acta phys. slov. 34, (1984), No. 1

SOME ELECTRICAL AND PHOTOVOLTAIC PROPERTIES OF A GRAPHITE—InSe METAL-SEMICONDUCTOR CONTACT

О НЕКОТОРЫХ ЭЛЕКТРИЧЕСКИХ И ФОТОГАЛЬВАНИЧЕСКИХ СВОЙСТВАХ КОНТАКТОВ ГРАФИТ—InSe И МЕТАЛЛ-ПОЛУПРОВОДНИК

M. PERŠIN[1]), B. PIVAC[1]), N. URLI[1]), Zagreb

Electrical and photovoltaic properties of a metal-semiconductor contact between graphite and an n-type layer semiconductor InSe are studied. The contact shows rectifying behaviour; its d. c. current-voltage characteristics are measured in the dark and under illumination.

Indium monoselenide is a layered semiconductor, which has been shown to possess photovoltaic properties suitable for solar energy conversion [1—4]. Photovoltaic properties of metal—InSe contacts have been studied with bismuth [1, 3], gold [2] and platinum [4]. In this work a graphite-n-InSe contact was formed simply by coating (painting) freshly cleaved InSe with graphite colloidal paste; its electrical and photovoltaic properties were studied here for the first time.

The InSe compound was prepared by direct synthesis of stoichiometric amounts of high-purity indium (purity 6N) and selenium (purity 5N8) in evacuated and sealed silica tubes at 690 °C. During the preparation molten InSe was cooled in a furnace at a temperature gradient of 0.3 °C/cm. The InSe thus obtained had large single crystal regions with suitable cleavage properties [5]. All these samples were of the n-type electrical conductivity. The metal-semiconductor contact with graphite was not formed in a classical way, for instance by vacuum thermal evaporation, but by coating (painting) freshly cleaved InSe platelets about 50—100 μm thick with graphite colloidal paste — aquadag colloidal graphite in water (Acheson Colloiden B. V., Scheemde Holland). The thickness of the graphite layer was about 500 nm, and its transmittancy was 0.10.

Soldered indium proved to be a good ohmic contact to InSe. The graphite—InSe contact area was 10^{-5} m^2.

Fig. 1 shows the room-temperature dark J—V characteristic of a graphite-n-InSe contact. The contact exhibits rectifying behaviour and the forward current flows when graphite is biased positively with respect to the semiconductor. The semilogarithmic plot of the forward characteristic drawn in the inset to Fig. 1 shows more clearly the dependence of the current density J on the bias voltage V. This dependence has the form of a current-voltage relation for a Schottky-barrier diode [6]

$$J = J_0[\exp(eV/nkT) - 1]. \qquad (1)$$

Here e is the electron charge, k the Boltzmann constant, T the absolute temperature, n an experimentally determined factor called the diode quality factor and J_0 the saturation current density given by the relation

$$J_0 = A^*T^2[\exp(-e\Phi_{Bn}/kT)] \qquad (2)$$

---

[1]) "Ruder Bošković" Institute, Bijenička c. 54, 41001 ZAGREB, Yugoslavia.

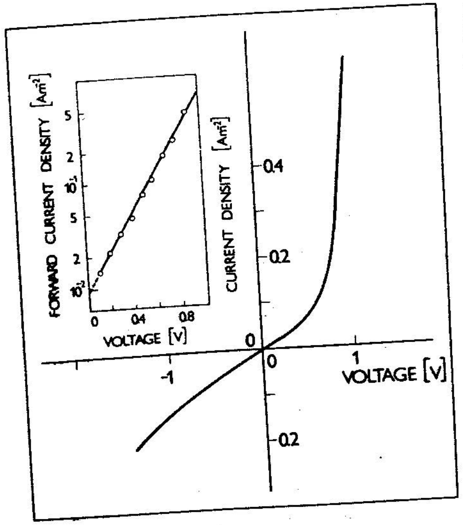

Fig. 1. Current density-voltage characteristic of the graphite-*n*-InSe contact in the dark. The inset shows the semilogarithmic plot in the forward bias region.

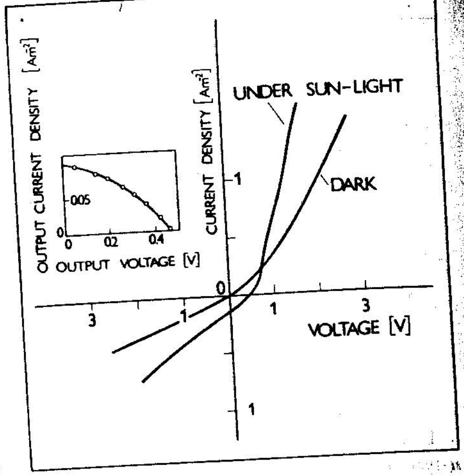

Fig. 2. Current density-voltage characteristic for the graphite-*n*-InSe contact under illumination. The inset shows the output characteristic of the contact under direct sun illumination.

where $e\Phi_{Bm}$ is the barrier height between the metal and the *n*-type semiconductor, and A^* is the effective Richardson constant. The value J_0 derived from Fig. 1 at the zero bias voltage intercept was found to be 9×10^{-3} Am^{-2}. The barrier height $e\Phi_{Bm}$ from rel. (2) was found to be 0.78 eV, whereas A^* was taken as 1.2×10^6 Am^{-2} K^{-2}. The diode quality factor *n* calculated from the slope of the log *J* vs *V* curve was 8.1. This high value of factor *n* indicates presumably the presence of a thin oxide layer at the interface of the metal-semiconductor contact [7].

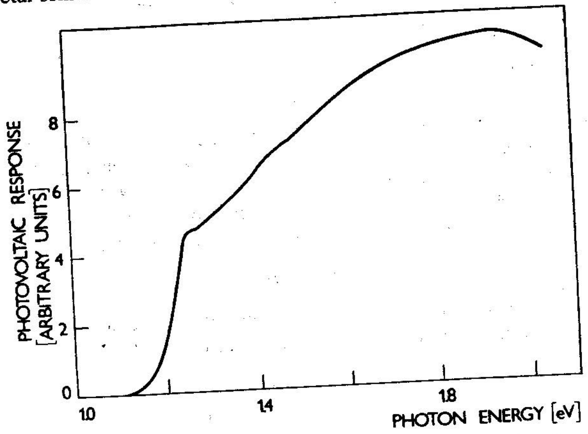

Fig. 3. The spectral response of the open-circuit voltage V_{oc} of the graphite-*n*-InSe contact.

Fig. 2 shows a typical *J*—*V* characteristic of a graphite -*n*-InSe contact when graphite was illuminated with direct sunlight (flux ≈ 300 Wm^{-2}) and when it was in the dark. The inset to Fig. 2 shows the output current density-voltage characteristic under approximately equal sunlight illumination. The open-circuit voltage V_{oc} was equal to 0.450 V, while the short-circuit current density J_{sc} was 0.1 Am^{-2}. The fill factor of ≈ 30 % was determined from this figure. The conversion efficiency is about 0.01 %.

A representative photovoltaic response between 1 and 2 eV of a graphite-*n*-InSe contact at constant photon flux is shown in Fig. 3. The response increases abruptly at 1.2 eV, corresponding to the optical gap energy of InSe. The evolution of the spectrum between 1.2 and 2.0 eV is representative of the absorption coefficient of InSe which increases from 10^5 m^{-1} at the gap to over 10^6 m^{-1} at 2.3 eV [4].

Although at this moment the conversion efficiency of the samples is low, it can be improved by choosing optimum thickness of InSe crystals [4], by increasing the transmittancy of the graphite layer, which was very low in the present case, and by applying a grid contact.

REFERENCES

[1] Segura, A., Besson, J. M.: Il Nuovo Cim. *38 B* (1977), 345.
[2] Clemen, C., Saldana, X. I., Munz, P., Bucher, E.: Phys. Stat. Sol. *(a) 49* (1978), 437.
[3] Segura, A., Guesdon, J. P., Besson, J. M., Chevy, A.: Rev. Phys. Appl. *14* (1979), 253.
[4] Segura, A., Chevy, A., Guesdon, J. P., Besson, J. M.: Solar Energy Materials *2* (1979/1980), 159.
[5] Čelustka, B., Peršin, A., Bidjin, D.: Fizika *2* (1970), 137.
[6] Rhoderick, E. H.: *Metal Semiconductor Contacts.* Clarendon. Oxford 1978.
[7] Card, H. C., Rhoderick, E. H.: J. Phys. D: Appl. Phys. 4 (1971), 1602.

Received December 22th, 1982