THE TIME EVOLUTION OF THE FIRST ORDER MAGNETIC PHASE TRANSITION IN Dy-4%Y ALLOY

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The first order magnetic transition of spiral to ferromagnetic structure of Dy-4%Y alloy has been investigated by means of Synchrotron X-ray diffraction. The development of the ferromagnetic phase could be studied by X-ray diffraction measurement for the observation of the hexagonal to orthorhombic crystal distortion accompanying the first order magnetic transition. Below T_c , the ferromagnetic and spiral phases coexist and the development of the ferromagnetic phase exhibits a time dependent behaviour and is proportional to $\log t$ except in the early stage of the phase transition.

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Rare earth metals exhibit the first order magnetic phase transformation which is induced by both temperature and/or magnetic field¹⁾. The spiral magnetic structure is transformed into the ferromagnetic structure accompanied by the hexagonal to orthorhombic crystal distortion²⁾. Recently, X-ray diffraction study on Dy-4%Y alloy using the rotating anode source was performed to detect the development of the spiral to ferromagnetic transition by observing the hexagonal to orthorhombic crystal structure change³⁾. The spiral and ferromagnetic phases were found to coexist below the Curie temperature T_c of 55K and the volume fraction of the ferromagnetic phase increases with increasing time t . The time dependence of the development of the ferromagnetic phase is proportional to $\log t$. The gradient of the linear relation to $\log t$ decreases at low temperature and no time development of the ferromagnetic phase was observed at 10K. The development under magnetic field³⁾ was also studied by means of both X-ray diffraction and magnetization measurements and these results suggest that the spiral phase in Dy-4%Y below T_c is in a metastable state.

In order to study the development of the ferromagnetic phase in more detail, especially the development of the early stage of the first order magnetic transition, X-ray diffraction experiment has been performed using the National Synchrotron Light Source at

Brookhaven National Laboratory (NSLS). The intensity of the monochromatic X-ray beam may be at least one order of magnitude higher than that of a rotating anode type X-ray source, which makes it possible to obtain the information on the early stage of the phase transition. Observations of the time dependence of the (006) diffraction pattern have been made on the same single crystal sample used in the previous experiment³⁾ at several temperatures below T_c . The temperature control of the sample was made by a helium gas closed cycle refrigerator. In each measurements, the temperature was decreased from 90K, and it was kept constant at a certain measuring temperature, T_m . The temperature was measured by a thermometer which is located about 2 cm above the sample. By putting an additional thermometer at the sample position, it was confirmed that when the temperature is changed, there is only a time delay of few seconds between the thermometer at the sample position and the thermometer 2cm above. Fig.1 is the (006) diffraction patterns of $t_i=100$ and 32000 seconds for the time t_i at 45K. Two peaks which are indicated by "s" and "f" are the reflection from the c-plane of the spiral (hexagonal) and ferromagnetic (orthorhombic) phases respectively. These two reflections are well separated from each other compared with the previous observation made by a rotating anode X-ray beam³⁾. The intensity of the ferromagnetic peak increases with increasing time, but

the appreciable change of the line width of the reflections from both ferromagnetic and spiral phases could not be observed throughout the measurements. The time development of the volume ratio of the ferromagnetic phase to the total volume observed at several temperatures is plotted against $\log t$ in Fig. 2. The linear relation of the development of the ferromagnetic phase to $\log t$ holds in the time range larger than approximately 100 seconds, which is in agreement with the previous measurement. Near the spiral to ferromagnetic phase transition of the rare earth metal, the boundary of the two phases are parallel to the c-plane and the ferromagnetic phase may develop along the c-axis with decreasing temperature or increasing magnetic field⁴⁾. It is speculated that the $\log t$ dependence of the development can be described in terms of the one dimensional kink model⁵⁾ which was also applied to explain the process of two to three dimensional antiferromagnetic order in $\text{Rb}_2\text{Co}_{0.7}\text{Mg}_{0.3}\text{F}_4$ ⁶⁾. In the present experiment, the deviation from the $\log t$ relation has also observed in the time range less than about 100 seconds, which could not be obtained in the previous experiment with the rotating anode X-ray. These results may suggest that we have observed two stages in the development of the ferromagnetic phase, and the deviation from the $\log t$ corresponds to the characteristic development of the the

ferromagnetic phase in the early stage of the phase transition.

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Figure Captions

Fig.1 The (006) diffraction patterns of time 100 and 32000 seconds after reached to the temperature of 45 K from 90 K. "s" and "f" are the position of the reflection from the c-plane of spiral (hexagonal) and ferromagnetic (orthorhombic) phase respectively. ζ is the scattering wave vector along the c-axis in reduced unit.

Fig.2 The time development of the ratio of the ferromagnetic region $I(\text{ferro})$ to the total volume $I(\text{total})$ at various temperatures obtained from the analysis of the (006) reflections.