Magnetic Structure and Its Long-Time Variation in the Multistep Metamagnet CeIr3Si2

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A ternary compound CeIr3Si2 shows successive magnetic transitions at TN1=4.1 K and TN2=3.3 K. At T $<$ TN2 it shows three-step metamagnetic transitions below H=1.43 T. A long-time variation in magnetic structure was observed. [1] After rapidly cooling the sample below TN2, the intensity of the Bragg peaks corresponding to a magnetic phase at TN2 $<$ T $<$ TN1 (IT phase) remains and decreases with time. Instead, the Bragg peak intensity corresponding to a magnetic phase at T $<$ TN2 (LT phase) increases with time. The characteristic time for this variation follows the Arrhenius law with an activation energy E/k=4 K. Although the magnetic transition at TN2 had been known as an incommensurate to commensurate phase transition, the detailed magnetic structure in each phase had not been clarified.

We measured the intensities of many magnetic and nuclear Bragg reflections and determined the magnetic structures in both phases. Magnetic Bragg reflections in the IT phase were observed at the (0 1.375 0.64) and equivalent reciprocal lattice points. The position (0 1.375 0.64) is very close to (0 11/8 5/8), which means that the magnetic propagation vector in the IT phase is expressed as qI=2?(0, -3/8b, 3/8c). Magnetic Bragg peaks of the LT phase were observed at the (0 4/3 2/3) and equivalent reciprocal lattice points. This shows that the magnetic propagation vector corresponding to the LT magnetic structure is qL=2?(0, -1/3b, 1/3c) and that the volumes of the magnetic unit cells of the IT and LT phase magnetic structures are a x 8b x 8c and a x 3b x 3c, respectively. We calculated the magnetic structure factors based on various magnetic structures and found that the calculations based on stripe-type magnetic structures reasonably reproduce the observed scattering intensities for both the IT and LT phases. Figure 1 (a) illustrates the arrangement of the + (closed circle) and - (open circle) magnetic moments in the b-c plane of the IT phase structure. Magnetic coupling within a zigzag chain along the a-axis is ferromagnetic. Therefore, ferromagnetic sheets of + and - moments are aligned in the sequence ...|+−+-++- |..... Figure 1 (b) shows the arrangement of the + and - moments in the b-c plane of the LT phase structure. Magnetic coupling along the a-axis is the same as in the case of the IT phase. In this structure, ferromagnetic sheets of + and - moments are aligned in the sequence ....| ++-|..... Therefore, a net ferromagnetic moment exists in this structure. The amplitudes of the magnetic moments of Ce atoms for the IT and LT phases are 1.0(+-)0.4 ? at 3.3 K and 1.0(+-)0.3 ? at 2.7 K, respectively.

The determined magnetic structures in the IT and LT phases enable us to discuss the mechanism of the time variation of magnetic structure in CeIr3Si2. We showed in ref. 1 that the amplitude of Bragg peaks for the IT and LT phase structures varied with time. In this process, neither the peak position nor the line width of Bragg peaks changes with time. These results show that we have observed the time variations of the volume fractions of two distinct magnetic regions and that the magnetic structure of these two regions does not vary with time. Furthermore, the time variation behaviors of the peak width for the IT and LT phase signals have shown that the magnetic correlation length for both structures is 250 A and does not change appreciably with time. All these observations suggest that the magnetic structure varies with time as follows. Immediately after the sample is cooled below TN2, the entire sample

volume is divided into many magnetic regions (domains) having the IT phase structure shown in Fig. 1 (b). The average size of these domains is 250 A. With time, domains with the IT phase structure are gradually transformed to the LT phase structure shown in Fig. 1 (b). In order to accomplish this transformation, half of the ferromagnetic sheets of Ce atoms must reverse their moment direction. We speculate that the reversal of ferromagnetic moments expands in a sheet by means of the movement of the boundary line between regions of oppositely directed moments. This process is similar to the movement of domain walls in the magnetization process of ferromagnets. If the transition to the LT phase structure begins and proceeds uniformly in each domain, the magnetic correlation length for each structure should vary with time accordingly.
This is not the case.
We present an alternative scenario of the time-dependent magnetic transition. In this model, the transition to the LT phase structure in a particular domain is accomplished in a short time once a nucleus of the LT phase structure is formed in a domain. Because of the low rate of formation of such a nucleus, the number of domains having the LT phase structure increases slowly with the observed time constant.
If we assume that the observed energy barrier 4K corresponds to this nucleation energy, the time variations of the amplitude as well as the line width for both signals can be satisfactorily explained in terms of this scenario. Details of the mechanism of the long-time variation of magnetic structure of this material will be published in a forthcoming paper. [2]

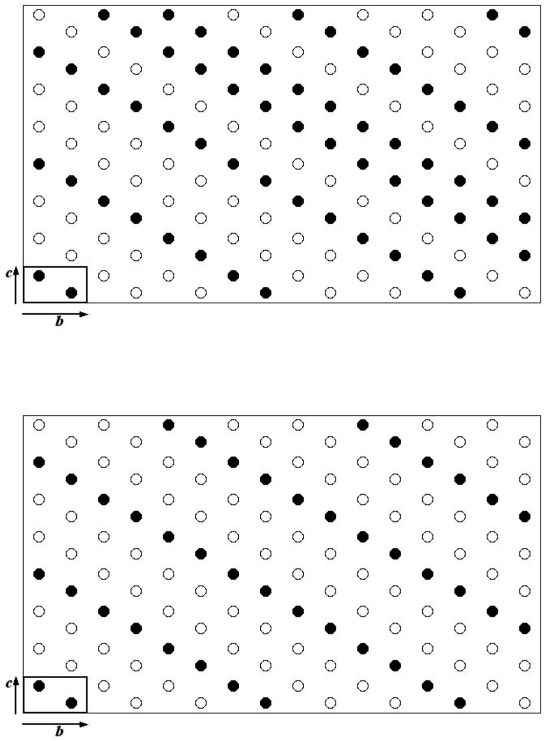

Fig. 1. Illustration of the arrangement of + (closed circle) and - (open circle) magnetic moments in the b-c plane of the (a) IT and (b) LT phase structures.

References

[1] K. Motoya et al. J. Phys. Conf. Series:200 (2010) 032048.
[2] T. Moyoshi et al. J. Phys. Soc. Jpn.: to be published.