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DOMAIN STRUCTURE IN $Ho_{0.5}Dy_{0.5}FeO_3$ IN THE VICINITY OF SECOND-ORDER PHASE TRANSITION

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Domain structure in $Ho_{0.5}Dy_{0.5}FeO_3$ orthoferrite in the temperature region close to the Néel temperature T_N was investigated by using the magneto-optical Faraday effect. It was found that in the neighbourhood of T_N the domain structure has a linear character. The measured dependence of the linear structure period on temperature and plate thickness is close to the theoretical considerations of the domain structure properties near the transition temperature.

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The influence of crystal finite dimensions on the second-order phase transition has been studied in many papers (see [1] for references). In the recent paper by Kaganov and Karpinskaya [1] the role of surface energy in the phase transition from the paramagnetic to the ferromagnetic state was investigated. It was shown that the surface energy influences significantly the character of a phase transition and the values of thermodynamic quantities in the ferromagnetic thin film. In case of films with the easy axis perpendicular to the surface, the appearance of a spontaneous magnetic moment is associated with a nonuniform distribution of magnetization.

The theory of inhomogeneous magnetic states in ferromagnetic films in the vicinity of a second-kind phase transition was developed by Tarasenko et al. [2]. The results of their theoretical predictions were confirmed experimentally in [3] for $YFeO_3$ orthoferrite plates. Particularly, it was shown that the domain structure in $YFeO_3$ near the Néel temperature has a linear character.

The existence of the linear domain structure depends on the value of the ratio K/P, where K is an anisotropy constant and P is the parameter describing the change of magnetization amplitude near T_N [4]. If $K \geqslant P$, the linear domain structure is energetically favourable. At present there are no detailed data on the values of K and P near T_N. In such a situation it seemed interesting to carry out observations similar to those performed in [3]

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on other materials than $YFeO_3$, with different values of K and P. The main purpose of this paper was to study the behaviour of the domain structure in $Ho_{0.5}Dy_{0.5}FeO_3$ orthoferrite near T_N. $Ho_{0.5}Dy_{0.5}FeO_3$ single crystals were chosen, because:

(1) the Faraday effect in orthoferrites is high enough to observe the domain structure near T_N;

(2) rare-earth ions Ho^{3+} and Dy^{3+} have an important influence on the anisotropy constant K [3, 5] and of course on the parameter P.

$Ho_{0.5}Dy_{0.5}FeO_3$ orthoferrite is a weak ferromagnet with $T_N = 645$ K. It was shown in [5] that in $Ho_{0.5}Dy_{0.5}FeO_3$ two spin-reorientation phase transitions take place $\Gamma_4(G_x, A_y, F_z; F_z^R) \to \Gamma_1(A_x, G_y, C_z; C_z^R)$ at $T_{R1} = 45$ K and $\Gamma_1(A_x, G_y, C_z; C_z^R) \to \Gamma_2(F_x, C_y, G_z; F_x^R, C_y^R)$ at $T_{R2} = 25$ K. It results from the above that near T_N one can expect a $\Gamma_4(G_x, A_y, F_z; F_z^R)$ spin configuration. The measurements of the domain structure were carried out on plates 26 μm and 52 μm thick cut perpendicular to the c-axis. To observe the domains, the magneto-optical Faraday effect was used. A special microscope heater was built in which temperature was stabilized with the accuracy better than 0.1 K. The

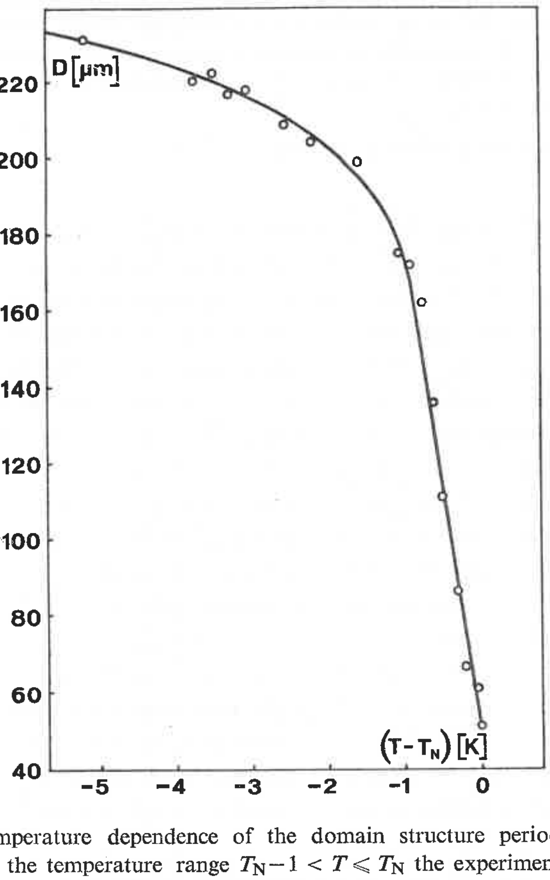

Fig. 1. Experimental temperature dependence of the domain structure period D in 52 μm thick $Ho_{0.5}Dy_{0.5}FeO_3$ plate. In the temperature range $T_N - 1 < T \leqslant T_N$ the experimental data are described by the relation $D = D_c + A(1 - T/T_N)$

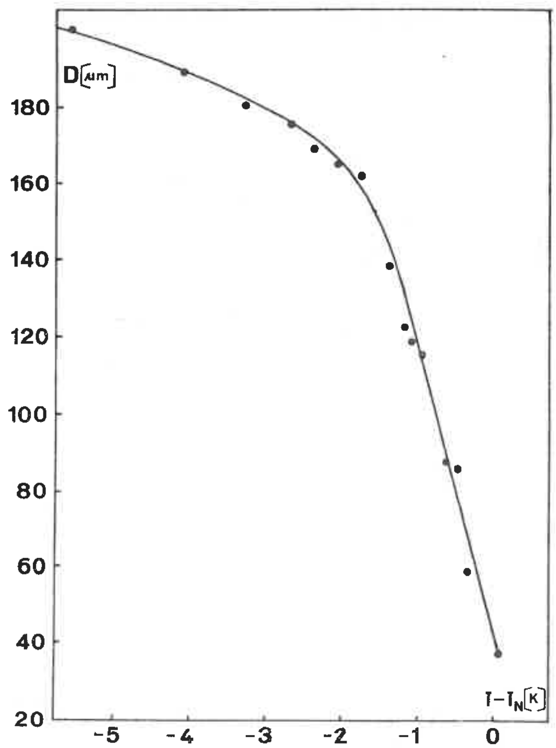

Fig. 2. Experimental temperature dependence of the domain structure period D in 26 μm thick $Ho_{0.5}Dy_{0.5}FeO_3$ plate. In the temperature range $T_N-1.4 < T \leqslant T_N$ the experimental data are described by the relation $D = D_c+A(1-T/T_N)$

experimental dependence of the stripe domains period D on the temperature is shown in Figs. 1 and 2 (for plates of different thickness). It can be seen that in the neighbourhood of T_N the domain structure period depends on temperature and on the platelet thickness L in the following way:

$$D = D_c+A(1-T/T_N),$$

where

$$D_c = (51\pm3)\ \mu\text{m}, \quad A = (8.6\pm1.3)\times10^4\ \mu\text{m} \quad \text{for} \quad L = 52\ \mu\text{m}$$

$$D_c = (38\pm3)\ \mu\text{m}, \quad A = (5\pm1)\times10^4\ \mu\text{m} \quad \text{for} \quad L = 26\ \mu\text{m}.$$

Such properties of domain structure in $Ho_{0.5}Dy_{0.5}FeO_3$ confirm the theoretical predictions [2].

The theoretical calculations in [2] are based on the classical Landau theory of phase transitions. Stauffer [6] applied the scaling theory to calculate the period of domain structure in the vicinity of the second-kind phase transition. According to his calculations the domain structure period D vanishes near the transition temperature as $(T_N-T)^{(\gamma-\nu)/2}$, where γ and ν are defined by parallel zero field susceptibility $\sim(T_N-T)^{-\gamma}$, and zero field coherence length $\sim(T_N-T)^{-\nu}$, respectively. According to scaling theory the domain wall energy density σ_w changes with temperature as $(T_N-T)^{\gamma+2\beta-\nu}$, where β is the index describing the temperature dependence of magnetization $M\sim(T_N-T)^{\beta}$. As it could be expected, the calculated temperature dependences of domain energy are quite consistent in both theories [2, 6]. The difference in the theoretical temperature dependence of D is connected rather with the fact that in [6] the calculations were performed under the assumption that domain wall thickness is much smaller than domain width D.

As it results from the present experimental data, the above assumption is no longer true in the critical region, i.e. near T_N. In conclusion one should emphasize that the obtained results confirmed the applicability of the classical Landau-theory for description of orthoferrites in the vicinity of the second-kind phase transition.

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