537.312

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. .              ,   . .              ,   . .            .

. .              .

*Isothermal depolarization currents occurring in the nanocomposites such as polyethylene-carbon at small polarization electric fields have a polarity opposite to current polarization. They are characterized by a stretched dielectric relaxation time distribution. With increasing percentage of nanocarbon is an increase in the width of this distribution. Detected the identity of kinetic dependences of these currents for polyethylene matrix with and without the presence of nanocarbon filler, which can be considered as evidence of the same nature rechargeable centers. Obtained estimates of the activation energy of the investigated depolarization process is ~ 0,32 eV are consistent with the current idea of the energy trapped in polyethylene.*

**Keywords:** *isothermal depolarization, nanocomposites, compo, polymer, carbon, approximation.*

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[1].                                                                                                             -

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[2-7],                                                                                                            -

[8; 9],                          [10]                                                                           -

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.              ,                                                           -

,                                                         -

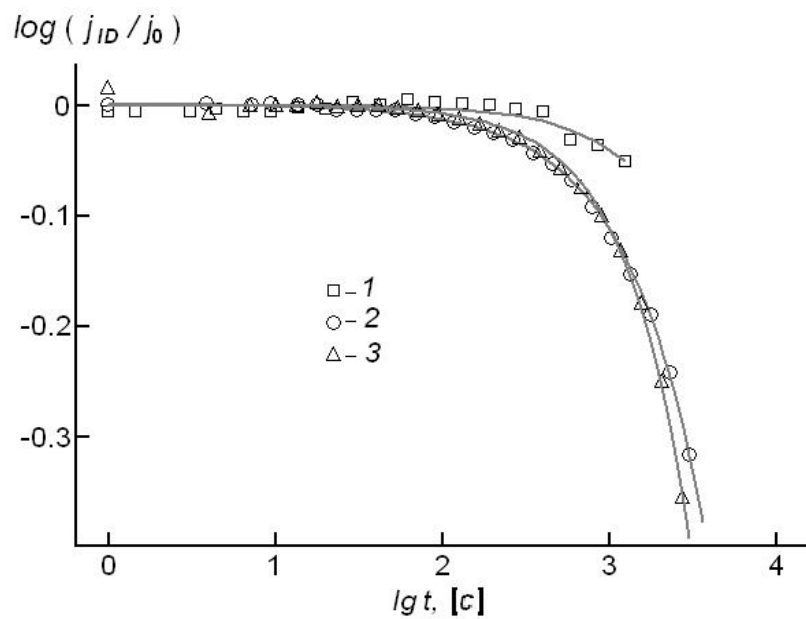.                                                                                                               -

,                                                                                                             -

[11-13].

**1.**

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(     ),                                                                                        ,                 -

-              .

**2.**

**2.1.**

LDPE (15803-020)                          N330 (      ASTM D1765)                          28-36       ,

0%      30%                .     -

200 °

,                                                                    .

500       .                                                                                                        -

.

(                           ~ 10      )                                                                13,5

~ 3      .                                                                                                         -

100 °   .

**2.2.**

$(\sim 10^{-2}$     . .)                    [14]

.                              (                              )

(                )

.

0,5        .

30        .                              (

10   )                              60       .

,

.

,

,              c

$\lg j_{ID}^{(k)}$              $\lg t_k,$      $k = 0, 1, ..., K.$                    $K$

,

(   . 1 –        ).

$\log t_k$                    $n \ (n \geq 100)$                              .

$\overline{i-}$        $(k=0, 1, ..., n)$

$\lg j_{ID}^{(i)} = \overline{\lg j_{ID}^{(k)}},$                                        .



**. 1.**

(                                        - 15    .%)

$\hat{I}\hat{I}\hat{I} >$                              $\lg j_{ID}^{(k)};$ Ññ̃ >                    $\overline{\lg j_{ID}^{(k)}}$

,              [15, 16],   -

Kohlrausch-Williams-Watts (KWW)

$$j_{ID}(t) = j_{ID}(0) \cdot f_{KWW}(t) = j_{ID}(t) \cdot \exp\left[-(t/\ddagger)^s\right], \tag{1}$$

$\tau$              (                              )                    ,

$j_{ID}(0) = Q/\ddagger; \ Q -$        ,        -

[17; 18].

$s$                    $t^{(i)} \times \left[d\left(\lg j_{ID}^{(i)}\right)/dt\right]$    $\lg j_{ID}^{(i)},$                              . 1

$$( \quad .2 ),$$
$$s = \Delta\{t \times [d\,(\lg j_{ID})/dt]\}/\Delta \lg j_{ID}.$$



**а**

. 2.

( – 15 . %) ,
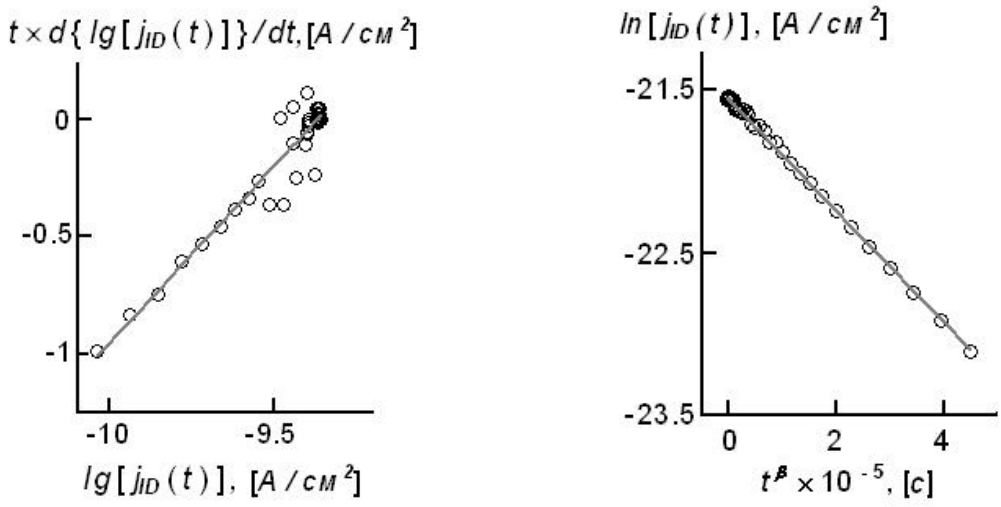
s ( ) ‡ j₀ ( ). – , **KWW** >

**KWW-**

$$\ln\left(j_{ID}^{(i)}\right) \quad \left(t_i\right)^s, \qquad j_{ID}^{(i)} = 10^{\log j_{ID}^{(i)}}$$

$$t_i = 10^{\log t_i}, \qquad \qquad . \qquad \qquad (1)$$

( .2 ) , , $\ddagger = \left[-\Delta \ln(j_{ID})/\Delta(t^s)\right]^{-1/s}$ $j_0 = \exp\left\{\ln[j_{ID}(t)] + (t/\ddagger)^s\right\}.$

**2.3.**

, , -

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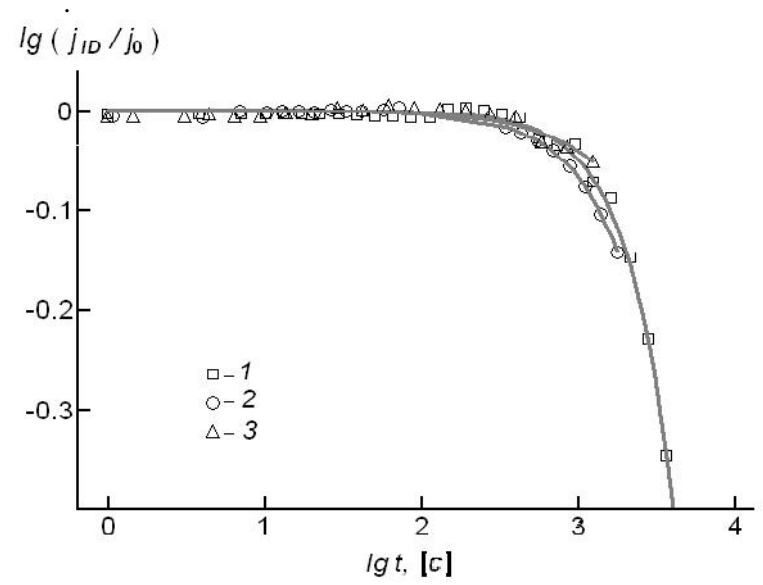


. 3. ( ),

( )

% :1 – 0; 2 – 15; 3- 30     300

. 3 $j_{ID}(t)$ -

,

.

$\log\left(j_{ID}/j_0\right)$ lg $t$, -

$j_0$ , ,

( . 1).

**1.** s **KWW**

-

| , . % | , | s |
|---|---|---|
| 0 | 300 | 1,5 |
| 15 | 300 | 1,3 |
| 30 | 300 | 1,1 |

. 1. , :

- c -

(s > 1);

- .

$\tau$ 1,5 2,5 . -

-

. -

, (1) -

. -

,

.

**2.4.**

( . 4).

( =

$1,06 \pm 0,11$).

$\tau$

( . 5).



. 4. ( )

( ) , 30%

, : 1 – 301; 2 – 318; 3 – 328

$, \ddagger(T) = \ddagger_0 \cdot \exp(W/kT)$ [19], $\tau_0$ ,     -

, $W -$                                 , $k -$                                 . 4

:  $W \approx 0,32$     $\tau_0 \approx 0,036$  .
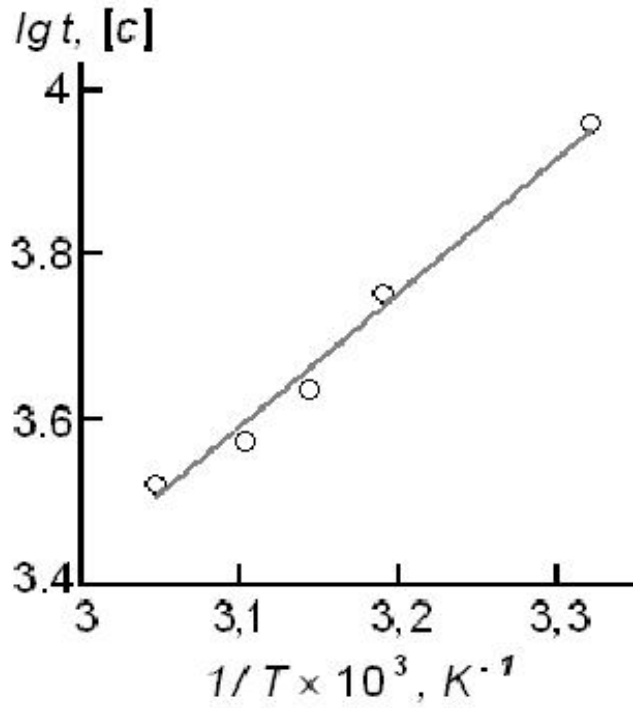


. 5.

**2.5.**

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,
[20].                                                               ,     -

,                                           LDPE,           ,                 ,

.

,                                                                                 -

,                                                                   [21].     -

-

,                                                                             [22;

23]                                         [12; 21; 24].

$(\leq 40$  /  $)$

,                               ,                                                 .

-           ,                                                           ,           -

-                                           [9],                                   -

,                                       -

.                               ,               ,                                 -

,               ,                                                                 -

[21].

-

(τ)

KWW-

(

).

[21].

~0,32  ,

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1.          ,  .                                                                                        /
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2.  Ezquerra, T. A. Calleja Electrical transport in polyethylene-graphite composite materials / T. A. Ezquerra, M. Kulescza, F. J. Baltá // Synthetic Metals. – 1991. – Vol. 41. – P. 915-920.
3.  Mamunya, E. P.  Effect of polymer-filler interface interactions on percolation conductivity of thermoplastics filled with carbon black / E. P. Mamunya, V. V. Davidenko, E. V. Lebedev // Composite Interfaces. – 1997. – Vol. 4. – P. 169-176.
4.  Glot, A. B. Non-Linear Electrical Characteristics of Composite Layers Conductor-Dielectric / A. B. Glot, A. M. Makeev // Physics and chemistry of solid state. – 2001. –   . 2,    3. –   . 375-378.
5.  Zheng, W. Electrical conductivity and dielectric properties of PMMA/expanded graphite composites / W. Zheng, S.-C. Wong  // Composites Science and Technology. – 2003. – Vol. 63. – P. 225-235.
6.  Degtyar'ov, A. V. Electric conductivity of PTCR polyethylene–graphite composites / A. V. Degtyar'ov, A. S. Tonkoshkur // Ukr. J. Phys. – 2007. – Vol. 52,    9. – P. 863-867.
7.  Shin, S.-G. Effect of Temperature on the Dielectric Properties of Carbon Black-Filled Polyethylene Matrix Composites below the Percolation Threshold / S.-G. Shin, I.-K. Kwon // Electronic Materials Letters. – 2011. – Vol. 7,    3. – P. 249-254.
8.  Degtyar'ov, A. V.   lectrical properties of posistor composite materials based on polyethylene-graphite / A. V. Degtyar'ov, A. S. Tonkoshkur, A. Yu. Lyashkov // Multidiscipline Modeling in Mat. and Str. – 2006. – Vol. 2,    4. – P. 435-441.
9.           ,  .  .                                                                                        –
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       . – 2012. –   . 54,      . 4. –   . 791-796.

10. Brosseau, C. Dielectric and microstructure properties of polymer carbon black composites / C. Brosseau, F. Boulic, P. Queffelec [et al.] // J. Appl. Phys. – 1997. – Vol. 81. – P. 882-891.

11. Mizutani, T. Anomalous Discharging Currents due to Space Charge / T. Mizutani, K. Kaneko, M. Ieda // Jpn. J. Appl. Phys. – 1981. – Vol. 20. – P. 1443-1448.

12. Neagu, E. R. Charge injection/ejection and trapping in low-density polyethylene at low and medium fields / E. R. Neagu, J. N. Marat-Mendes // Appl. Phys. Lett. – 2003. – Vol. 83. – P. 75-77.

13. Mazurek, B. Polarization spectra analysis for the investigation of space charge in dielectric nanocomposites / B. Mazurek, L. Moron // Materials Science-Poland. – 2007. – Vol. 25,    3. – P. 899-911.

14. Kremer, F. Broadband Dielectric Spectroscopy / F. Kremer, A. Schonhals. – Berlin : Heidelberg, New York : Schonhals Springer Verlag. – 2003. – 729 p.

15.              ,  . .                          -        -       /  . .            ,  . .                //
        . – 2012. –      1(78). – C. 111-120.

16. Tonkoshkur, Yu. A. Isothermal depolarization current in metal-oxide varistor ceramics under various polarizing fields / Yu. A. Tonkoshkur, A. Yu. Lyashkov and A. S. Tonkoshkur // J. Adv. Dielect. – 2013. – Vol. 3,    2. – P. 1350016.

17. Williams, G. Non-symmetrical dielectric relaxation behaviour arising from a simple empirical decay function / G. Williams, D. C. Watts // Trans. Faraday Soc. – 1970. – Vol. 66. – P. 80-85.

18. Weiss, G. H. Improved computational methods for the calculation of Kohlrausch-Williams-Watts (KWW) decay functions / H. W. George, M. Dishon, A. M. Long [et al.] // Polymer. – 1994. – Vol. 35. – P. 1880-1883.

19.              ,  . .                          :        .    .                /  . .              . – K. :
          , 1980. – 400   .

20.              ,  . .                                          /  . .              –
     . :          , 1988. – 160   .

21. Jerilyn, B. Hopping Conductivity and Charge Transport in Low Density Polyethylene. Utah State University : All Graduate Theses and Dissertations, – 2010, Paper 562.

22. Fischer, P. Thermally stimulated and isothermal depolarization currents in low-density polyethylene / P. Fischer, P. Röhl // Journal of Polymer Science: Polymer Physics Edition. – 1976. – Vol. 14. – P. 531-542.

23. Orrit, J. Identification of dipolar relaxations in dielectric spectra of mid-voltage cross-linked polye-thylene cables / J. Orrit, J. C.Cañadas, J. Sellares [et al.] // Journal of Electrostatics. – 2011. – Vol. 69(2). – P. 119-125.

24. Sawa, G. Field assisted trapping in polyethylene / G. Sawa, M. Kawade, M. Ieda // J. Appl. Phys. – 1973. – Vol. 44. – P. 5397.

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