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DIELECTRIC INVESTIGATIONS ON COMPOSITE MATERIALS OBTAINED FROM WASTE PLASTICS

BY

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Abstract. Investigation by dielectric spectroscopy method emphasizes that the composite material obtained by mixing recycled plastics such as poly (ethylene terephthalate) (PET) and low density polyethylene (LDPE) with various compatibilizers agents can be successfully used as electrical insulators.

Key words: recycled material; dielectric spectroscopy; electric appliance.

1. Introduction

Plastics are a crucial part of twenty-first century life. Not only do they provide us with useful, lightweight and durable products, but they play a key role in the sustainable development of our world. Plastics enable the eco-efficient manufacture of products (Arădoaie *et al.*, 2010). Lighter plastic components enable safety and resource efficiency solutions for cars and aircraft. Plastics help to insulate buildings and save lives in healthcare applications. 12% to 15% of a modern car is made of plastic to help to reduce weight, save fuel and reduce emissions.

The interest related to recycling is continuously increasing nowadays, due to the new European policy of superior reconversion of industrial waste. The continuously increasing demand for plastic materials for different societal

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sectors (Table 1), correlated with the continuously decreasing of supplies, determined the scientists to consider any possibility of superior recycling of plastic waste (R. Ciobanu *et al*., 2006).

As with all materials, once plastics are sorted and prepared ready for recycling, they are available for the recycling market. This market has developed, as with other recycled raw material, into a global market. A significant amount of secondary raw materials are recycled within Europe. This is due to a well developed recycling industry and the fact that many recycled materials are used in the production of new products.

Table 1
Demand for Plastic Materials for Different Societal Sectors in Year 2009

Sector	Mil. tonne	%
Packaging	18.04	40.1
Building & Construction	9.18	20.4
Automotive	3.15	7.0
Electrical and electronic equipment	2.52	5.6
Other	12.11	26.9
Total	45	100

The most used resin types are polyolefins (polyethylene including low density (PE-LD), linear low density (PE-LLD) and high density (PE-HD) and polypropylene (PP)), which account for around 50% of all plastics demand. PVC is the third largest resin type at 11% (Fig. 1).

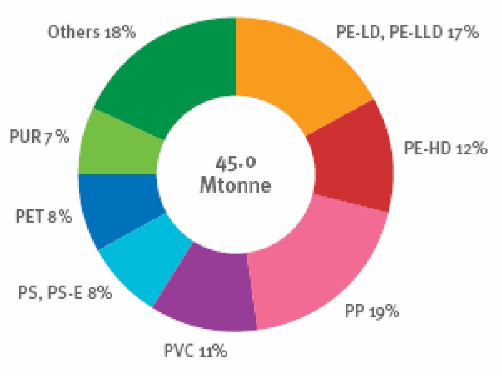

Fig. 1 – Europe plastics demand by resin types 2009 (source: APME 2009).

2. Experimental Part

2.1 Materials

Blends of poly(ethylene terephthalate) (PET) and polyolefins (POs) have recently attracted considerable research activity since both materials are among the most frequently used thermoplastics, especially as packaging materials. Owing to their broad-scale applications, PET/PO mixtures represent a significant part of post-consumer waste.

Poly(ethylene terephthalate) and polypropylene (PP) are incompatible due to differences in chemical nature and polarity; therefore, their blends exhibit a clear two-phase morphology (Xanthos *et al*., 1990). Hence, appropriate compatibilization is needed to achieve better adhesion between the two phases (Xanthos *et al*., 1990). It seems that compatibilizers containing maleic anhydride (MA) or epoxy functionalities are effective in improving the properties of blends of polar engineering polymers like polyamides, polyesters, or polyester-type liquid crystal polymers with non-polar polymers like POs (Chiu & Hsiao, 2006). Thanks to its various properties, lignin can be used for different technical purposes.

Lignin, the most abundant substance in plant kingdom after cellulose, is an aromatic biopolymer and results mainly as a by-product from pulp and paper industry and is conventionally treated as a waste material with low practical usage (Glasser & Kennedy, 1987). Unmodified lignin possesses a poor solubility in common solvents and its thermoplastic melt flow characteristics are like those of cellulose. Similar to the thermoplastic ester derivatives of cellulose, one method to improve the thermoplastic behavior of lignin polymer is etherification (Constantinescu *et al*., 2005).

Etherification of lignin has been in practice from the late forties when it was found to be useful as a mold lubricant, possessing characteristics of softening point and solubility (Glasser & Jain, 1993). However, lignin and its derivatives are biodegradable polymers, which can be used in combination with other biodegradable materials. The use of lignin as a modifier for biopolymers would certainly be advantageous from the viewpoint of new potential applications as well as the economical recovery of this waste material resulted from biomass processing (Vasile *et al*., 2006).

In this study, the reactive blending of post-consumer poly(ethylene terephthalate) (PET) with low density polyethylene (LDPE) in presence of different compatibilizers as ethylene–propylene rubber grafted with maleic anhydride (EP–MA) or modified lignin, was studied in an attempt to obtain new materials with enhanced properties with respect to the starting materials.

The composites were obtained from the mixture of recycled LDPE (rLDPE), PET and different compatibilizers as EP–MA or esterified lignin (LER). The samples compositions, which were analysed, containing 20 wt% of rPET, 73/75 wt% of rLDPE and 7/5 wt% of EP–MA/LER were obtained by injection molding and are relatively homogeneous and compact (Arădoaei *et al*., 2010).

2.2. Methods

Broadband dielectric spectroscopy analysis was submitted to a Novocontrol GmbH Concept 80 Broadband Dielectric Spectrometer with an

Alpha A analyser in the frequency range of 0.01 Hz to 20 MHz. The sample material has 0.1 mm thickness, and is usually mounted in a sample cell between two gold plated electrodes, with 20 mm in diameter, forming a sample capacitor.

Broadband dielectric spectroscopy has proven to be a very useful tool to study the structure and the dynamics of polymeric systems. This knowledge is important for the development of new materials and also to understand the eventual degradability of those materials.

The complex dielectric function, $\varepsilon^* = \varepsilon' - i\,\varepsilon''$, is a materials property depending on frequency, temperature and structure, where ε' is related to the energy stored in the material and ε'' is proportional to the energy that is dissipated in each cycle. These quantities are quite important for the technical characterization of the material (Kremer & Schonhals, 2002). Dielectric analysis provides information about important dielectric parameters such as dielectric constant, dielectric loss, loss tangent and conductivity.

3. Results and Discussions

The dielectric spectroscopy method represents an interesting pursuit for studying molding resins, compounds and composites, because it can provide information related to the potential application of such materials for electrical domain. The dielectric constant curves of secondary LDPE, PET and different compatibilizers as EP–MA/Lignin samples *vs*. frequency are presented in Fig. 2. The dielectric domain of this type of composites is defined by the highest value of the rPET permittivity and the minimum value of the rLDPE permittivity.

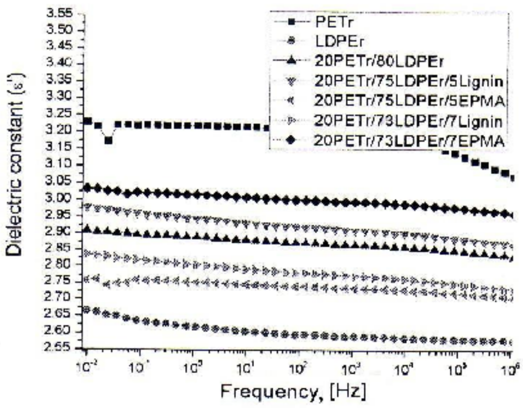

Fig. 2 – Variation of the dielectric constant (ε') *vs*. frequency for rPET/rLDPE.

The permittivity of rPET/rLDPE compound without mass additives occupies a middle position within this domain, being a consistent proof of an optimum coupling process of rPET/rLDPE. The composite material with 7% EP–MA and with 5% lignin provided a superior value of permittivity when are compared with rPET/rLDPE compound without mass additives, considering optimum receipts of polymers coupling technology with EP–MA/Lignin.

As regards the dielectric losses (Fig. 3), negligible dipolar or interfacial effects of composites with EP–MA/Lignin mass additives are noticed, in spite of, *e.g*. a strong dipolar effect expected for lignin. An important influence of EP–MA/Lignin mass additives was noticed only for dielectric permittivity of LDPEr/PETr composites.

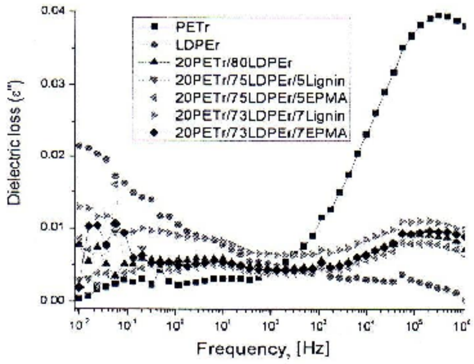

Fig. 3 –Variation of the dielectric loss (ε″) *vs*. frequency for rPET/rLDPE002E

Also, the conductivity of the rPET/rLDPE composites was analysed *vs*. frequency (Fig. 4). For all materials, the conductivity increases with increasing of frequency in range of 10^4 Hz up to 10^6 Hz. It seems that the conductivity of composite materials rPET/rLDPE not dependends on percentage and type of mass additives.

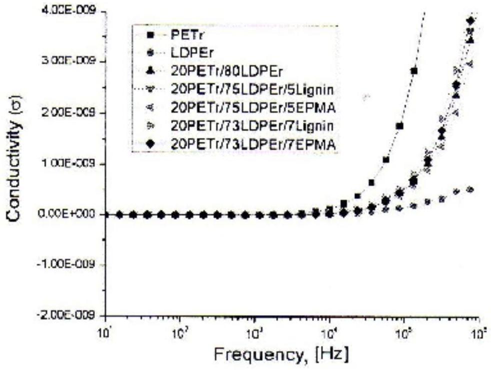

Fig. 4 –Variation of the conductivity (σ) *vs*. frequency for rPET/rLDPE.

Taking into account all dielectric properties, the compound with 7% EP–MA is considered the most convenient material for potential applications in electrical domain as insulating systems.

4. Conclusions

The experimental results highlight the possibility of producing materials with new properties from secondary PET and LDPE by overcoming the lack of interfacial adhesion of polyolefin–PET blends typical of an immiscible system.

The composite material with 7% EP–MA and with 5% lignin provided a superior value of permittivity when compared with rPET/rLDPE compound without mass additives, considering optimum receipts of polymers coupling technology with EP–MA/Lignin.

Taking into account all dielectric properties, the compound with 7% EP–MA is considered the most convenient material for potential applications in electrical domain as insulating systems.

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INVESTIGAŢII DIELECTRICE PRIVIND MATERIALELE COMPOZITE OBŢINUTE DIN DEŞEURI DE MASE PLASTICE

(Rezumat)

Investigaţiile cu ajutorul spectroscopiei dielectrice evidenţiază faptul că materialele compozite obţinute prin amestecarea materialelor plastice reciclate, cum ar fi PET-ul şi LDPE cu diverşi agenţi de compatibilizare, pot fi folosite cu succes în domeniul electric ca izolatori.