International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization on TPE (IOTPE)

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

September 2010 | Issue 4 | Volume 2 | Number 3 | Pages 79-81

ELECTRIC PROPERTIES OF THIN FILM COMPOSITES ON THE BASIS OF SILICON AND POLYVINILDENFTORYDE

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Abstract- In this paper volt-ampere characteristics and electroconductivity of the composites on the basis of silicon and polivinildenftoryde have been investigated. Values of concentration of the ionized centres, length of free run of charge carriers, value of coefficient of Frenkel, and also the form of potential holes have been defined.

Keywords: Composite Materials, Polymer, Semiconductor, Barrier.

I. INTRODUCTION

The synthesis of composite materials based on polymers and fillers with special electrophysical properties, to a considerable extent, depends on the condition of synthesis technology; on the filler′s nature, on the form dimensions, and the filler′s characteristics, and on degree of interaction between the components.

It should be emphasized that conditions of the crystallization and other factors greatly change a structure of the finished composite components, morphology of the polymer matrix and as a result, composite materials acquire unique properties. In turn it increases their opportunities for practical use. In this connection, there is a special interest in electroactive polymer composite materials such as polymer –metal oxide, polymer - semiconductor, polymer-polymer, polymer-metal fillers and etc. [1-4].

Furthermore, the contact condition, change of the electroactivity and electrophysical properties of a heterogeneous polymer- semiconductor system, and also peculiarities of the interphase interaction still remain insufficiently explored.

This present paper is devoted to the study of the influence of the volume content filler on volt-ampere characteristics, on the electroconductivity, and on the form of the potential holes of composite nonlinear resistors based on polar polymers and single-crystal of silicon.

II. EXPERIMENTAL METHOD AND DISCUSSION OF THE OBTAINED RESULTS

Monocrystalline semiconductor silicon (p-Si) and polar polivinildenftoryd (PVDF) powder were used as the composite components. The composites were prepared from a homogenous mixture of powders by hot pressing at a temperature T=180^{0}C and a pressure P=15 MPa. The content of the composite components was varied in a wide range (10-50% Si and 90-50% for polivinildenftoryd respectively). In order to receive composite resistors, a necessary quantity of a mixture that consists of silicon(C) and polivinildenftoryd (PVDF) is weighed and ground with the dimensions of the particles being less than 60 μm in a porcelain ball mill. The thickness of the samples amounted to 150 μm. Note that, for all the samples the volt-ampere characteristics (CVC) electroconductivity, depending on volume content of the filler (Si), and were studied. These parameters were registered at T=293 K. The experimental results are shown in Figures 1-2.

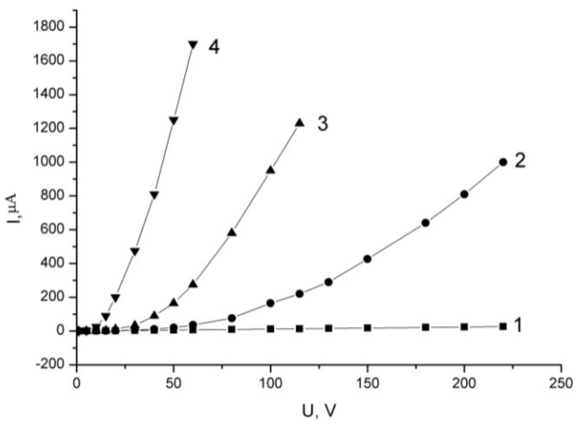

Figure 1. Volt-ampere characteristics of composites with the various maintenance of silicon:
1- 10% Si + 90% PVDF; 2- 30% Si + 70% PVDF;
3- 40% Si + 60% PVDF; 4- 50% Si + 50% PVDF

From Figure 1 the following features of the investigated parameters are evident:

1) For all the samples, the dependence of the value of the resistor's current on the supplied voltage has nonlinear character;
2) The value of the current through the varistor increases by 2-3 orders, namely the volt-ampere characteristics has varistor's character.

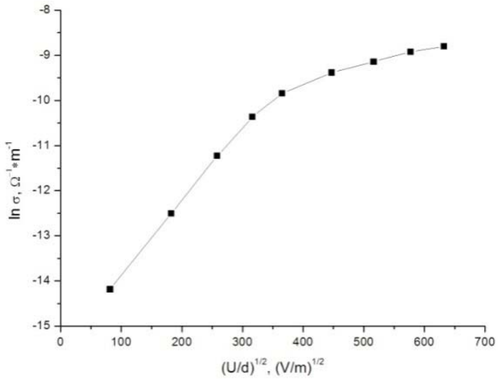

Figure 2. Dependence of the electroconductivity on the electric field in coordinates ln $\sigma \sim \sqrt{V/d}$ at a room temperature for a composite of 50 % Si + 50 % PVDF

From Figure 2, it is seen that, experimental dependence of the electroconductivity, which is observed in the coordinate $\ln\sigma = f\left(V/d\right)$, has much correspondence to the thermo-field ionization theory of Pool-Frenkel [5].

$$\sigma = \sigma_0 \exp(\beta\sqrt{V/d}) \qquad (1)$$

where β is the coefficient of Frenkel, σ_0 is the electroconductivity of a weak electric field, d is the thickness of the sample.

$$\beta = \frac{\sqrt{e^3}}{kT\sqrt{\pi\varepsilon\varepsilon_0}} \qquad (2)$$

e is the charge carrier, ε is the dielectric permeability of the composite, ε_0 is the electrical constant, k is constant Boltzmann, T is the absolute temperature.

The value of the coefficient of Frenkel $\beta = 2.2*10^{-2}(sm/V)^{1/2}$, which is in close agreement with the literary data [6], is given by the dependence's slope $\ln\sigma = f(V/d)$.

According to works [6, 7], minimum value of an electric field, that is corresponded to the beginning of the nonlinear dependence on the supplied voltage, contains information about concentration of the defects responsible for the termofield ionization and conductivity of the composite system.

By minimum values of the electric field E_{kr}, in the presence of which the nonlinear dependence takes place, the concentrations of the ionized centers N_t in the resistors are evaluated by the following formula

$$N_t = \left(2e/kT\beta\sqrt{E_{kr}}\right)^3 \qquad (3)$$

where k is the coefficient of Boltzmann, T is the absolute temperature, E_{kr} is the voltage of an electric field, e is the charge carrier, β is the coefficient of Frenkel.

From Table 1 it is evident that by increasing the filler's content percentage, the value of N_t increases.

Table 1. Relationship between the filler's content percentage and the value of N_t

	U_{kr}, V	$\lambda*10^{-8}$, m	N_t*10^{23}, m^{-3}
30% Si+70% PVDF	13	2.2	1.01
40% Si+60% PVDF	10	1.84	1.7
50% Si+50% PVDF	5	1.52	3.04

The determination of a potential hole's form is very important, for knowing it one can define the spatial distribution of charge carrier nearby an admixture centre or trap (owing to equation of Puasson).

According to works [7, 8], this connection is well described by the formula (4)

$$\phi(x) = -kT\beta/2e\sqrt{E} = -eEx \qquad (4)$$

where

$$x = kT\beta/2e\ 1/\sqrt{E} \qquad (5)$$

Using experimental data obtained by the formulas (4) and (5), for all the investigated composites (Figure 3) the forms of the potential holes - traps have been determined, and this in its turn can allow evaluating the parameters of capture centers of charge carries.

From Figure 3 it is seen that by increasing the current value and filler's content percentage, the height of the potential holes decreases in the studied samples.

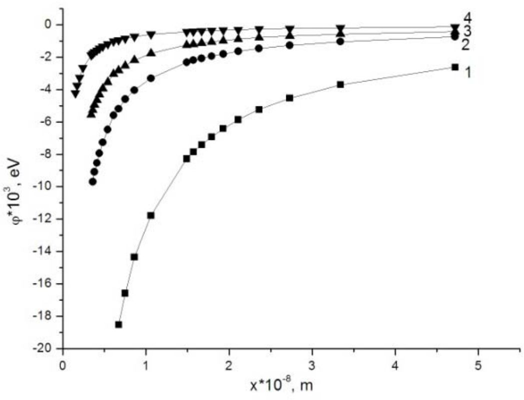

Figure 3. The forms of the potential holes connected with electronic traps for composites. (T=300 K)
1- 10% Si + 90% PVDF; 2- 30% Si + 70% PVDF;
3- 40% Si + 60% PVDF; 4- 50% Si + 50% PVDF

Indeed, the following condition must be carried out for a charge carrie to leave a centre $\varepsilon_e > E_0 - \Delta U$ [8] (where E_0- the depth a level at which a charge carrie become localized, ΔU -the reduction of the potential hole′s height under the influence of current).

Note that it is necessary for a charge carrie to keep its energy before that moment when it will go past the passing point ,and also not to lose its energy by thermal impacts of a crystal lattice.

It can be possible only in those cases when the length of free run of charge carrie is longer than effective dimensions of a potential hole. The length of free run of charge carrie is determined by the formula (6) [8,9].

$$\lambda = \frac{kT\beta}{2e}\frac{1}{\sqrt{E_{cr}}} \qquad (6)$$

As it is seen from Table 1, for all composites the value of the length of free run of a charge carrie decreases when the filler′s content percentage increases.

III. CONCLUSIONS

For all the studied composites the values of concentration of the ionized centres, length of free run of charge carriers, value of coefficient of Frenkel, and also the form of potential holes have been defined.

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BIOGRAPHIES

Arif Hashimov was born in Azerbaijan, 28.09.1949. He graduated from Azerbaijan State Oil Academy in 1971. He was awarded the Diploma (MS) in Electrical Engineering in 1980, Diploma of Candidate of Sciences (Ph.D.) in Kiev, Institute of Electrodynamics of Ukrainian Academy of Sciences in 1993, Diploma of Doctor of Sciences, Kiev, Institute of Electrodynamics of Ukrainian Academy of Sciences. Currently he is the First Vice-President of the Azerbaijan National Academy of Sciences (Baku, Azerbaijan)) and the head of Laboratory of High Voltages Physics and Technology.

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