Photoinduced pinning of domain walls in the magnetic semiconductor $CdCr_2Se_4$

V. E. Makhotkin, G. I. Vinogradova, and V. G. Veselago

P. N. Lebedev Physics Institute, USSR Academy of Sciences
(Submitted 5 June 1978)
Pis'ma Zh. Eksp. Teor. Fiz. **28**, No. 2, 84–86 (20 July 1978)

It is shown that the decrease of the magnetic permeability of $CdCr_2Se_4$ under the influence of light is due to photoinduced pinning of domain walls.

PACS numbers: 75.30.Cr, 75.60.Ch, 75.50.Cc, 78.20.Ls

It is known that in a number of nonmetallic magnetic compounds, such as $CdCr_2Se_4$, $Y_3Fe_5O_{12}$ and others, light exerts a direct action on the initial magnetic permeability.[1–3] It is assumed that this influence is due to photoinduced appearance of centers that pin the domain wall, and it is this which decreases the magnetic permeability. Up to now, however, no experiments confirming this assumption have been performed.

Wantenaar *et al.*[4] have recently proposed a new method of investigating the pinning of domain walls and used this method to study the properties of the pinning centers in ferromagnetic gadolinium. The initial magnetic permeability of magnetic materials depends on whether the domain wall is free or is bound to definite pinning centers. In the latter case application of a pulsed magnetic field can tear the wall away from the pinning center and make it free. The time during which the permeability returns to the equilibrium value, and this is equivalent to the pinning of the wall by new centers, is a definite characteristic of the domain structure. If an external field of sufficiently short duration and amplitude is applied, it is possible to make the wall relax to the very same center. This is the main idea of the method proposed in[4]. We have used this method to investigate a photoinduced decrease of the magnetic permeability.

The object of the study was chosen to be the ferromagnetic semiconductor $CdCr_2Se_4$ doped with gallium ($x=0.035$), inasmuch as at this degree of doping this compound exhibits the maximum effect of light on the magnetic permeability, heretofore called the photoferromagnetic effect (PFE).[3–5] The magnetic permeability was measured by determining the transfer coefficient of a high-frequency ($f=4$ MHz) signal. The sample was nearly toroidal in shape and had three windings, one to apply the pulsed magnetizing field, the other to introduce the high frequency, and the third for reception. The high-frequency amplitude was kept low enough to allow reversible displacements of the domain wall to prevail. The duration of the rectangular magnetizing-field pulse was varied in a wide range. The sample was illuminated by an ordinary 100 W incandescent lamp without using any optical filters. All the experiments were performed at liquid-nitrogen temperature.

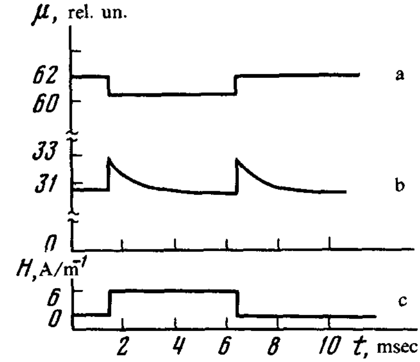

FIG. 1. Behavior of high-frequency magnetic permeability of $CdCr_2Se_4$ under the influence of a magnetizing field: a—sample not illuminated; b—sample exposed to white light; c—magnetizing-field pulse ($\tau = 5$ msec, $H = 6$ A/m).

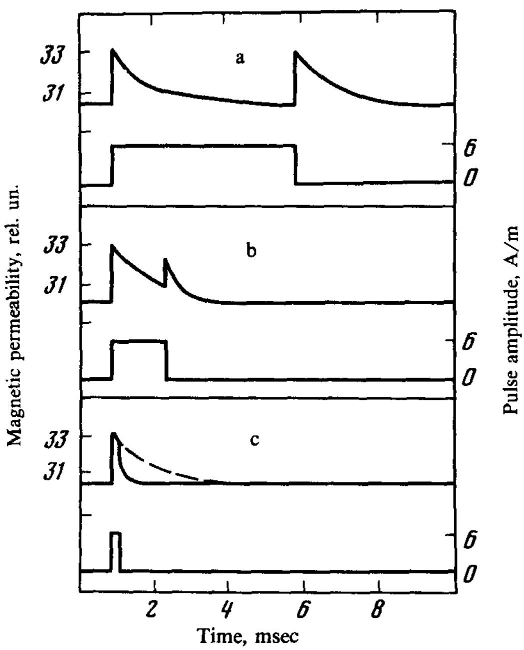

FIG. 2. Behavior of high-frequency permeability of $CdCr_2Se_4$ sample exposed to white light under the influence of a magnetizing field ($H = 6$ A/m): a) pulse duration $\tau = 5$ msec; b) $\tau = 1$ msec; c) $\tau = 0.2$ msec.

Figure 1 shows the result obtained for a magnetizing-pulse duration $\tau = 5$ msec and an amplitude $H = 6$ A/m. In the non-illuminated sample, the magnetic permeability is decreased by the field (Fig. 1a). In the illuminated sample, an increase of the permeability is observed on the rising and trailing edges of the pulse, and can be treated as a partial detachment of the domain walls from the pinning centers. If we denote by $\Delta\mu_L$ the decrease of the permeability under the influence of the light, and by $\Delta\mu_{\text{per}}$ the maximum increase of the permeability of the illuminated crystal under the influence of the magnetizing field, then the maximum ratio $\Delta\mu_{\text{per}}/\Delta\mu_L$ in our experiments was 15%, i.e., only a partial restoration of the permeability was observed. The pinning of the domain walls by the new centers occurs within times of the order of several milliseconds.

Figure 2 shows the effect of a rectangular field pulse of varying duration on the permeability of an illuminated $CdCr_2Se_4$ crystal. For a pulse duration 0.1 msec, the relaxation time of the permeability is much shorter and is apparently a characteristic of the properties of the pinning centers themselves. At a pulse duration 1 msec the permeability has a more complicated behavior. In the unilluminated crystal, at all the given pulse durations, the magnetic permeability decreases.

It can be concluded from the results that the decrease of the permeability under the influence of the light is connected with the pinning of the domain walls on the photoinduced centers, but no such pinning is observed in darkness.

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