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DIFFUSION LENGTH STUDIES IN CdMnTe BY THE SURFACE PHOTOVOLTAGE METHOD*

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The surface phototovoltage method provides a nondestructive means of measuring minority carriers diffusion length and is suitable for process control applications and for material acceptance tests. Application of the method in the case of CdMnTe compounds has been studied in the present paper. The optimum measurement conditions have been investigated by studying the dependence of measured diffusion length on the experimental conditions. As the surface photovoltage method requires the exact values of absorption coefficient as a function of wavelength , $\alpha = f(\lambda)$, the dependence has been determined. The minority carrier diffusion length for the sample investigated has been found to be equal to several tenth of μm.

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The surface photovoltage is the change in the surface barrier height, ΔV_{sp}, produced by illumination of the free semiconductor surface. If the low injection condition is fulfilled, (i.e. when $\Delta V_{\mathrm{sp}} < kT/2e = 12$ meV at $T = 300$ K [1]), the surface photovoltage, ΔV_{sp}, is the monotonic function of the excess carrier density injected at the surface [2] $\Delta V_{\mathrm{sp}} = f(\Delta n)$. Having neglected multiple reflections, it can be shown [2] that

$$\Delta n = \frac{\eta I_0(1-R)\alpha L_D}{(D/L_D + s)(1+\alpha L_D)},$$

where η is the quantum efficiency, I_0 — light intensity, R — reflection coefficient, D — minority carrier diffusion coefficient, s — surface recombination velocity, α — optical absorption coefficient, L_D — minority carrier diffusion length. If we also neglect small variations of η and R with wavelength, λ, and assume that $d \gg L_D$, $d > \alpha^{-1}$, $t \ll L_D$ (where d is the sample thickness and t is the space charge layer

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thickness), then the incident light intensity I_0 required to produce constant ΔV_{sp} is a linear function of the reciprocal absorption coefficient, α^{-1}:

$$I_0 \approx c(\alpha^{-1} + L_D),$$

where c is a constant, independent of λ. The linear plot of $I_0 = f(\alpha^{-1})$ is then extrapolated to zero light intensity and negative intercept value is the effective minority carrier diffusion length L_D.

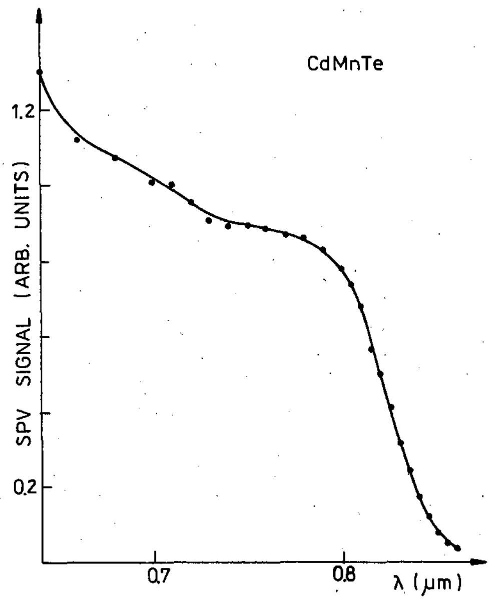

Fig. 1. Spectral characteristic of surface photovoltage, $\Delta V_{sp} = f(\lambda)$ for a wide-gap ($E_g = 1.47$ eV at 300 K) CdMnTe.

The p-type CdMnTe samples (with energy gap $E_g = 1.47$ eV at $T = 300$ K) were purchased from IF PAN Warsaw. The surface photovoltage measurements were performed as follows. Monochromatic light chopped with 12 Hz frequency illuminated surface of the specimen capacitatively coupled into the phase sensitive lock-in amplifier. Figure 1 shows spectral dependence of ΔV_{sp} for the samples studied. Simultanously, the intensity of the light incident on the sample was measured by a thermocouple: $I_0 = \lambda V_{th}$, where V_{th} is the voltage read from another lock-in connected with the thermocouple. Light intensity was adjusted to produce the same ΔV_{sp} value within measured λ range by varying the stabilized d.c. voltage applied to the lamp. The measurements of $\alpha = f(\lambda)$ were carried out also. Results are given in the Table.

TABLE

Optical absorption coefficient of CdMnTe at 300 K ($E_g = 1.47$ eV).

λ (μm)	.810	.815	.820	.825	.830	.835	.840	.845	.850	.855
α (cm^{-1})	625	483	400	339	266	193	161	112	104	54.8

The results of the experiment plotted on the I_0 versus α^{-1} graph, with ΔV_{sp} as a parameter, are shown in Fig. 2. The value of minority carrier diffusion length, read off as a negative intercept of zero light intensity with α^{-1} axis, is equal to $L_D = 26$ μm, independent of the value of ΔV_{sp} adjusted. However increasing departure from linearity with increasing ΔV_{sp} for higher value of λ is observed. This can be due to the fact that in this case, assumption $l > \alpha^{-1}$ is no longer valid and the surface photovoltage at the back face becomes significant (similar results were reported in [3]).

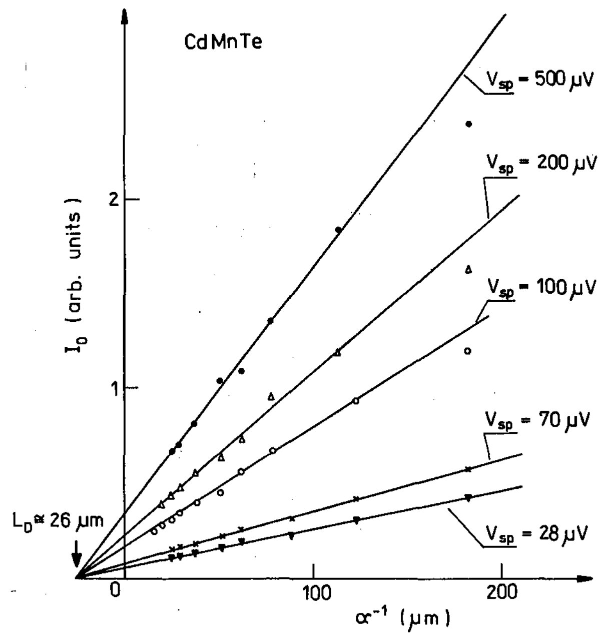

Fig. 2. Light intensity I_0 versus reciprocal of absorption coefficient α^{-1} with surface photovoltage ΔV_{sp} as a parameter for a wide-gap ($E_g = 1.47$ eV at 300 K) CdMnTe. Sample thickness $d = 290$ μm.

We also observed that scattered light and decrease of aperture affect the $I_0 = f(\alpha^{-1})$ linearity. In the latter case, the condition of low injection is probably not fulfilled.

In the present paper we have shown the applicability of surface photovoltage method to determine minority carrier diffusion length in wide-gap CdMnTe compound. The value of L_D was found to be equal to 26 μm, for the samples investigated.

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