Magnetodielectrical Polymer Compositional Materials

Sh. V. MAMEDOV, Y. LENGER, S. BOLCAL, V.A. ALEKPEROV
Yıldız Technical University, Department of Physics,
80270, Şişli, İstanbul-TURKEY
M. A. RAMAZANOV, R. Z. SADIKHOV
Institute of Physics of the Azerbaijan Academy of Scien.,
Baku, H.Javid St 33, Azerbaijan

Abstract

Magnetodielectrical polymer compositional materials containing carbonyl iron (CI) were obtained. The changes of permittivity and permeability, loss angle tangent, resistivity, mechanical and electrical properties, depending on the content of carbonyl iron have been investigated. It is shown that the magnetodielectrical materials with 20-40 % mass content of carbonyl iron have possible practical use.

1. Introduction

The problem of searching for and developing technology for the production of new and more effective compositional dielectrics is almost wholly connected with the difficulties encounted during their practical use. Such dielectrics must embody positive properties among separate components. Among them of great practical interest are polymer compositional materials with optimal magnetic and dielectrical properties which may be used in medical, electronic and other branches of industry and in particular, in the production of cores for radioelectronic apparatus. Carbonyl iron-based termoreactive magnetodielectric compositions and their characteristics have been discussed in [1,2]. The permeability (μ) and resistivity (ρ) of those compositions are smaller than the standard (for B=0.3 T, μ=5-12 Wb/A.m. and ρ=10^4-10^5 Ωm). This shows that CI-based materials are not convenient for technical use. On the other hand, the reception of these materials is very complicated. The aim of this investigation is to obtain new magnetic filler-added composite CI polymers which contain fluorine (Polyvinylidene fluorine-PVDF) or polyolefin (Polypropylene-PP, Polytehylene-PE), to examine their properties, and subsequently increase their permeability and resistivity as well as improve their dynamical-mechanical and electric strength properties to within acceptable standards.

2. Experimental

Compositional materials with specific mass fractions of CI, PE and PVDF were thoroughly mixed on a ball mill then hot-pressed at the melting point of the polymer matrix under pressure of 15 MPa at 200-220°C for 15 minutes. Samples of thickness 0.2 mm and radius 30-mm were obtained after removing the pressure and submerging in water.

Changes of permittivity (ε) and permeability (μ), loss angle tangent (tg δ) and resistivity (ρ) depending on filler's mass content have been investigated. Also investigated was the dependence of specific magnetization as a function of different CI mass content and magnetic field. At the same time, mechanical and electrical properties (σ, E elasticity, lifetime) were measured under constant external loads and electrical field intensity by the "lever mechanism" method [3,4]. These results, explainable by the well known "Thermofluctuation Theory", can be examined with the help of by the equation $\tau_\sigma = \tau_0 exp \left[\frac{U_0 - \gamma\sigma}{kT} \right]$: Where, U_0 is the maximum height of the energy well, when the polymer chain is broken (maximum broken activation energy), σ is the mechanical strength, T is the absolute temperature, k is the Boltzmann constant; τ_0 is between $10^{-12} - 10^{-13}$ sec for polymers, appropriate for the frequency of the oscillation about the equilibrium position of the atom, γ is known as the structure-sensitive parameter and its physical meaning is nonhomogenous dispersion of external mechanical strain (excessive strain dispersion constant).

3. Results and Discussion

The experimental results showed that, with increase of CI content, the completion of technical magnetisation occured at weak field strengths, for all compositions for which the magnetic saturation paraprocess was perceptible. At large, concentrations of CI, the paraprocess is insignificant.

Table

Compositions	Parameters	Mass	%	of	(C:Fe)			
		10	20	30	40	50	60	70
PV+(C:Fe)	μ	2.1	4.2	6.5	17	21	23.5	24
	ρ, ohm.m	10^9	10^8	$2\ 10^7$	10^7	$8\ 10^6$	$6\ 10^6$	$2\ 10^2$
	ε	6.5	6.4	6.1	5.1	4	3	1.8
	tg δ 10^{-4}	200	290	320	400	580	700	980
PE+(C:Fe)	μ	1.1	1.4	1.9	2.4	4.2	4.7	5.0
	ρ, ohm.m	10^{10}	10^9	10^7	$2\ 10^6$	$5\ 10^5$	$2.4\ 10^5$	$2\ 10^2$
	ε	2.1	2.05	1.95	1.8	1.7	1.5	1.3
	tg $\delta.10^{-4}$	56	75	92	110	130	145	200

At B=0.3 T, values of permeability, resistivity, permittivity and loss angle tangent for PVDF- and PE-based compositions are given in Table.
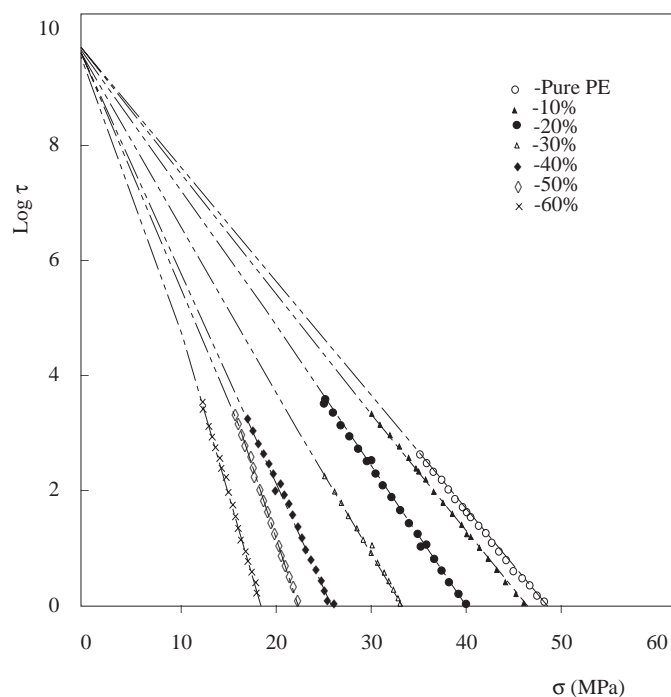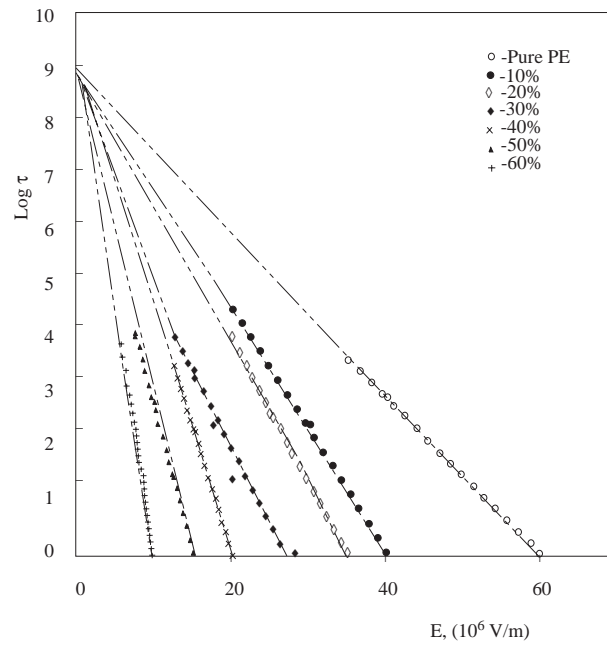
Figure 1a. The dependence of Log τ on mechanical strength (σ) in the composite PE+CI.

It is seen from Table that for (PVDF+C:Fe) compositions, μ increases slowly for concentrations up to 30%. With further increase of CI content μ increases sharply from 6.5 at 30% till 17 at 40%, then increasing slowly till $\mu=24$ at 70% CI content. μ also undergoes a sharp change in the 30-40% concentration region.

It is also seen for both compositions that, with the increase of CI content up to 30%, there is a sharper decrease of resistivity compared with decreases in similar samples with 40-60 % of CI (by mass).

The character of change of μ and ρ of investigated compositional materials with CI content in the region 30-40 % mass is obviously connected with the formation of supramolecular structures and the interaction of the polymer matrix with CI.

At 70% CI content, resistance of the compositions decreases sharply which may result in significant decrease of polymer layer thickness. For large fillers, concentration, the probability of direct electrical contact to CI regions increases which may be a reason for the sharp decrease of μ at 70% CI content. The relation between the lifetime (τ) and mechanical strength (σ), electrical strength (E) is given in Figures (1-a, b). From this figure it is shown that although σ and E decrease while the CI content increases, for 40% concentration the aforementioned properties are much better than those of the same compositions mentioned in [1,2].

Figure 1b. The dependence of Log τ on electric strength (E) in the composite PE+CI.
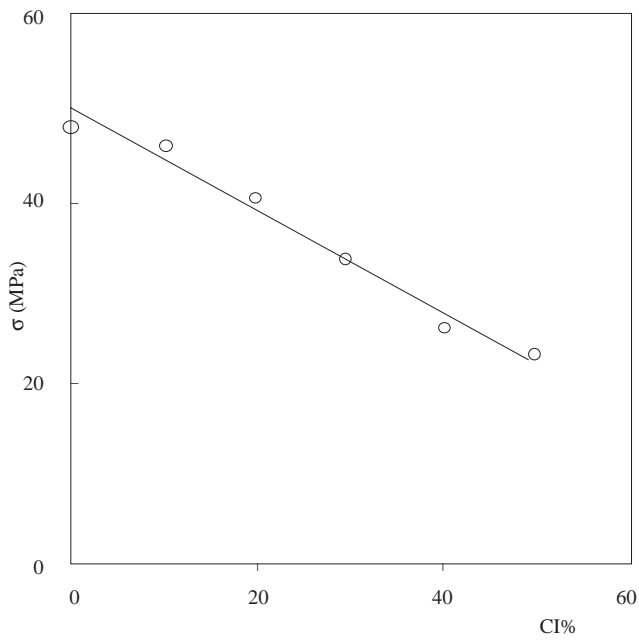
Figure 2a. The dependence of mechanical strength σ on the amount of CI.
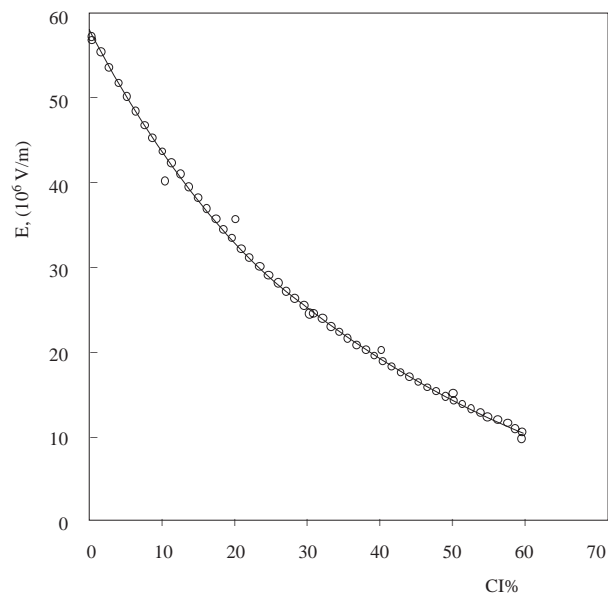
Figure 2b. The dependence of electric strength (E) on the amount of CI.

Supporting the above explanation for $\tau=1$ sec, the relationship between CI quantity and each of σ and E are given in Figures (2-a, b), constructed by using the values of Figure (1-a, b). Thus the required elasticity of the samples can be optimized at 40% CI content.

Considering the results in our article, it can be judged that all the properties of composites we have obtained are better than those mentioned in the other articles. Polyethylene fluorine and polyethylene compositions with 20-40 % CI may be used in electromotors, in the production of magnetic wedges and preparing cores for radioelectronic devices.

It is worth noting that the value of μ obtained for compositions with 20-40 % mass slightly exceeds numerical values of μ of compositional magnetodielectrics known in publications that represent these materials perspective for practical use.

References

[1] D. A. Kuzurman, F. K. Makarov, V. A. Vojtovich, Patent(USSR), N 1483496, 1987

[2] L. J. Lisenko, Patent (USSR), N 1591082, 1988.

[3] A. P. Aleksandrov, S. N. Zhurkov, Brittle Fracture (In Russian), Gosteortekhizdat, Moscow (1933).

[4] V. R. Regel, A. I. Slutsker, E. E. Tomashevskii, Kinetic Nature of Durability of Solids (In Russian), Izdat. Nauka, Moscow (1974), p.560.

515