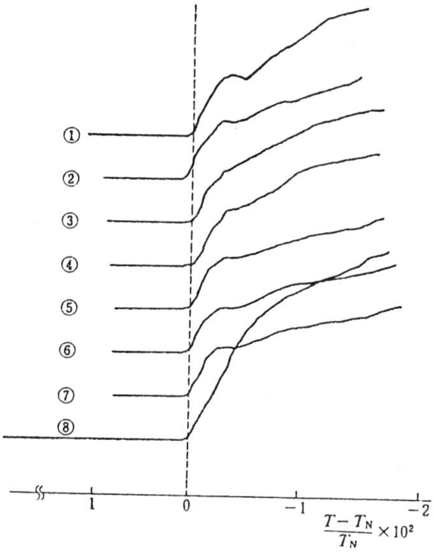
Fig. 1

2. Learning and Forgetting, how?

In the following figures, we give M_s (arbitrary unit) as a function of $\mathcal{E}=(T-T_N)/T_N$, left hand side is in paramagnetic region, the dotted lines at about center indicates the position of T_N and right hand side is in ordered region. We start the sweeping of temperature from $\mathcal{E}_s$, and stop the cooling at about $\mathcal{E}=-2\times10^{-2}$. H_{ex} gives the very weak external field value (not giving absolute but relative value , for instance in the case of Fig. 3, absolute zero field is somewhere between 4.56 and 3.99mOe.)

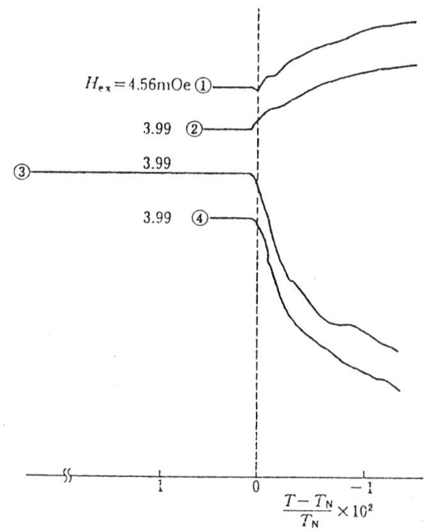
Now, in Fig. 2, we start from $\mathcal{E}_s=1.1\times10^{-2}$ in every run of ①~⑦. M_s repeated almost the same to each other under the same $H_{ex}=6.04$mOe. They learn the features of M_s. To forget them, warming up to $\mathcal{E}_s \gtrsim 5.3\times10^{-2}$, is necessary and perhaps sufficient as seen from ⑧.

Fig, 3 shows the effect of changing H_{ex} on changing the memory once obtained. No substantial change was not observed between ① and ② when $\mathcal{E}_s$ was $\cong 1.1\times10^{-2}$ in each run. However, the drastic change of the memory was observed between ② and ③ when $\mathcal{E}_s$ was changed to 5×10^{-2} after ②. As M_s developed towards just the other direction, absolute zero field would be just between 4.56 and 3.99mOe.



$H_{ex}=6.04$ mOe. $\varepsilon_s \lesssim 1.1\times10^{-2}$

Fig. 2



①, ②, ④ ; $\varepsilon_s=0.7\times10^{-2}$.
③ ; $\varepsilon_s=2.7\times10^{-2}$.

Fig. 3

3. Learning and Forgetting, where?

From these studies, we could have a guess the crystal learnt the ways of the development of M_s and got the memory of them in the long range order region lower than T_N, and they did not forget it in some short range order region, if the temperature of the crystal did not rise up to so high, say $\mathcal{E}\cong5\times10^{-2}$.

Fig, 4 shows the very existence of the boundary of the region where the learning of M_s would start. The first run ① shows that M_s goes upwards under $H_{ex}=6.84$mOe. And the second run ② suggests that if H_{ex} shifts to 0.00mOe in paramagnetic region. M_s will go downwards. Even if the temperature of this shift approaches much closer to T_N in short range order region, as shown in ③~⑤, M_s goes still downwards. Surprizing enough, M_s in ⑥ keeps going upwards if the shift from 6.84 to 0.00mOe is given just after crossing T_N line.

This is a definite indication that the direction of the development of spontaneous magnetization and the building up of memory would be assumed just after the starting of long range order array below T_N.

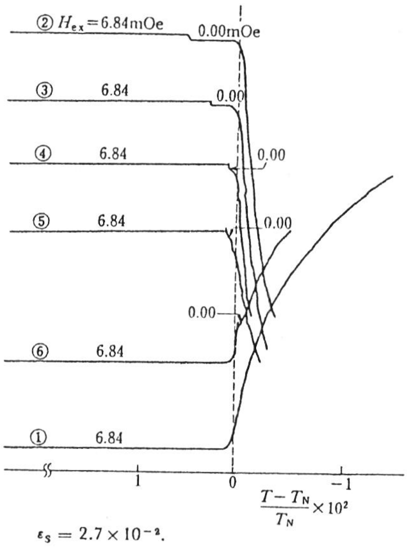


Fig. 4

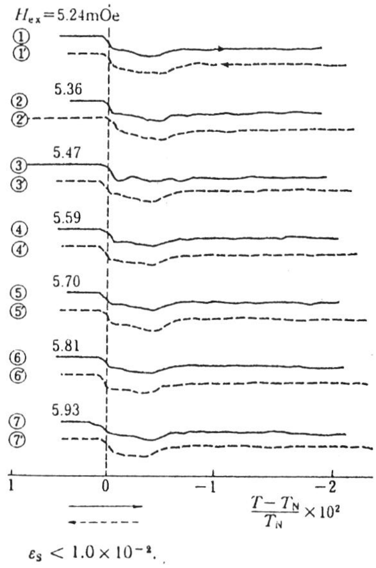


Fig. 5

4. The memory, its reproducibility

The last Fig. 5 shows the trace of M_s in the course of cooling down and warming up under the same H_{ex} for each run. The memories or features of M_s are reproduced exactly, as a whole, in amplitude and also in its position of bending on temperature scale. Some details are not reproduced suggesting that there are a kind of hierarchy in themselves. The details of experimental methods and results will be published shortly elsewhere.