ВІСНИК ЛЬВІВ. УН-ТУ *VISNYK LVIV UNIV.*
Серія фіз. 2009. Вип. 43. С. 76–80 *Ser. Physics. 2009. Is. 43. P. 76–80*

PACS number(s): 72.80.-r

ELECTRICAL CONDUCTIVITY IN THIN POLYMERIC LAYERS

J. Świątek-Prokop[1], J. Świątek[2], St. Tkaczyk[2], Ł. Laskowski[2]

[1]*Institute of Technical Education*
[2]*Institute of Physics, Jan Długosz University*
al. Armii Krajowej 13/15, Częstochowa, Poland
e-mail: j.swiatek@ajd.czest.pl

The dark electrical conductivity of thin low density polyethylene layers doped with ZnO was investigated. Measurements were performed over the temperature range 40 to 380K. Layers of thickness from 20 to 60 μm were used and current-voltage, current temperature characteristics were obtained. Voltages up to 100 V and Al and Au as electrode materials were used.

The experimental data may be interpreted in terms of space charge effects. The potential barrier around localized states (traps) is lowered by the electric field according to Poole-Frenkel equation.

Key words: polyethylene, electric properties, modification.

The commercial importance of polyolefines is one of the reasons for the attention devoted to all aspects of theirs properties. Especially polyethylene in view of easiness of forming, modificability and trouble-free manufacturing is an interesting material. In recent years polymers are used in nanotechnolgy as the matrix of nanomaterials [1–3] doped with nanoparticles or with the bigger sized particles of metal oxides like ZnO, MgO etc. [4–6]. The electronic industry is interested in thin dielectric layers made from these materials.

ZnO has got a great electroluminescence properties, and inserted into polymeric matrix can be used as luminescent screen. Elasticity and easiness of forming should be characteristic for them.

The purpose of the present paper is to determinate the electrical conductivity of low density polyethylene doped with ZnO.

Low density polyethylene [LDPE], (Malen E, Petrochemia Płock Poland) (solubility parameter δ=15,4 $\cdot 10^3$ $J^{0,5}/m^{1,5}$) was doped with 5g ZnO/100 LDPE.

Compounds were prepared, by means of a micro-mixer (Brabender, Plasti-Corder) at 155°C. The ready made compound was used to form a film by means of Plasti-Corder extruder at 125–130°C. Then, the prepared films were heated in metal moulds at 160°C.

The degree of crystallinity was investigated by WAXS method, thickness of transition layers by SAXS method and are shown in table 1.

Table 1

Degree of crystallinity of LDPE and LDPE/ZnO

Sample	Degree of crystallinity [%]	Magnitude of crystal. area [nm]		Thickness of transition layers [nm]
		$D_{(110)}$	$D_{(200)}$	
LDPE	35,2	19,4	12,2	13,8
LDPE, ZnO	30,0	20,4	12,9	7,2

Using DSC method we observed, that ZnO doesn't change the position of peak of melting of crystalline phase, but decrease heat of phase transition about 1,8 times. The more important influence was observed in the case of the second exothermic transition of LDPE. In the case of LDPE/ZnO, temperature of second phase transition was reduced about 13^o, and heat of phase transition more than twice. The second phase transition is connected with thermooxidizing processes.

Table 2

Results of DSC for LDPE and LDPE/ZnO

Sample	T_{m1} [^{o}C]	ΔH_1 [J/g]	T_{m2} [^{o}C]	ΔH_2 [J/g]
LDPE	107,6	44,39 en	192,3	363,34 eg
LDPE/ZnO	105,8	25,3 en	178,6	179,03 eg

T_{m1} – minimum temperature of melting crystalline phase, ΔH_1 – changing of heat of melting crystalline phase, T_{m2} – maximum temperature of second phase transition, ΔH_2 – changing of heat of second phase transition

Sample preparation method was described in our previous paper [7]. Samples had a sandwich form with Au and Al electrodes. Thickness of an investigated materials changed from 20 to 60 μm. The scheme of measuring system is shown in fig.1

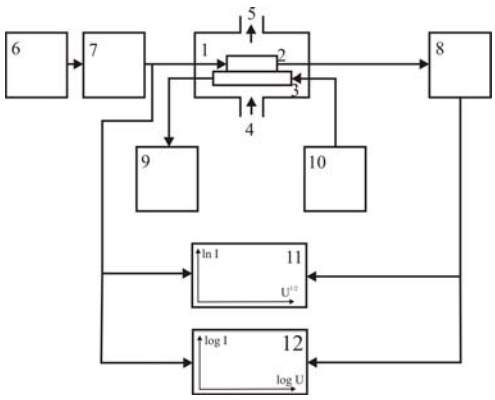

Fig. 1. Experimental set-up for electrical measurements: *1* – cryostat, *2* – sample, *3* – holder, *4* – liquid nitrogen, *5* – vacuum valve, *6* – power supply, *7* – linear rising voltage unit, *8* – electrometer, *9* – temperature-voltage transmitter, *10* – temperature regulator, *11* –logI-U register, *12* – logI-logU register

Measurements of a constant current flowing through the sample were performed over the temperature range 40-380 K. Voltages up to 100 V were used.

Typical current-voltage characteristic for understudying layers on the logarithmic coordinates logI=f(logU) is shown in fig. 2.

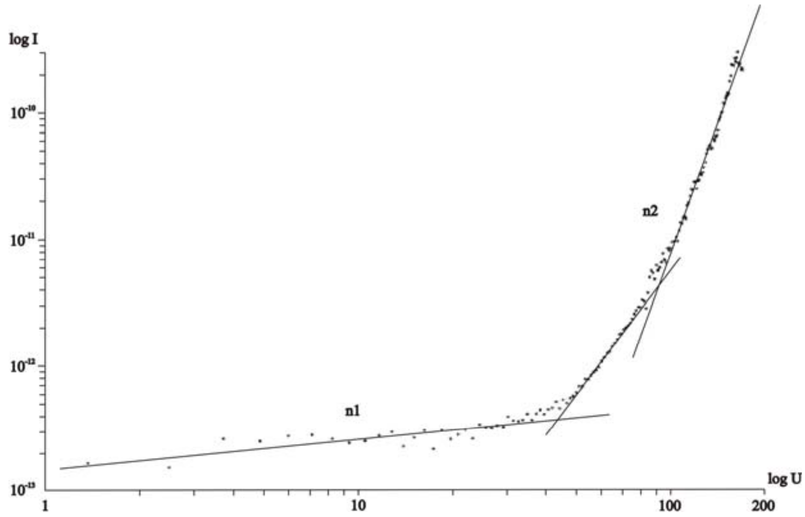

Fig. 2. Current-voltage characteristic for LDPE/ZnO layer thickness of 40 μm at temperature 265 K

As can see up to about 40 V current is weak dependent on electric field (slope of this part characteristic is about $n_1 = 0{,}3$). At higher voltages slope changes between 3 and 5 ($n_2 = 4{,}86$). It enable us to conclude that at higher voltages electrical conductivity is controlled by bulk properties e.g. predominant mechanism of conductivity is Space Charged Limited Current (SCLC). We wanted to obtained also some informations about kind of localized states. At large electric fields and relatively high temperatures the conduction process can be interpreted in terms of the Poole-Frenkel mechanism [8]. In this mechanism "Poole-Frenkel plots" gives a linear dependence of the logarithm of the current the square root of voltage. We obtained this kind of dependence in our experiment (fig. 3).

It may be read as a confirmation that the Poole-Frenkel mechanism is responsible for decreasing of potential barrier around the traps.

Exact qualification of electrical conduction mechanism requires more detailed researches, especially dependence current of the thickness of the sample, temperatures and crystallinity. Researches are in progress.

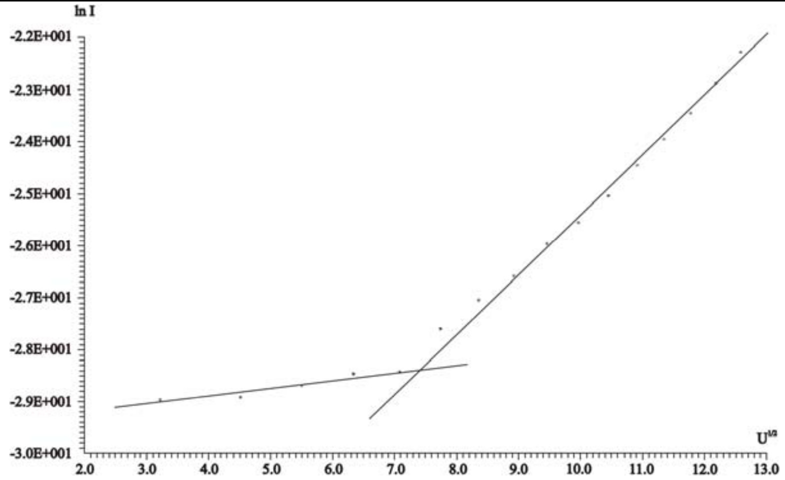

Fig. 3. Typical ln I-$U^{1/2}$ characteristic for LDPE/ZnO at temperature 265 K

1. *Ding Ch., He H., Guo B., Jie D.* Structure and properties of polypropylene/clay nanocomposites compatibilized by solid-phase grafted polypropylene, Polymer Composites, 2008. Vol. 29. N 6. P. 698–701.
2. *Chandra A., Turng L., Gong S., Hall D.* et al. Study of polysterene/titanium dioxide nanocomposites via melt compounding for optical applications, Polymer Composites, 2007. Vol. 28. N 2. P. 125–130.
3. *Avasthi D.K., Mishra Y.K., Kabiraj D.* et al. Synthesis of metal-polymer nanocomposite for optical applications, Nanotechnology, 2007. Vol. 18. N 12. P. 125604–125608.
4. *Bondioli F., Daigato A., Fabri P., Messori M.* et al. High-density polyethylene reinforced with submicron titania particles, Polymer Engineering & Science, 2008. Vol. 48. N 3. P. 448–457.
5. *Shen K., Kochesfachani S., Jouffret F.* Zinc borates as multifunctional polymer additives, Polymers for Advanced Technologies, 2008. Vol. 19. N 6. P. 469–474.
6. *Mu Q., Feng S., Diao G.* Thermally conductivity of silicone rubber filled with ZnO, Polymer Composites, 2007. Vol. 28. N 2. P. 125–130.
7. *Lach G., Laskowski Ł., Świątek-Prokop J.* et al. The influence of dodecyl maleate admixture on the dielectric and electric properties of polarized polyethylene, Visnyk Lviv Univ. Ser. Physic. 2007. N 40. P. 168–173.
8. *Świątek J.* Electrical Conduction Mechanism in Thin Coronene Films // Phys. Stat. Sol. 1976. Vol. 38. 285 p.

ЕЛЕКТРОПРОВІДНІСТЬ В ТОНКИХ ПОЛІМЕРНИХ ШАРАХ

Й. Свіонтек-Прокоп[1], Й. Свіонтек[2], Ст. Ткачик[2], Л. Ласковский[2]

[1]Інститут технічної освіти, Університет Яна Длугоша
ал. Армії Крайової 13/15, Ченстохова, Республіка Польща
[2]Інститут Фізики, Університет Яна Длугоша
ал. Армії Крайової 13/15, Ченстохова, Республіка Польща

Досліджено темнову електричну провідність тонких поліетиленних шарів, легованих ZnO. Вимірювання проводились в температурному діапазоні від 40 до 380 K. Як матеріал для електродів використовувались алюміній та золото. Експерементні дані інтерпретовано з погляду ефектів просторового заряду. Показано, що потенційний бар'єр навколо локалізованих станів опускається відповідно до рівняння Пула–Френкеля.

Ключові слова: поліетилен, електричні властивості, модифікація.

ЭЛЕКТРОПРОВОДИМОСТЬ В ТОНКИХ ПОЛИМЕРНЫХ СЛОЯХ

Й. Свионтек-Прокоп[1], Й. Свионтек[2], Ст. Ткачик[2], Л. Ласковский[2]

[1]Институт технического образования, Университет Яна Длугоша
ал. Армии Краевой 13/15, Ченстохова, Республика Польша
[2]Институт Физики, Университет Яна Длугоша
ал. Армии Краевой 13/15, Ченстохова, Республика Польша

Исследовано темновую электрическую проводимость тонких полиэтиленовых слоев, легированных ZNO. Измерения проводились в температурном диапазоне от 40 до 380 K. Как материал для электродов использовались алюминий и золото. Экспериментальные данные интерпретированы с точки зрения эффектов пространственного заряда. Показано, что потенциальный барьер вокруг локализованных состояний опускается в соответствии с уравнением Пула–Френкеля.

Ключевые слова: полиэтилен, электрические свойства, модификация.

Стаття надійшла до редколегії 04.06.2008
Прийнята до друку 25.03.2009