PREPARATION AND SOME PROPERTIES OF THE SEMICONDUCTING COMPOUND CdSnAs$_{2}$

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PREPARATION AND SOME PROPERTIES OF THE SEMICONDUCTING COMPOUND $CdSnAs_2$

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Recently, ternary semiconducting compounds of the type $A^{IIB}IVC_2$^V, which are electronic analogues of compounds of the type $A^{IIIB}V$, have attracted interest. In the USSR, studies of these ternary compounds were begun at the A. F. Ioffe Physico-Technical Institute of the Academy of Sciences of the USSR by N. A. Goryunova and co-workers (^1). Numerous works have been devoted to the preparation (^{2}-4) and the study of the electrical (^5), optical (^6), and magnetic (^7) phenomena in the compound $CdSnAs_2$.

Crystals of the semiconducting compound $CdSnAs_2$ belong to the tetragonal-scalenohedral class (point group $\bar{4}2m$) with parameters $a = 6.0937$ Å and $c = 11.9184$ Å. The melting temperature of $CdSnAs_2$ is $596 \pm 2^\circ$ (^9).* Despite the reduced symmetry of the crystal structure, the electron mobility in this substance reaches high values (of the order of 10^4 cm^2/V · sec at room temperature) and is not inferior to that of such semiconducting compounds as InAs, HgTe, and HgSe.

In works (^4, ^8, ^9) it was shown that in the interval 600–550° a thermal effect is observed, explained by the presence of a polymorphic transformation. It was also shown that at temperatures above this transformation $CdSnAs_2$ has the zinc-blende structure ($a = 6.0510 \pm 6.0005$ Å), while upon cooling below $587 \pm 2^\circ$ a transition to the chalcopyrite structure occurs.

Most of the previously published work on the study of the physical properties of $CdSnAs_2$ was carried out on samples that were either fine-grained polycrystalline ingots or polycrystals with fairly large grains; however, even in the latter case the samples contained a large number of cracks arising because of the considerable tetragonal compression ($c/a = 1.96$) during the polymorphic transformation. This made it considerably more difficult to prepare samples with a predetermined crystallographic orientation, which is necessary for a detailed study of such an anisotropic semiconductor as $CdSnAs_2$.

Fig. 1. Distribution of resistivity along the length of a single-crystal ingot.
$CdSnAs_2$-n, ingot No. 2

Figure 1: Fig. 1. Distribution of resistivity along the length of a single-crystal ingot. $CdSnAs_2$-n, ingot No. 2

We succeeded in obtaining oriented single crystals of $CdSnAs_2$ free of cracks. The substance was synthesized in an optical-quartz ampoule at 750° in an atmosphere of spectrally pure argon from elements taken in stoichiometric ratio. The synthesized material was then subjected to thorough zone purification using additional heating ($T = 470°$). The optimum zone-travel rate was 3.4 cm/hr, and the use of copper chromized concentrators placed in the furnace for melting the zone made it possible to vary the zone width from 0.8 to 1.5 cm. The total number of zone passes did not exceed 20–25.

* We use the term "melting temperature" conditionally, since it has not yet been shown that the melting process of this compound is congruent in character.

The purified polycrystalline ingot, together with a previously prepared seed, was treated with an etchant of the following composition: 3 parts CH_3OOH + 3 parts HF + several drops of HNO_3, subjected to repeated washing in deionized water, and loaded into an optical-quartz ampoule, in which single crystals were grown by the zone-recrystallization method.

Since thermal analysis showed that the polymorphic transition occurs at $587 \pm 2°$, precisely this temperature, or a slightly higher one, must be maintained with high accuracy by additional heating in order to exclude the possibility of transition of the crystal from the zinc-blende structure to the chalcopyrite structure immediately after solidification. The temperature of the molten zone exceeded the heater temperature by only $12 \pm 2°$, while the temperature gradient at the crystallization front was about 10 deg/cm. The rate of motion of the molten zone was 0.8 cm/h. After seeding and one passage of the zone, the entire ingot was slowly cooled at a rate of no more than 3 deg/h to a temperature of 400°. With slow cooling, the polymorphic transformation, associated with a change in the lattice parameters, occurs in the plasticity region of the crystal; therefore the probability of crack formation is small.

Fig. 1. Distribution of resistivity along the length of a single-crystal ingot. $CdSnAs_2$-n, ingot No. 2

By the method described, we obtained large single crystals (up to 7 cm long and about 1 cm in diameter), free of cracks; the direction of the longitudinal axis of the crystal usually coincided with the crystallographic direction [110]*.

Figure 1 shows the distribution of resistivity along the length of one of the ingots, measured by the four-probe method with an accuracy of $±10_{2}$ is well amenable to zone purification, since most impurities have a segregation coefficient $K \ll 1$. However, because of the presence of a small amount of unidentified impurities with $K > 1$, the middle part of the ingot turns out to be the purest.

Table 1

Basic characteristics of the investigated $CdSnAs_2$ samples at room temperature

Sample No.	R, cm^3/C	ρ, ohm • cm	n, cm^{-3}	μ_H, $cm^2/V \cdot s$
17-n	80	$5.0 \cdot 10^{-3}$	$7.8 \cdot 10^{16}$	16 000
18-n	3.7	$4.9 \cdot 10^{-4}$	$1.7 \cdot 10^{18}$	7650

Note. Sample 17-n is from the middle of the ingot, and 18-n is from the end of the ingot. $T = 295°$ K.

Measurements of the resistivity and Hall coefficient on n-type samples cut from the middle and the end of the ingot (see Table 1) show that the ingots obtained possess a sufficiently high perfection of crystalline structure, although it is quite clear that they cannot be free of dislocations and internal mechanical stresses because of the deformation occurring during the polymorphic transformation.

The high value of the mobility in the sample with an electron concentration of about $2 \cdot 10^{18}$ cm^{-3}, considerably exceeding those known from the literature ([3,6,8]), makes it possible to suppose that the degree of impurity compensation in the investigated sample is small.

* The authors express their gratitude to A. A. Vaipolin for carrying out the X-ray structural analysis.

No dependence of the Hall coefficient on magnetic-field strength up to 12 kOe was found in the investigated n-type samples.

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Note: Figure translations are in progress. See original paper for figures.