

do not depend on the dysprosium concentration in the system. Below 10°K, the temperature dependences of the susceptibilities of samples with $n \geq 85\%$ and of samples with low dysprosium concentrations differ strongly. (Figure 2 pertains to an external field parallel to the C axis of the crystal, an orientation for which the effect is particularly noticeable.) Above $\sim 1.5^\circ\text{K}$, judging from our measurements of the magnetic susceptibility, $\text{KDy}(\text{MoO}_4)_2$ is a paramagnet, so that the change of the slopes of the $\chi(T)$ curves of samples with large dysprosium concentrations near $T \sim 10^\circ\text{K}$ indicates that the phase transition observed at this temperature is structural and not magnetic.

It is shown in [3] that the change of the distance between the doublets, due to the cooperative Jahn-Teller effect, should be described by the expression $\Delta E_{1-2}(0)/\Delta E_{1-2}(\infty) = \tanh \Delta E_{1-2}(\infty)/2kT_D$, where the indices 0 and ∞ correspond to temperatures much lower and much higher than the phase-transition point T_D . For our data, this relation is well satisfied, and we are therefore inclined to assume that the observed structural phase transition in $\text{KDy}(\text{MoO}_4)_2$ is due to the cooperative Jahn-Teller effect.

The investigated rare-earth Jahn-Teller compounds have one large and two small principal values of the g-factor. The Ising model was therefore used in the formalism of the molecular-field theory to describe the interaction in the Jahn-Teller effect. In $\text{KDy}(\text{MoO}_4)_2$, two values of the g-factor are large and almost equal (~ 10), and the third is small (~ 1), so that the x-y model is apparently more suitable here.

The authors are indebted to V.V. Eremenko for a discussion of the results, and to L.N. Pelikh and M.I. Kobets for help in growing the single crystals.

- [1] A.H. Cooke, C.J. Ellis, K.A. Gehring, M.J.M. Leask, D.M. Martin, B.M. Wanklym, M.R. Wells, and R.L. White, *Solid State Comm.* **8**, 689 (1970).
- [2] T.S. Stetsenko, V.G. Yurko, S.D. El'chaninova, and A.I. Zvyagin, in: *Fizika nizkikh temperature (Low-temperature Physics)*, Physico-tech. Inst. of Low Temp., Ukr. Acad. Sci., Khar'kov, No. 20, 74 (1972).
- [3] G.A. Gehring, A.P. Malozemoff, W. Staude, and R.N. Tyte, *J. Phys. Chem. Solids* **33**, 1487 (1972).

ABSORPTION LINE SPECTRA OF ZnP_2 CRYSTALS

I.S. Gorban', V.V. Lugovskii, I.I. Tychina, and A.V. Fedotovskii
Kiev State University, Kiev State Pedagogical Institute
Submitted 9 January 1973
ZhETF Pis. Red. **17**, No. 3, 193 - 197 (20 February 1973)

We obtained the edge absorption spectrum of ZnP_2 crystals with monoclinic syngony at 4.2°K . Its distinguishing feature is that it consists of a large number of narrow lines forming sequences that converge to the boundary lines at 1.5471 eV ($E \perp C$), 1.5471 eV and 1.4972 eV ($E \parallel C$).

ZnP_2 is a semiconducting compound of the $A^{II}B_2^V$ type and is formed in two different modifications, tetragonal and monoclinic [1].

We have investigated samples of monoclinic ZnP_2 obtained by sublimation in a two-temperature oven in quartz ampules evacuated to 10^{-4} mm Hg. The initial materials were red phosphorus and metallic zinc (grade V-5), in the stoichiometric ratio. Unlike the procedures used in [1], we obtained crystals of monoclinic syngony only by adjusting the temperature conditions in the ampules. The single crystals had regular faceting with perfect face surfaces.

Energies of the absorption lines in spectra of types A and A' and the shifts between the corresponding lines

A-spectrum		A'-spectrum		$h\nu - h\nu'$ eV
Line Nos.	$E \perp C, E \parallel C$ $h\nu, \text{ eV}$	Line Nos.	$E \parallel C$ $h\nu', \text{ eV}$	
1	1.5471	1'	1.4972	0.0499
2	1.5466	2'	1.4966	0.0500
3	1.5460	3'	1.4961	0.0499
4	1.5455	4'	1.4957	0.0498
5	1.5459	5'	1.4953	0.0496
6	1.5441	6'	1.4943	0.0498
7	1.5430	7'	1.4939	0.0491
8	1.5425	8'	1.4925	0.0500
9	1.5414	9'	1.4919	0.0495
10	1.5400	10'	1.4894	0.0506
11	1.5390	11'	1.4868	0.0496
12	1.5366	12'	1.4861	0.0498
13	1.5357	13'	1.4850	0.0496
14	-	14'	-	-
15	1.5337	15'	1.4842	0.0495
16	1.5328	16'	1.4832	0.0495
17	1.5310	17'	1.4817	0.0493
18	1.5268	18'	1.4772	0.0496
19	1.5250	19'	1.4733	0.0517

The monoclinic ZnP_2 crystals had the following crystal-lattice parameters: $a = 8.85 \pm 0.02 \text{ \AA}$, $b = 7.29 \pm 0.02 \text{ \AA}$, $c = 7.56 \pm 0.02 \text{ \AA}$, and $\beta = 102.3 \pm 0.2^\circ$ [1]. The unit cell contains eight ZnP_2 molecules. It is important that in such crystals, as in the tetragonal ones, all the atoms are tetrahedrally coordinated, but are not in equivalent positions. For the phosphorus, for example, the non-equivalence means that there are atoms that are bound into a tetrahedron with one nearest Zn atom and three nearest P atoms, as well as atoms bound with two nearest Zn atoms and two P atoms.

The absorption spectrum of monoclinic ZnP_2 near the edge of the ground state band at 4.2° and at different orientations of the electric vector E of the light wave relative to the optical axis C of the crystals is shown in Fig. 1. We see that it contains a rather large number of narrow lines that can be gathered into groups (spectra of type A, A' and of type B, B' in Fig. 1). Particular interest attaches to the spectra of type A and A'. At $E \perp C$ there exist in the 1.52 - 1.55 eV region about 20 absorption lines, which in general converge in the short-wave region of the spectrum towards the end-point line 1.5471 eV (spectrum A). For $E \parallel C$ there exists, in addition to such a line group, an analogous group of lines of longer wavelength (1.47 - 1.50 eV) converging towards an end-point line located at 1.4972 eV (spectrum A'). The energy positions of the lines in the spectrum are given in the table. We see that the energy distance between the line groups as a whole in the spectra for $E \perp C$ and $E \parallel C$, and also between each individual corresponding line of the groups (1 - 1', 2 - 2', 3 - 3', ...), remains constant at an average of 0.0497 eV. It is also important to note that a correlation exists between the intensities of the corresponding lines in the spectra A and A'. This allows us to assume that both groups of lines in the absorption spectrum stem from the same source. They are probably due to exciton-impurity complexes localized on the

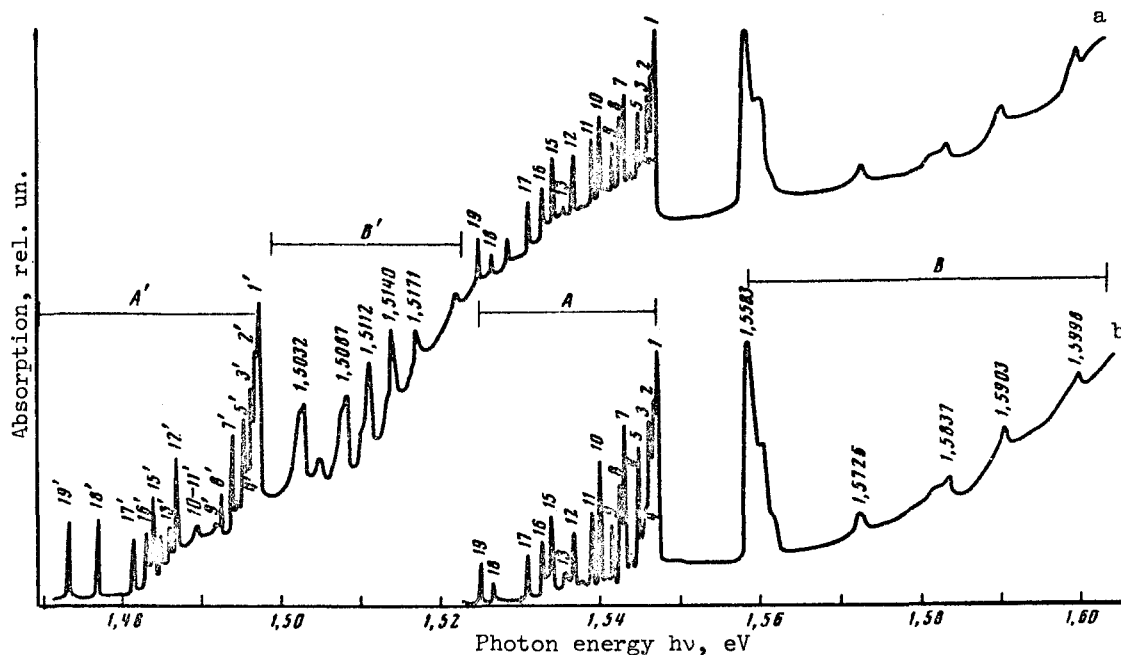


Fig. 1. Absorption spectrum of monoclinic ZnP_2 crystals: a) $E \parallel C$; b) $E \perp C$. The numbers of the spectral lines correspond to those in the table.

isoelectronic pair centers. The basis for this assumption is the presence of the convergence of sequences of narrow lines towards short-wave limits, which recall the convergences observed earlier in gallium-phosphide crystals [2, 3], where the isoelectronic impurities are due to nitrogen substituted for phosphorus¹⁾.

The energy difference 0.0497 eV between the A and A' spectra at $E \perp C$ and $E \parallel C$, according to all data, is equal to the crystal splitting of the valence band.

Figure 2 shows the spectrum of a different type of monoclinic ZnP_2 crystals. Its distinguishing feature is the total absence of the spectrum A, although the polarization characteristics are the same here as in the one considered above. In all probability this spectrum, like the spectrum B(B') in Fig. 1, is due to the presence of other uncontrollable impurities that can enter in the ZnP_2 crystal.

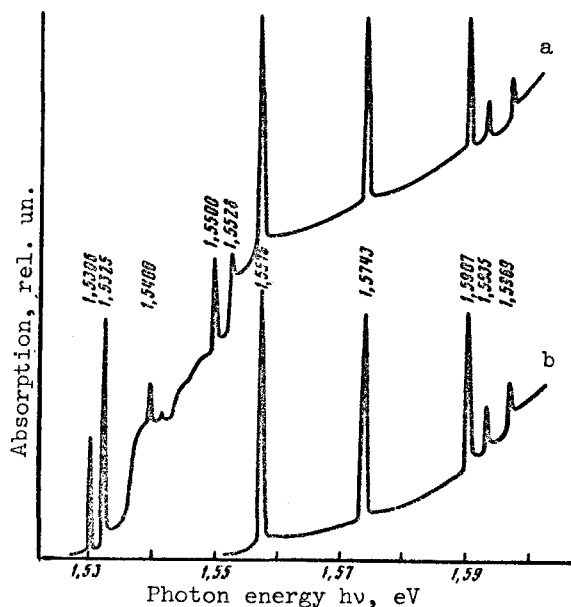


Fig. 2. Absorption spectrum of ZnP_2 crystals: a) $E \parallel C$; b) $E \perp C$.

¹⁾ It is quite probable that the isoelectronic impurity in our case is also nitrogen.

We have thus observed in monoclinic ZnF_2 , near the edge of the ground-state band, a line structure of the absorption spectrum, assumed to be due to exciton localized on paired isoelectronic centers. It follows from the singularities of the observed spectrum that the crystal splitting of the valence band amounts to 0.0497 eV.

- [1] I.J. Hegyi, E.E. Loebner, E.W. Poor, and J.G. White, J. Phys. Chem. Sol. 24, 333 (1963).
- [2] D.G. Thomas, J.J. Hopfield, and J. Frosch, Phys. Rev. Lett. 15, 857 (1965).
- [3] P.J. Dean and D.G. Thomas, Phys. Rev. 150, 690 (1966).

SPATIALLY INHOMOGENEOUS FILTERS FOR THE ULTRASOFT X-RAY REGION

V.D. Peskov, Ya.A. Sakharov, and E.A. Tishchenko
Institute of Physics Problems, USSR Academy of Sciences
Submitted 11 January 1973

ZhETF Pis. Red. 17, No. 4, 197 - 201 (20 February 1973)

To separate the 50 - 2000 Å radiation region it is proposed to use filters of uneven thickness obtained by sputtering aluminum on a collodion substrate. The operating principle of such filters is analogous to that of the spatially inhomogeneous filters used in the far infrared.

The region most difficult to investigate in plasma spectroscopy is that of ultrasoft x-radiation (UXR) (50 - 2000 Å). This is due to the fact that plasma radiation in this region has usually low intensity and the absorption of the UXR in the receiver windows is large. In addition, the useful signal must be separated against the background of strong ultraviolet radiation of the plasma. Therefore even if receivers without windows are used, filters in the form of aluminum or beryllium films are placed ahead of the detector [1]. Such films, however, absorb also the UXR.

An anomalous transparency of very thin aluminum films (less than 200 Å thick) to UXR was noted but not explained in [2]. We became interested in this fact. Additional investigations have shown that such properties are possessed by structures of uneven thickness.

We have decided to test such structures for use as filters to separate the UXR region of the spectrum from a high-power background of ultraviolet radiation. Just as in [2], such filters were prepared by sputtering aluminum on a collodion substrate 1000 Å thick. During the initial stage of sputtering (at a rate 100 Å/min in a vacuum on the order of 10^{-5} Torr), a structure of uneven thickness was produced in the form of aluminum crystallites that have not grown together. An electron-microscope picture of such a film is shown in Fig. 1¹). At larger masses of sputtered aluminum, the structure thickness became more uniform.

We measured the transparency of the filters by the transmission method. In the wavelength region $\lambda < 100$ Å we used for this purpose radiation from an x-ray tube; the signal was registered with a proportional counter. For $\lambda > 1000$ Å we used microwave radiation from a low-pressure discharge. The required spectral interval was separated with a VM-1 monochromator. The signal was registered with an FEU-39 photomultiplier with a scintillator of sodium salicylate. Unfortunately, for lack of an x-ray spectrograph, we could not measure

¹) We are grateful to V.N. Rozhanskii (Crystallography Institute, USSR Academy of Sciences) for the electron-microscopic investigations.