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Determination of Scattering Anisotropy Parameter with the Use of Measurements of Anisotropic Electrical Conductivity

In the study of Baranskii and Kolomoets the procedure of measuring the scattering anisotropy parameter of electrons, $K = \mu_\perp/\mu_{||}$, in semiconductor crystals having several equivalent minima within the conduction band at the edge (or adjacent the edge) of the Brillouin zone has been described ($\mu_\perp$ is the mobility of electrons moving across an isoenergetic ellipsoid, $\mu_{||}$ is the mobility of electrons moving along this ellipsoid). This method is based on measuring the dependence of piezoresistance of a sample under investigation on the uniaxial elastic deformation X, applied along the major axis of one of equivalent isoenergetic ellipsoids. Simplicity and reliability of results obtained with the use of this method have made it a rather effective means of investigation into the scattering mechanisms and band structure of semiconductor materials. However, its application for determining K will be correct only in the case where the intervalley scattering of electrons can be neglected. At the same time, in numerous multivalid semiconductors this scattering mechanism can be rather significant, and in this case the determination of K by this method is unsubstantiated.

We propose another method of determining the value of the scattering anisotropy parameter, which has been used for the determination of K values in GaP and Si (Baranskii et al.); this method is also based on the use of uniaxial elastic deformation but is not connected with the above limitation. The essence of this method consists in in that under a strong uniaxial compression of a crystal at a certain (not very large) angle φ to the direction of location of the main minima, the separated valleys will be also lowered (similarly to Baranskii, Kolomoets), as a result of which under a certain pressure, $X = X_{\text{sat}}$, all the free carriers will be in these valleys. Now, in the case where a sample which is cut out as shown in Figure 1a is applied to an electric field $E_l \,||\, X$, the processes connected with the passage of current within this sample are to be considered from the standpoint of an anisotropic single-ellipsoid crystal the electrical conductivity of which is described by the second-rank tensor (Denis). Due to this, an electrical field E_t will appear in the direction perpendicular to E_l, the magnitude of which is determined from the following expression:

$$E_t = (K - 1) \sin\varphi \cdot \cos\varphi (K \cos^2\varphi + \sin^2\varphi)^{-1} \cdot E_l \,. \tag{1}$$

Thus, by measuring E_l and E_t with $X \geqq X_{\text{sat}}$, the value of K can be determined:

$$K = 1 + E_t \cdot (E_l \cdot \sin\varphi \cdot \cos\varphi - E_t \cdot \cos^2\varphi)^{-1} \,. \tag{2}$$

The errors with such determination of K are mainly associated with the accuracy of determining the angle φ and the value of E_t. The modern X-ray methods allow to determine the magnitude of φ with an accuracy of 1 to 5 minutes; therefore the disorientation of a sample is determined only by the care of its preparation. As for the accuracy of determining the value of E_t, a great error can be introduced in this case by the non-equipotentiality of the transverse contacts of a sample (Fig. 1b), as a result

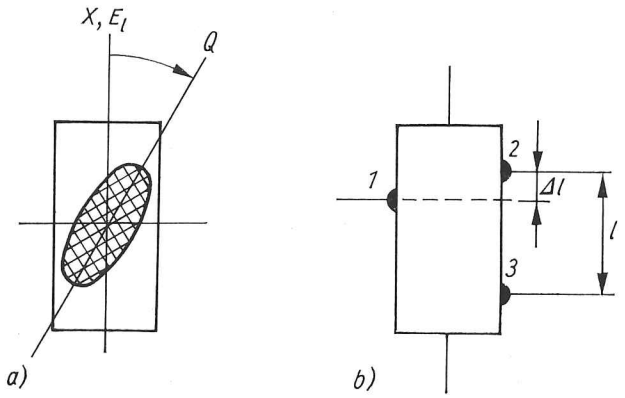

Fig. 1. a) Sample orientation in measuring K (Q is direction along which main minima of crystal are located; $X \parallel E_1$ is direction along which sample is cut out, and deformation and electric field are applied); b) Schematic representation of location of contacts during measurements (see explanations in text)

of which a measuring, apart from the transverse potential difference, $E_t \cdot d$ (d is the distance between the transverse contacts 1, 2), associated with the anisotropy of electrical conductivity, also contains a component of a longitudinal electrical field $\Delta E_l : E_\perp = E_t + \Delta E_l$.

However, the magnitude of ΔE_l (if a sample may be considered to be uniform) is completely determined by the ratio $\Delta l/l$ and is $\Delta E_l = \Delta l/l\,(E_l)$. The value of E_l is determined from a ratio of potential difference measured across the contacts 2, 3, to the distance l between these contacts (Δl is the non-equipotentiality of contacts). Upon determining the values of $\Delta l/l = \Delta E_l/E_l|_{X=0}$ which remains constant under all the values of X and E_l. Then the value of E_t for $X \geqq X_{sat}$ is found from the following expression:

$$E_t = E_\perp - \frac{\Delta l}{l} E_l \,. \tag{3}$$

With the use of the proposed procedure we have determined the values of K for several Ge and Si samples at a temperature of 77 K and $\varphi =$ (20 to 25°). The following table demonstrates the results of these measurements, which are compared with the K values obtained for the same crystals by the procedure described by Baranskii and Kolomoets.

Ge		Si	
Method (Baranskii)	present method	method (Baranskii)	present method
15.0 ± 0.3	15.1 ± 0.6	5.85 ± 0.1	5.84 ± 0.3

It can be seen from the foregoing table that the correlation between the results obtained by different methods is rather well.

It should be taken into account that in semiconductor crystals in which shear strains, used in the proposed procedure, result in a change of interaction between main and subsidiary extremes of the conduction band (which can result in different changes of longitudinal $m^*_\parallel$ and transversal $m^*_\perp$ effective masses of electrons) (Bir, Pikus), the values of K which are obtained by other methods (since the ratios $m^*_\parallel/m^*_\perp$ in

our and other instants can be different). To avoid this undesirable effect, it is necessary to choose such orientation of a sample in which the shear strain would not change the effective mass of electrons as a result of mutual compensation. For example, for GaP (as well as for Si), the sample should be cut out at an angle φ to the direction [100] in the plane (001).

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