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INVESTIGATION OF PHOTOELECTRIC WORK FUNCTION IN GaAs *n*-TYPE MONOCRYSTALS

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Photoemission of electrons from (111) and (110) surfaces of *n*-type GaAs was studied. The current-voltage characteristics were measured when samples were subjected to the illumination of incident photon energy, $h\nu$, from 4.89 to 5.80 eV. The photoelectric work function, φ_{ph}, increases lineary with $h\nu$ for both types of surfaces. It was found that $\varphi_{\text{ph}}^{(111)}$ increases quicker than $\varphi_{\text{ph}}^{(110)}$.

The photoemission measurements on GaAs single crystals were made for energies of incident photons from 4.89 to 5.80 eV. Current-voltage characteristics were obtained for monochromatic radiation by a retarding potential method, in a spherical glass capacitor, whose inner surface was covered with aquadag. The samples were cut out from a single crystal of GaAs, produced in Czekoslovakia (Metalimex Praha). The samples had the *n*-type conduction with the electron concentration from 4.3 to 5.2×10^{17} cm^{-3}, at room temperature. Polyhedral specimens were first cut out from the ingot, and then the planes (111) and (110) were exposed by a stepwise lapping and X-ray orientation. The samples were etched immediately before being placed in the capacitor. 5 to 15 current-voltage characteristics were obtained for each plane orientation and for each wave length listed in Table I. The reproducibility

TABLE I

The mean values of the photoelectric work function, φ_{ph}, for the (111) and (110) orientations GaAs single crystals

$h\nu$ (eV)	$\varphi(110)$ (eV)	$\varphi(111)$ (eV)
4.89	4.10	4.36
4.99	4.18	4.45
5.16		4.59
5.28	4.37	4.69
5.41		4.80
5.8	4.76	5.13

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of the results was very good. The ends of curves showing the dependence of the current on the retarding potential coincided within ±0.02 eV. The values of the photoemission work function, φ_{ph}, presented in Table I were averaged over the all taken characteristics. The results are presented in the Figures 1 and 2 and in the Table I. Photoelectric measurements on GaAs were also made by Haneman [1], Arseneva-Geyl and Van Bau-Kun [2], and recently by Gobeli and Allen [3], who also gave a comparative study on several well-known semiconductors. Arseneva-Geyl and Van Bau-Kun studied the dependence of φ_{ph} on $h\nu$ on lapped and polished surfaces of polycrystalline GaAs, consisting of several large monocrystals.

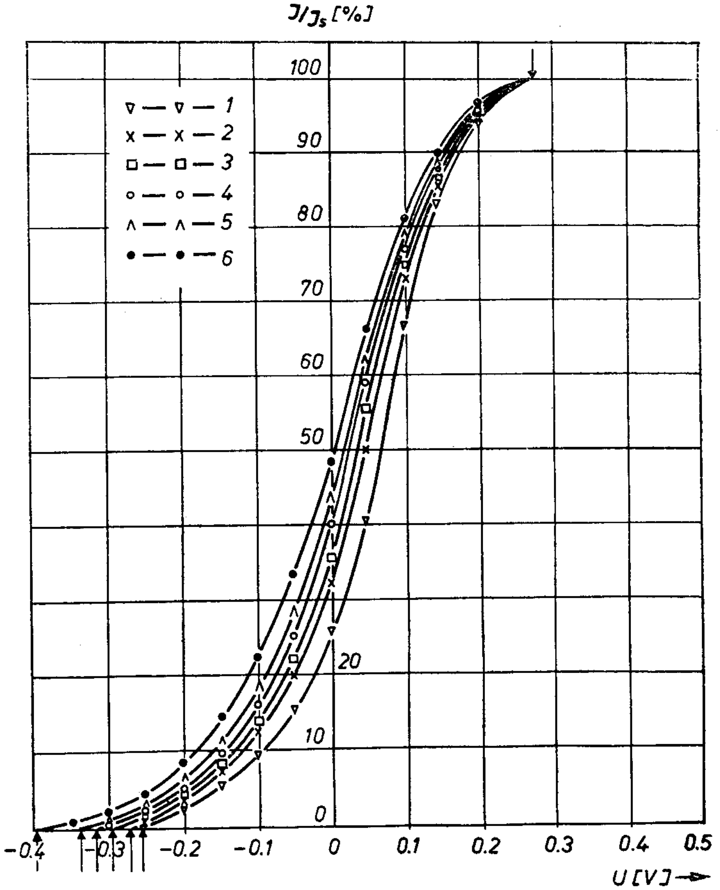

Fig. 1. Current-voltage characteristics on the n-type sample of GaAs for the following energies of incident photons: *1* — 4.89 eV, *2* — 4.99 eV, *3* — 5.16 eV, *4* — 5.28 eV, *5* — 5.41 eV, *6* — 5.8 eV

In the work presented here it has been found that *1*) The values of $\varphi_{\mathrm{hp}}^{(111)}$ and $\varphi_{\mathrm{ph}}^{(110)}$ differ by the amount that is significantly larger than the experimental error. *2*) φ_{ph} is a linear function of $h\nu$ for both (111) and (110) planes. As one can readily see from Fig. 1, the linearity of the $\varphi(^{111)}_{\mathrm{ph}}$ is particularly good. Also the energy difference between the Fermi level and the

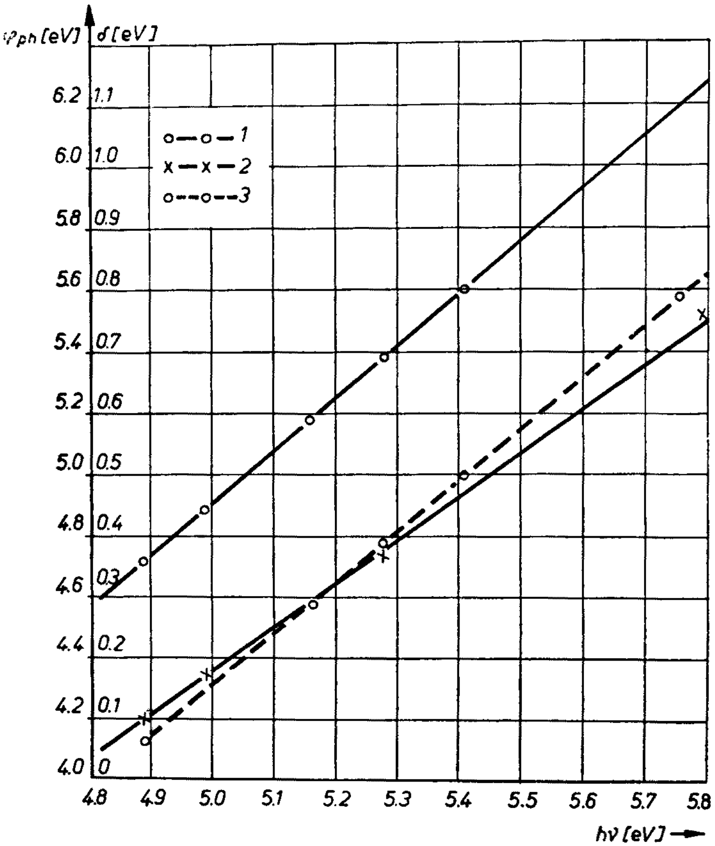

Fig. 2. The photoelectric work function: *1* — $\varphi_{ph}(111)$, *2* — $\varphi_{ph}(111)$, and *3* — $\delta(111)$ as functions of the photon energy. δ defined in text

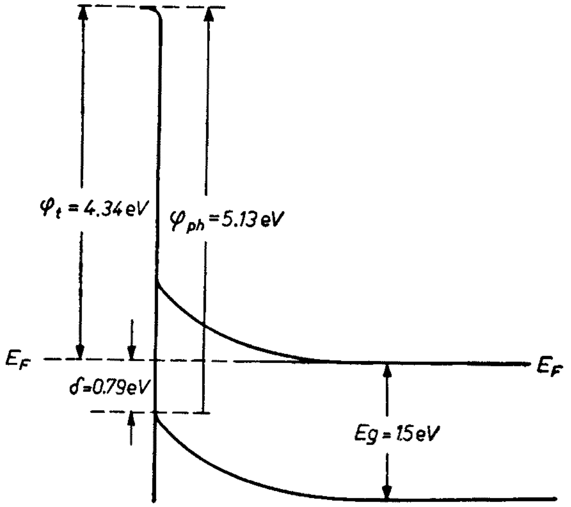

Fig. 3. The model of deflection of the energy bands for the (111) face of *n*-type GaAs. The numerical values obtained from measurements for the photon energy of 5.8 eV

level from which the electrons are excited, δ, is a linear function of $h\nu$. The value of $\delta^{(111)}$ changes from 0.06 to 0.79 eV for $h\nu$ changing from 4.89 to 5.80 eV. This indicates that the thermoelectric work function stays constant. The comparison of results from papers [1], [2] and [3] with our results is given in Table II. For $h\nu = 5.80$ eV the values of φ_{ph} obtained in [2] ans δ obtained by Gobeli and Allen agree with ours. The slopes of the functions $\varphi_{\mathrm{ph}} = \varphi_{\mathrm{ph}}(h\nu)$ expressed as their derivatives, were calculated for our results and results of Arseneva and Wan Bau-Kun. These results are presented in Table II. It is readily seen that the slope of φ_{ph} depends on the type of the surface. The model of the surface deflection of the energy bands is proposed for the (111) plane and is presented in Fig. 3. The bent is typical for the n-type GaAs. The model involves the assumption [4] that the position of the Fermi level in the bulk coincides with the bottom of the conductivity band and that the energy gap, $E_g = 1.5$ eV.

TABLE II

Comparison of the photoelectric data for GaAs

$h\nu$ (eV)	φ_{ph} (eV)	δ (eV)	$\mathrm{tg}\,\alpha = \frac{\Delta\varphi}{\Delta(h\nu)}$	Author
5.8	$\varphi(110) = 4.70$*	$\simeq 0.3$		Haneman [1]
	4.48—4.64	0.5	0.45	Arseneva-Geyl and Wan Bau-Kun [2]
	$\varphi(111) = 5.13$ $\varphi(110) = 4.66$	0.79 0.84	0.85 0.71	Present work
5.75 ($h\nu_{d_1}$)	5.47	0.76		Gobeli and Allen [3]

* The φ_{ph} values have been determined with the accuracy ± 0.05 eV by the all afore mentioned authors.

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