PACS 72.80.-r

L.I.Fenenko[1], M. Kuzma[2], L.P.Pochekaylova[1], P.S. Smertenko[1], G.A.Sukach[1], S.V. Svechnikov[1]

Peculiarities of transport mechanism of stretched polyaniline in temperature range from 100 K to 350 K

[1] Institute of Semiconductors Physics, NASU, prospekt Nauki, 45, 03028 Kyiv, Ukraine
[2] Institute of Physics, Higher Pedagogical School, Rejtana, 16a, 35-309 Rzeszow, Poland

I-V and σ-T characteristics and conductivity versus applied shift dependences of In-PANI-In structures with emeraldine was investigated. The temperature characteristics had constant slope in the range from 160 K to 250 K under various voltages. This determined the activation energy of about 0.23 eV. The behaviour $I \sim V^{5/4}$ was recognized, which can be evidence of the hopping conductivity. The anomalous effect of conductivity enhance with stretch encrease at low voltages is conditioned by the prevalence of increase of cross part of conductivity over decrease of longitudinal one at hopping conductivity.

Keywords: Polyaniline; Transport mechanism; I-V characteristic; Differential treatment.

Стаття поступила до редакції 17.09.2000; прийнята до друку 3.11.2000

I. Introduction

The investigation of properties of electroconducting polyaniline (PANI) are intensive up to date [1,2]. In spite of achievments in this field there is the interest yet to research the electrophysical phenomena including perculiarities of conductivity in structures on the base of electroconducting polimers in general [3,4] and polyaniline in particular [5,6]. One of the methods for conditions changing for charge flow is the stretching both during sample preparation and after one [7,8]. The goal of the present paper is to investigate the perculiarities of charge flow in the In-PANI-In structures by the differential approach [9,10].

II. Experimental

Emeraldine polyaniline has been deposided on the microporous nylon-6 membranes by the standard technique and has been doped in HClO . The In contacts have been thermically deposited in vacuum. The intercontact length was 1.5 mm. The steady state I-V and temperature characteristics of In-PANI-In structures were measured using the automatizated tester 14 TCS-100 and processed by the differential method [9]. This method is based on the determination of dimensionless differential slope, $\alpha = d(\lg y)/d(\lg x)$, of the theoretical or experimental characteristics under investigation. With such definition a range of constancy of the α(x) corresponds to the part of y-x dependencies characterized by the power behavior $(y \sim x_{\alpha})$.

III. Results and discussion

The I-Vcharacteristics of In-PANI-In structures under investigation and differential slope of some of them are shown in Fig. 1.

The temperature dependence of conductivity

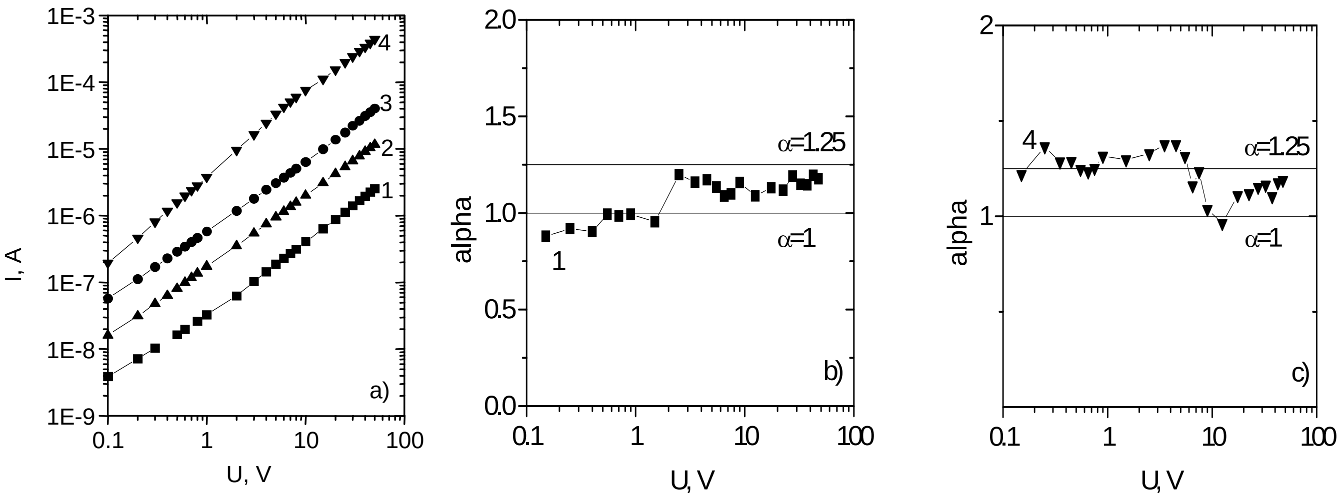

Fig.1. I-V characteristics of In-PANI-In structure at various temperatures: 1 - 153 K; 2 – 184 K; 3 – 240 K; 4 - 294 K (a) and differetial slope of 1 (b) and 4 (c) curves.

and conductivity versus shift are shown in Fig. 2. The I-V characteristics have not been changed dramatically (Fig. 1a) and only differential method allowed underline the fine changing of curves behaviour (Figs. 1b,c).

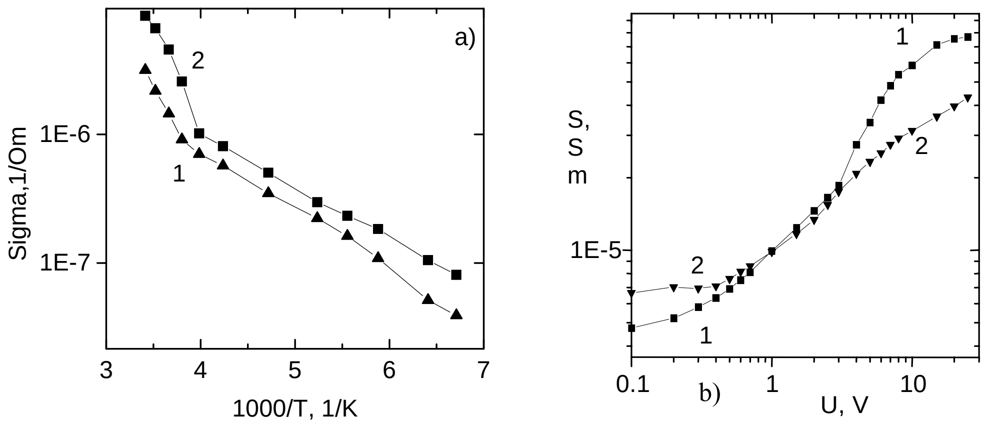

Fig.2. (a) – temperature characteristics of In-P.ANI-In structure at 0.1 V (1) and 50 V (2) and (b) – conductivity versus shift without (1) and with longitudinal stretch 40 % (2).

From Figs. 1b,c we can see characteristic range with α=1.25. Such α value can not be explaned by the bimolecular recombination (R) in the structure, when the minority (n) and majority (p) carriers of charge are equal, another way, $R = \gamma np = \gamma p^2$, where γ is recombination coefficient [10, 11]. Note, that at low temperatures the $I \sim V^{5/4}$ region goes after Ohm's low whereas at room temperatures it dominates in all bias range. This evidences about carriers injection promotion with increase of temperature. While the injection behaviour entirely differs from one in crystalline solid state [12].

To clearify the transport mechanism in structures under investigation temperature characteristics and effect of strengh were used. Fig. 3 represents the differential slope of temperature characteristics for low and high biases. One can see hat the temperature characteristics both in the case of V=0.1 V and V=50 V (Fig. 2a, Figs. 3a,b) have constant slope in the range from 160 K to 250 K. This gives the activation energy of about 0.23 eV. Approximation of this range (σ~exp[-(1000/T)], line 3) does not be changed with biasis. In our opinion the results of Fig. 3 are more close to intersoliton hopping [12] which predicted the steady state conductivity on temperature in the form $\sigma \sim T^{\alpha}$, where α~13. In Fig. 3c we have α~11⊕2. S.Kivelson noted [13] that temperature dependence of steady state conductivity can be described good both by $\sigma \sim T^{\alpha}$ and $\sigma \sim \sigma_0 \exp[-(T_0/T)^{1/4}]$. Last approximation appropriate to the hopping model with changeable length between states localized in the forbidden gap. Really, from Figs. 3a,c and 3b,d one can see that both approximations can describe experimental $\alpha(1/T)$.

The unusual stretch-independent behaviour of conductivity has been recognised at middle voltages range of 1 V ... 4 V under stretching (see Fig. 2b) whereas at higher voltages the conductivity was decreased under stretching as

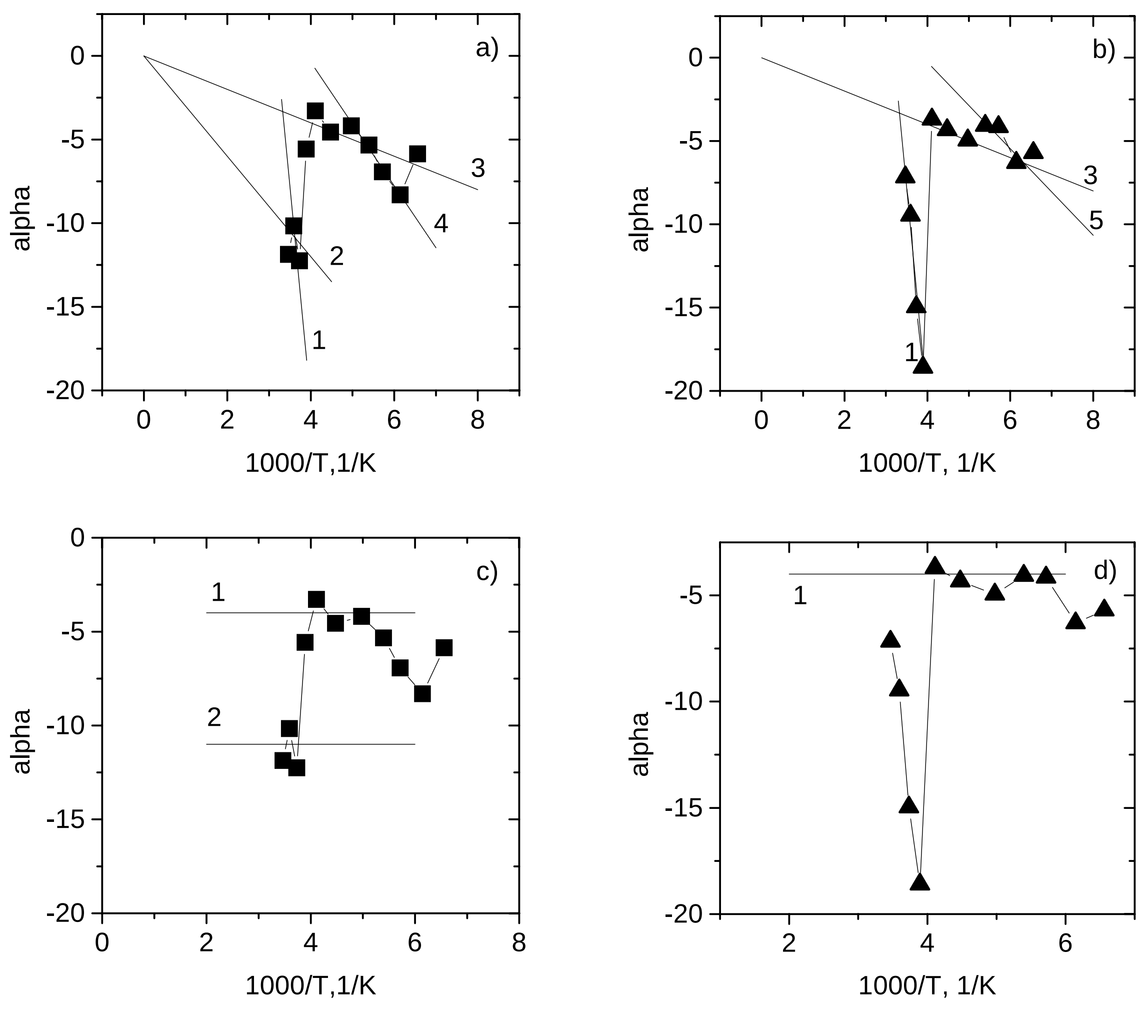

Fig.3. Approximation of the differential slope $\alpha(1/T)$ of temperature characteristic for In-PANI-In structure at 0.1 V (a,c) and 50 V (b,d) in the form:
For (a), (b): -26(1000/T-3.2) (line 1); -(3000/T) (line 2); -(1000/T) (line 3); -3.7(1000/T-3.9) (line 4); -2.6(1000/T-3.9) (line 5) and
for (c), (d): $-(1000/T)^{-4}$ (line 1); $-(1000/T)^{-11}$ (line 2).

usually. At lower voltages the conductivity was increased under stretching. The equation for mobility μ can be written as

$$\mu = fa^2 eN(kt)^2 \exp(-E_S / kT) / h^3 \omega^2,$$

where f is avarage corner between hopping direction and electric field vector, a is intermolecular length, N_S is quantity of neighbouring next molecula, ω is frequency of activation complex vibration, E_S is barrier energy. In this case the cross part of conductivity prevails the decrease of longitudinal one at hopping conductivity.

IV. Conclusion

The investigation of I-V and temperature characteristics and conductivity versus applied shift dependences in In-PANI-In structure have been shown that the regime of hopping conductivity with $I^{5/4}$ takes place. The anomalous effect of conductivity enhance with stretch encrease at low voltages is conditioned by the prevalence of increase of cross part of conductivity over decrease of longitudinal one at hopping conductivity. The activation energy of about 0.23 eV was determined.

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Л.І.Фененко[1], М.Кузьма[2], Л.П.Почекайлова[1], П.С.Смертенко[1], Г.О.Сукач[1], С.В.Свєчніков[1]

[1] *Інститут фізики напівпровідників НАН України, пр. Науки, 45, 03028 Київ, Україна*
[2] *Інститут фізики, Вища педагогічна школа, Рейтана, 16а, 35-309 Ржешів, Польща*

Особливості механізмів переносу в поздовжньому поліаніліні в диапазоні температур від100K до 350K

Досліджено вольт-амперні та температурні характеристики, а також провідність в залежності від прикладеної напруги структур In-PANI-In із емеральдиновим поліаналіном. Температурні характеристики мали постійний нахил в діапазоні температур від 160 K до 250 K при різних прикладених напругах. Це обумовлено величиною енергії активації 0.23 еВ. Визначена залежність $I \sim V^{5/4}$, яка може бути пов'язана із стрибковою провідністю. Аномальна поведінка зростання провідності із збільшенням розтягування при низьких напругах обумовлена переваженням підвищення поперечної складової провідності над поздовжньою при стрибковій провідності.