Short Communication

Schottky diodes based on poly(*p*-phenylene) and poly(1,4-dipyrrolobenzene)

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Abstract

Current–voltage characteristics of a sandwich-type device based on poly(*p*-phenylene) and poly(1,4-dipyrrolobenzene) films are investigated. The characteristics depend on the type of polymer and on the sample conductivity. Poly(*p*-phenylene) with a conductivity 10^{-3}–10^{-5} S/cm yields Schottky-type junctions with In and Pb. The device parameters are evaluated from current–voltage characteristics.

Introduction

Organic semiconductors have attracted much interest due to their possible application as basic materials in molecular microelectronic devices, such as diodes, transistors, sensors, etc. (see, e.g. [1–3]).

In particular organic polymers can be potentially used as semiconductive materials in solar cells [1–4]; they may be produced on the basis of a Schottky barrier diode between semiconductors and various metals having an appropriate work function. Such devices were initially constructed using thin films of *trans*-polyacetylene, polythiophene or polypyrrole [5, 6]. Recently, we have reported [7] the fabrication of a Schottky barrier on the basis of a sandwich-type element Pt/poly(*p*-phenylene)/In. Free poly(*p*-phenylene) (PPP) films were synthesized by benzene electropolymerization (EP) on a Ti electrode.

In this work we report the studies on Schottky barriers involving poly(1,4-dipyrrolobenzene) (PDPB) and PPP synthesized by EP of biphenyl.

Experimental

PPP films were obtained by the EP of biphenyl in CH_2Cl_2–Bu_4NBF_4–oleum solution on a Pt electrode at a constant current of 1 mA/cm^2 similar to

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of the secondary electrons from an organic semiconductor. This phenomenon was not observed for PPP films with a considerably lower conductivity.

Semilogarithmic plots of the forward current densities versus forward voltage for PDPB, PPP-I and PPP-II elements are presented in Fig. 2(a). The above *I–U* characteristics for PPP-I and PPP-II diodes have an exponential dependence following eqn. (1) up to $U_F = 1$ V, while that of PDPB have this dependence only up to about 0.6 V. This indicates that device resistances of PPP-I and PPP-II (unlike PDPB) are not higher than the combination of a polymer bulk resistance, a barrier In or Pb electrode sheet resistance due to the back-ohmic contact.

From the extrapolation of the linear part of the plots to zero bias voltage, the saturation current values I_0^F and the quality factor n for all these devices were estimated (Table 1). Note, that the quality factor n, determined from eqn. (1), is essentially higher than unity, whereas this value for the ideal diode must be equal to unity. Using the value of $A = 120$ A/(K^2 cm^2), the barrier heights were determined at room temperature from eqn. (2) (see Table 1).

In order to specify the saturation current density I_0, the semilogarithmic plot of the reverse current density versus reverse voltage was used. Figure 2(b) shows the semilogarithmic plots of reverse current densities versus $(U_C\text{-}U_R)^{0.25}$. Using the theoretical value $U_C = 1.48$ V for PPP [11] and extrapolating the plots to zero bias voltage, the saturation current density values I_0^R were

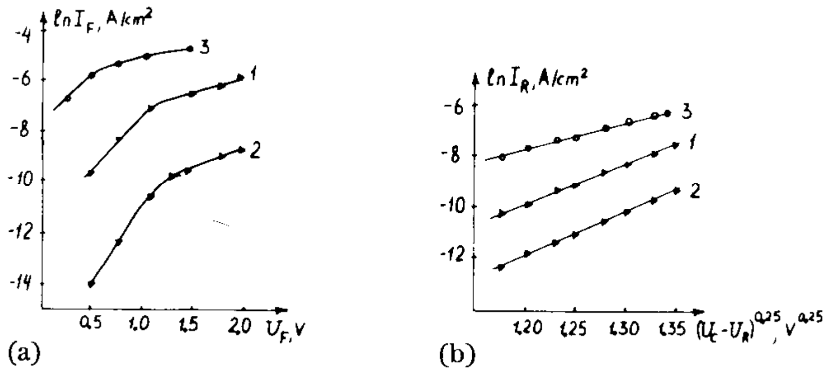

Fig. 2. Semilogarithmic plots of current density vs. (a) U_F and (b) $(U_C\text{-}U_R)^{0.25}$ for (1) Pt/PPP/In, (2) Pt/PPP/Pb and (3) Pt/PDPB/In devices.

TABLE 1

Saturation current density I_0, barrier height Φ_B and quality factor n for devices based on PPP and PDPB films

Sample	I_0^F (A/cm^2)[a]	I_0^R (A/cm^2)[a]	Φ_B (eV)	n
PDPB	5.0×10^{-4}	2.2×10^{-4}	0.61	8.4
PPP-I	0.78×10^{-5}	1.0×10^{-5}	0.70	8.6
PPP-II	0.68×10^{-7}	2.8×10^{-7}	0.82	7.1

[a] I_0^F and I_0^R values were determined using the data of Fig. 2(a) and 2(b), respectively.

estimated from the following relationship [10]:

$$\ln I_0^R = K_S(U_C - U_R)^{0.25} \quad (3)$$

where K_S is the coefficient, U_C and U_R are the contact and reverse potentials, respectively (Table 1). The values of I_0^R and I_0^F for all devices do not differ greatly. This fact demonstrates that the interpretation of the data obtained is coherent with the classical one for the Schottky barriers.

Conclusions

It has been observed that the constructed diodes have asymmetrical, strongly non-ohmic characteristics. The devices constructed with the PPP films have better characteristics because biphenyl was used as a monomer.

The experimental data enable further development of Schottky elements by varying the polymers and synthetic conditions. Further improvements of the Schottky device characteristics can be achieved by the use of thinner PPP films of higher quality with intermediate conductivity values.

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