

the 2p oxygen orbital [4]. The anomalously high level of the FE observed by us in films containing appreciable amounts of aluminum casts doubt on the correctness of the indicated mechanism, since the Al^{3+} ions replace the Fe^{3+} ions predominantly in the tetrahedral positions, and this should hinder the growth of the FE in accord with [3, 4].

Magnetic properties and parameters of the domain structure of films of the system $Y_{3-x}Bi_xFe_{5-y}Al_yO_{12}$

Film comp.	Thickness μ	Average CMD diam. μ	Coercivity H_c , Oe	Uniaxial anisotr. field H_k Oe	Saturation mag. $4\pi M_s$, G
1	6.9	2.0	1.0	1300	700
2	1.05	1.3	0.5	1500	350

The table lists the main magnetic characteristics of the films and the domain-structure parameters. We see that the ratio of the uniaxial-anisotropy field H_k to the saturation magnetization $4\pi M_s$ exceeds unity for both compositions, so that stable existence of cylindrical magnetic domains (CMD) is possible in the films. When observed in a polarization microscope, the strip and cylindrical domains exhibited a rather high optical contrast, attributed to the large values of the parameter ψ .

In view of the unprecedentedly large values of the magneto-optical quality and the existence of strip and CMD domain structure with low coercivity, the films with the investigated compositions are of practical interest for the development of magneto-optical devices using CMD and strip domains, and especially optical transparencies for holographic memory devices of large capacity.

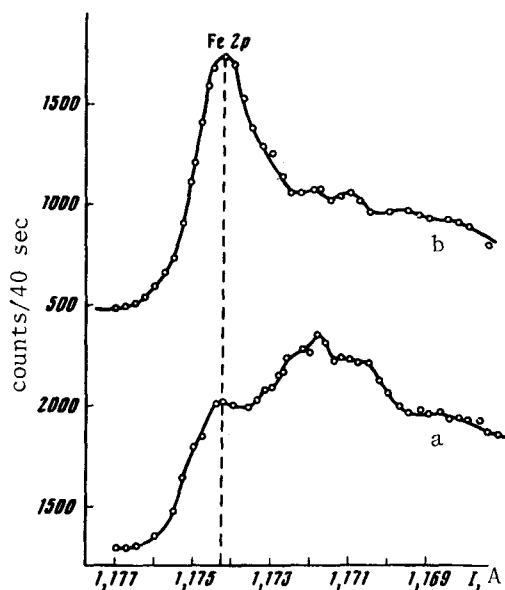
- [1] S. A. Medvedev, A. M. Balbashov, and A. Ya. Chervonenkis, in: Monokristally tugoplavkikh i redkikh metallov (Single Crystals of High-Melting-Point and Rare Metals), Nauka, 1969, p. 27.
- [2] W. F. Druyvesteyn, J. W. F. Dorleijn, and P. J. Rijniere, J. Appl. Phys. 44, 2397 (1973).
- [3] W. Shaw Roger, D. E. Hill, R. M. Sandfort, and J. W. Moody, J. Appl. Phys. 44, 2346 (1973).
- [4] S. Wittekoek and D. E. Lacklison, Phys. Rev. Lett. 28, 740 (1972).
- [5] S. Wittekoek and Th.S.A. Popma, Proc. Internat. Conf. on Magnetism, Moscow, 1973, paper 24m-U6.

TEMPERATURE DEPENDENCE OF THE INTENSITY OF THE CHARACTERISTIC ENERGY LOSSES OF 2p ELECTRONS OF IRON IN CEMENTITE

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A sharp decrease in the intensity of the characteristic losses was observed in an experimental electron-spectroscopy study of the spectra of the $2p_{3/2}$ level of iron in cementite at temperatures below and above the Curie point. This decrease is attributed to a decrease in the number of uncompensated 3d electrons of the iron on going from the ferromagnetic to the paramagnetic state.

One of the applications of the electron-spectroscopy method [1] is its use for the study of magnetic materials. In transition-metal compounds, the presence of uncompensated 3d electrons, which are responsible for the magnetic properties, leads to multiplet splitting of the internal levels [2, 3] and to effects of multielectron excitation (shake effects) [4, 5], as a result of which an intensive extended structure (in the binding-energy scale) is produced on the high-energy side of the fundamental line. This structure is superimposed on the region of the characteristic electron energy losses inherent in the electronic spectra of solids, and are



$2p_{3/2}$ spectra of iron (Al K_{α}) in cementite, obtained at 20°C (a) and 290°C (b).

consequently frequently also called "characteristic losses."

It is shown in [6, 7], by using the $2p_{3/2}$ electron spectra of the iron-group transition metals, investigated in iron silicides, the oxide Fe_2O_3 , the ferrocene, $K_4[Fe(CN)_6]$, and monosilicides of iron, cobalt, and nickel, that the intensities of the characteristic losses increase when the number of uncompensated 3d electrons is increased.

The possibility that the atomic magnetic moment of atoms of the same substance may change on going from the ferromagnetic to the paramagnetic state was indicated in [8], where experimental data on the paramagnetic susceptibility were used in the calculations of the atomic moments for iron, cobalt, and nickel. Investigations of the positions and shapes of the x-ray K absorption edges of iron and nickel, which reflect the position of the Fermi boundary and the density of states in the unoccupied part of the conduction band, on going through the Curie point, has shown that the spectra are independent of the temperature [9]. In [2], no difference was observed between the shapes of the electron spectra of the Fe 3p level in pure iron below and above the Curie point, indicating that the magnetic moment remains unchanged. On the other hand, disturbance of the magnetic order should not be noted in the electron spectrum, since the exchange coupling between the ions is $\sim 0.001 - 0.1$ eV.

The $2p_{3/2}$ spectra of iron in cementite at temperatures 20, 140, 240, 290, and 310°C were investigated with an electron magnetic spectrometer designed by the Institute of Metal Physics [10], using aluminum x-radiation (Al K_{α}) to excite the electrons. Iron carbide Fe_3C (cementite) has an orthorhombic lattice, an average magnetic moment $1.78\mu_B$, and a Curie temperature 215°C.

The figure shows characteristic iron $2p_{3/2}$ spectra for the ferromagnetic and paramagnetic states of cementite at temperatures 20 (a) and 290°C (b). The abscissas represent the measured current in the focusing coils of the spectrometer in amperes, and the ordinates represent the intensity. The binding energy of the $2p_{3/2}$ level of iron is 708.1 ± 0.3 eV in both states of the cementite. The spectra obtained in the ferromagnetic state (at 20 and 140°C) have an intense characteristic-loss structure, exceeding the maximum of the line intensity, and the intensity of iron-spectrum losses obtained in the paramagnetic state of the cementite (at 240, 290, and 310°C) is much lower than the line intensity.

By interpreting the spectra in accord with the foregoing data concerning the dependence of the characteristic losses on the number of the uncompensated electrons, we can conclude from the obtained experimental results that the number of uncompensated 3d electrons in the iron atoms of cementites is decreased on going from the ferromagnetic to the paramagnetic state. Consequently, a second-order phase transition in cementite is accompanied not only by a disturbance of the magnetic order, but also by a decrease of the magnetic moment. Emphasizing the significance of the second argument, we can state that we encounter in cementite a unique type of ferromagnetism, namely atomic ferromagnetism.

To check on the investigated surface layer, we obtained the spectra of the 1s level of carbon at the same temperatures as the iron spectra. No chemical shift was observed in the level energy with changing temperature. The binding energy of the carbon 1s level is 284.0 ± 0.1 eV.

- [1] K. Siegbahn, C. Nordling, A. Fahlman, R. Nordberg, K. Hamrin, J. Hedman, G. Johansson, T. Bergmark, S. E. Karlsson, I. Lindgren, and B. Lindberg. ESCA-Atomic Molecular and Solid State Structure Studied by Means of Electron Spectroscopy, 1967, North-Holland Publishing Co., Amsterdam.
- [2] C. Fadley, Core and Valence Electronic State Studied with X-ray Photoelectron Spectroscopy,

VCRL-19535, 1970.

- [3] H. J. Wertheim, Paper at Internat. Congress on Magnetism, Moscow, 22-28 August, 1973
- [4] T. Novakov, Phys. Rev. 3B, 2693 (1971).
- [5] A. Rosencwaig, J. K. Wertheim, and H. J. Juggenheim, Phys. Rev. Lett. 27, 479 (1971).
- [6] I. N. Shabanova, N. P. Sergushin, K. M. Kolobova, V. A. Trapeznikov, and V. I. Nefedov, Fiz. Met. Metallov. 34, 1187 (1972).
- [7] N. P. Sergushin, I. N. Shabanova, K. M. Kolobova, V. A. Trapeznikov, and V. I. Nefedov, ibid. 35, 947 (1973).
- [8] S. V. Vonsovskii and Ya. S. Shur, Ferromagnetizm (Ferromagnetism), OGIz, 1948.
- [9] V. A. Trapeznikov, Fiz. Met. Metallov. 3, 561 (1956).
- [10] V. A. Trapeznikov, A. V. Evstaf'ev, V. P. Sapozhnikov, I. N. Shabanova, O. I. Klyushnikov, F. B. Maksyutov, V. L. Kuznetsov, and O. B. Sokolov, Fiz. Met. Metallov. 36, No. 6 (1973).

BIEXCITON IN CdS SPECTRUM. INDUCED RADIATIVE DECAY OF EXCITON-IMPURITY COMPLEXES

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It is shown that the emission bands produced by strong optical excitation in CdS crystals at low temperatures, and ascribed by some authors to biexcitons and to collisions between them, are actually connected with induced radiative decay of electron-impurity complexes (EIC) with emission of long-wave acoustic phonons.

A number of recent papers report experimental observation of biexcitons in the recombination emission spectra of CdS and CdSe [1 - 3]. When these crystals are exposed to strong laser radiation at sufficiently low temperatures, several intense emission bands are produced, and two of them, designated M and P_M , were attributed by the authors to radiative decay of biexcitons [1] and to elastic collisions between them [2]. The main arguments favoring the biexciton concept are based on the faster-than-linear dependence of the intensities of the corresponding bands on the laser pumping, and also on an analysis of the band shapes. It must be borne in mind, however, that a significant restructuring of the radiative-recombination spectrum is still not an unambiguous consequence of a bimolecular process in the system of interacting excitons, and may have a more trivial cause, namely induced radiative processes.

The purpose of the present communication is to show that the CdS-spectrum singularities attributed to biexcitons are due to induced radiative decay of exciton-impurity complexes (EIC) on the neutral donors and acceptors, accompanied by emission of long-wave acoustic phonons.

We have investigated different CdS crystals, some of which were highly purified and contained not more than $(1 - 5) \times 10^{15} \text{ cm}^{-3}$ donor and acceptor impurities responsible for the EIC lines I_2 and I_1 . We have also investigated a number of crystals with different degrees of compensation for the acceptor impurities, and the intensity ratio of I_2 and I_1 differed as a result of this compensation by an order of magnitude or more.

The luminescence was excited with a pulsed nitrogen laser (peak power $\sim 1.6 \text{ kW}$, repetition frequency 100 Hz). The spectral resolution was worse than 0.2 \AA (10^{-4} eV).

Figure 1 shows the behavior of the luminescence spectrum of a high-purity CdS sample at $T = 1.3$ with increasing pumping (observation at 45° to the excited surface, dimension of laser spot on crystal $\sim 0.2 \text{ mm}$). Here M and P_M are the bands so designated in [1] and [2], A and A-LO denote the bands of direct radiative exciton annihilation and with emission of an LO phonon, I_2 and I_1 are the phononless EIC lines, and P is the emission band due to inelastic collisions of two free excitons [4, 5]. We confine ourselves to the properties of the bands M and P_M .

1. In uncompensated metals, the P_M band is clearly observed in the spontaneous-luminescence spectra even at low excitation levels (Fig. 1, spectra a and b), and constitutes the Stokes acoustic wing of the phononless line I (transitions with emission of long-wave acoustic