Green Materials Derived from Renewable Resource for Electrical Applications

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Nowadays, the growing environmental awareness throughout the world has triggered a paradigm shift towards designing environmentally friendly materials. The interest in cellulose fibers as reinforcement agents in composite materials with polymer matrices has increased dramatically in the last decades, the main reasons associated with this upsurge being their renewable and ubiquitous character, good mechanical properties, low density, low cost and recyclability. Focus on dielectric spectroscopy technique, the article makes a comparison between the dielectric properties of transformer board and composite materials obtained by mixing recycled polyethylene with wood powder or lignin in different percentages.

Keywords: recycled polyethylene, transformer board, dielectric spectroscopy analysis

Thanks to plastics, fewer resources are required to satisfy our daily needs. Fewer valuable goods are wasted when protected by plastic packaging, improvements in crops productivity are made possible and renewable energy solutions are unveiled. The plastics industry plays an important role in enabling growth through innovation in a wide range of industries key such as automotive, electrical and electronic, building and construction and food and beverage sectors.

Plastics are the true resource champions by saving more resources. For example substituting plastics with alternative materials would result in a 46% increase in energy consumption, a 46% increase in CO_2 emissions and generate 100 million t more of waste every year across the EU. The success story for plastics is expected to continue as its unique properties lend to more and more innovation applications. The global demand per capita is expected to grow by 4% each year.

Demand from European converters increased by 1.1% from 2010 to 47 million t in 2011. The market share of end use applications remained stable with packaging the largest segment representing 39.4% of overall demand. This is followed by Building and Construction (20.5%), Automotive (8.3%) and Electrical and Electronic equipment (5.4%). Others include different small segments like sport, leisure, agriculture, etc. (fig. 1).

Plastic products can contribute to sustainable development after their use phase if they are disposed of responsibly and processed for recycling and recovery. All plastics are recyclable – mechanically or chemically - but not all plastics are beneficial to recycle from an environmental and economic perspective.

Recycling is often perceived as sustainable development. It all starts with appropriately designed products. Once the functional needs are safeguarded the designer should factor in sustainability through material selection, manufacturing methods, reuse and recyclability. Sorting, reprocessing and marketing recycled materials back into applications as a complement to virgin plastics require a quality approach throughout the recycling operation and include quality systems and market knowledge. The European recycling value chain must continue to drive a quality focus so their products can complement virgin plastics and other materials. Global trade in plastics waste would still be a necessary complement to maximize the recycling opportunities [1].

The growing environmental awareness throughout the world has triggered a paradigm shift towards designing environmentally friendly materials. The composites or moulding resins based on recycled polyethylene (RPE) and wood derivates - used as fillers, are also examples in this direction.

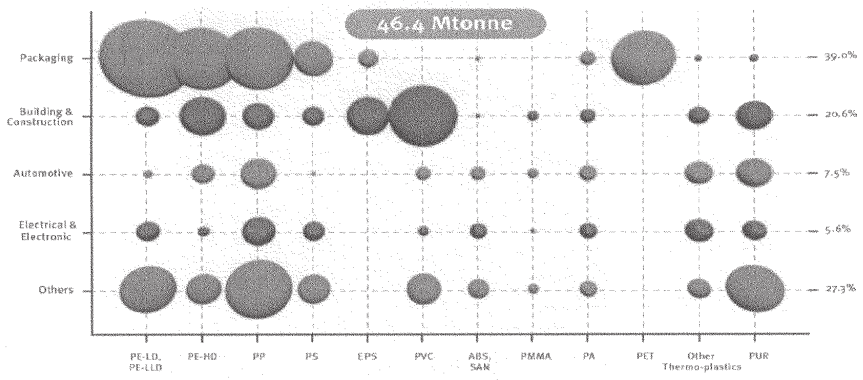

Fig. 1. Europe Plastics Demand by European Plastics Demand* by Segment and Resin type 2011

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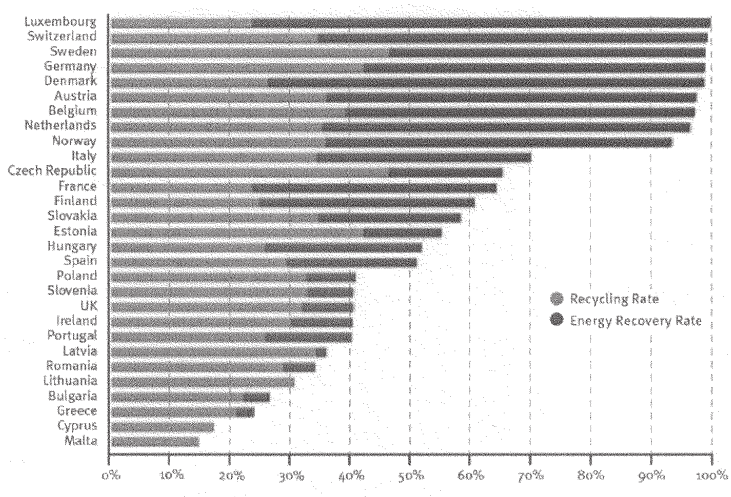

Fig. 2. Total Recovery Rate by Country 2011

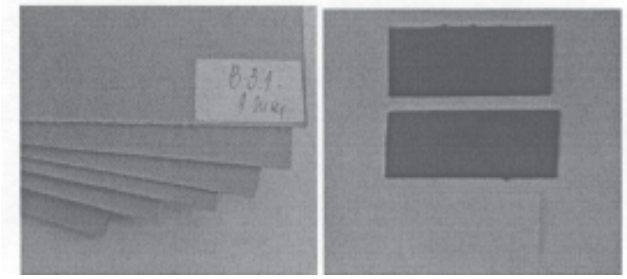

Fig. 3. Transformer board 1 mm thickness made by S.C. Petrocart S.A. Piatra Neamt, Romania (left) and composites obtained from recycled polyethylene with wood powder or lignin (right)

Such materials can provide a large domain of characteristics in accordance with the exploitation requirements and potential appliances, due to the possibility of varying the state components and their percentages, for example, by modifying the polymer structure by adding wood powder and / or lignin, or by including appropriate mass additives or short fibers [2].

The interest in cellulose fibers as reinforcement agents in composite materials with polymer matrices has increased dramatically in the last decades, the main reasons associated with this upsurge being their renewable and ubiquitous character, good mechanical properties, low density, low cost and recyclability [3].

There are few reports in the literature dealing with dielectric analysis of polymer reinforced with cellulose fibbers. Dielectric analysis provides information about important dielectric parameters such as dielectric constant, dielectric loss, loss tangent, conductivity and specific resistance [4].

Experimental part

In the present work, several blends containing different types of polyethylene and wood powder or lignin have been obtained by melt processing [5]. It was evaluated the influence of the amount of natural component during processing, on dielectric behaviour of biocomposites studied.

The transformer board (TB) was offered by the company S.C. Petrocart S.A. Piatra Neamt, Romania, in plate form, with 1 mm thickness figure 3. The transformerboard is manufactured according to the type B.3.1. of the CEI 641-3-1 standard and has a density by 1.0-1.3 g/cm^3. This International Standard gives the requirements for pressboard for electrical purposes comprised of 100 % sulphate wood pulp or a mixture of sulphate wood pulp and cotton.

Composite materials were obtained by mixing recycled PE with natural polymers and compatibility agents. The raw materials used in making composites are recycled high density polyethylene (RPE) as powder derived from recycling crates for soft drinks [3], wood powder (WP) used as filler obtained from grinding wood, commercial lignin powder. All compositions were made in collaboration with one type of modifying reagent C1803, based on modified maleic anhydride which, added in mass led to obtain some improved parameters and optimal structure [6]. Compatibility agent C1803 contains 0.7% of maleic anhydride and is grafted with ethylene-propylene copolymer.

Before mixing, the natural polymers and compatibility agents were subject to conditioning treatment in the oven for 24 h at a temperature of 105°C and 50°C. Then, the mixture was placed in an extruder with a single screw and was processed into test specimens with 1 mm thickness. Two formulations were produced with RPE as matrix and various content (20 wt% and 30 wt%) of wood powder (WP) or lignin (L).

This paper represents a part of an extended study about the use of dielectric spectroscopy analysis on composite materials, with target on their potential appliances as insulating systems. The polyethylene is a main chain semicrystalline polymer, providing dielectrically active α- and β-relaxation processes. Generally speaking, semicrystalline polymers are at least biphasic materials consisting of amorphous and crystalline regions, with important implication for dielectric measurements.

Dielectric spectroscopy has proven a powerful tool to investigate in details the dynamical processes of composites materials. The dielectric properties of composite material are affected by several factors, e.g. molecular chain arrangement, amorphous and crystalline phase fraction, molecular weight distribution, temperature and measuring frequency [3].

Broadband dielectric spectroscopy analysis were performed using a Novocontrol GmbH Concept 80 Broadband Dielectric Spectrometer with an Alpha A analyzer over the frequency range of 0.01 Hz to 20 MHz in combination with a Novocontrol Quatro temperature system providing control of the sample temperature with high accuracy [4]. The samples were sandwiched between two 20 mm gold plated electrodes and tested within ZGS Alpha Active Sample Cell, figure 4. The test temperatures were 20°C.

The experiments were conducted towards analyzing standard compounds obtained from recycled polyethylene, wood powder or commercial lignin and powder and compatibility agent in different percentages 77/20/3 or 67/

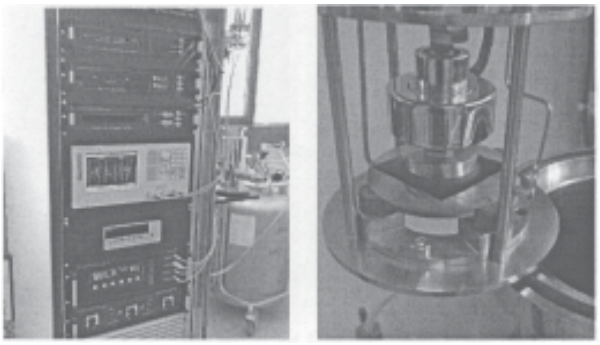

Fig. 4. Broadband dielectric analyzer Concept 80 Novocontrol GmbH, Germany and sample of material sandwiched between two 20 mm gold plated electrodes tested within Active Sample Cell

30/3.

Results and discussions

Including wood powder and lignin in the polyolefin matrix lead to changes in a wide range of dielectric characteristics and because of that dielectric properties evaluation is absolutely necessary.

The experimentally results are correlated and discussed in connection with dielectric characteristics of recycled polyethylene matrix (RPE) and board transformer characteristics (TB). Features permittivity (ε') and dielectric loss (tan δ) for mixtures of recycled polyethylene / wood powder or lignin and C1803 compatibility agent, added as filler, the frequency of applied field are presented graphically in figures 5 and 6.

Applying an electric field on probes is observed as the most significant variation is found in transformer board frequency, especially at frequencies below 50Hz. In absolute values, the dielectric constant for samples with 20% wood powder is about. 50% higher than for samples obtained from RPE without addition or with addition of lignin.

The influence of chemical structure of natural polymers in wood powder, highly polar, is close to the values determined homologous transformer board. By comparison

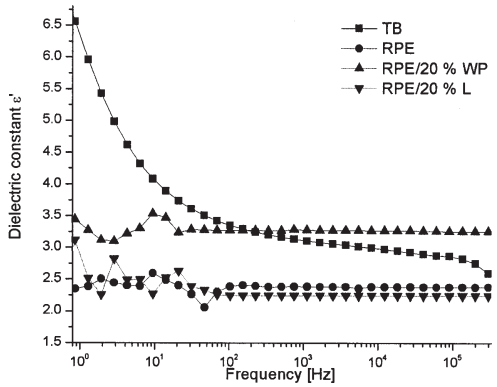

Fig. 5. Variation of dielectric constant ε' vs. frequency for studied blends

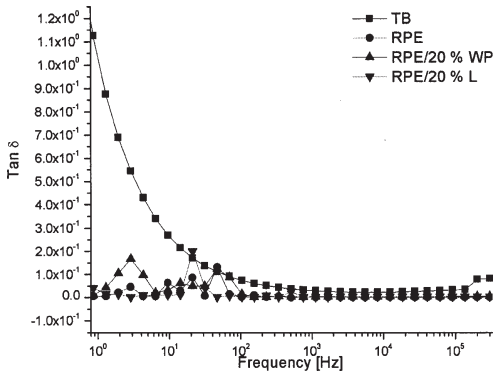

Fig. 6. Variation of tan (δ) vs. frequency for studied blends

with cardboard transformer characteristics obtained for composite materials have higher frequency stability.

Overall, it is anticipated that materials made from 20% RPE wood powder can be used for transformers as transformer board. Further considering the composite material with 30% wood powder/lignin to identify possible applications in the electrical industry, figure 7.

The characteristic of dielectric constant with 30% WP shown a slight increase compared with recycled polymeric matrix. Also, characteristics of dielectric loss tan (δ) for these materials are comparable with those of composite materials containing 20% filler, the effect of interfacial exchange is diminished, figure 8.

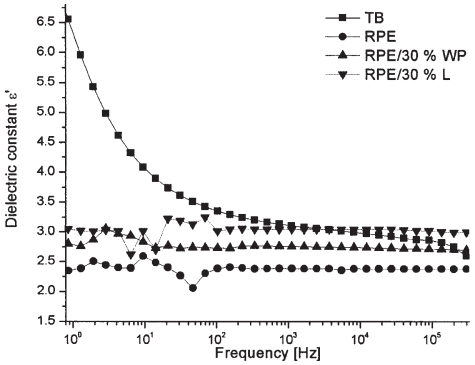

Fig. 7 Variation of dielectric constant ε' vs. frequency for studied blends

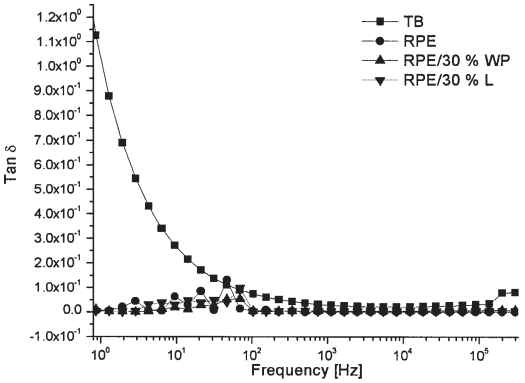

Fig. 8 Variation of tan (δ) function of frequency for studied blends

Dielectric properties	Frequency [Hz]	Transformer board (TB)	RPE	RPE/20% WP
Conductivity σ, S × cm	60 Hz	$2{,}506 \cdot 10^{-10}$	$1.27 \cdot 10^{-12}$	$4.132 \cdot 10^{-8}$
	100 Hz	$3.268 \cdot 10^{-10}$	$4.72 \cdot 10^{-13}$	$7.341 \cdot 10^{-9}$
	1000 Hz	$8.508 \cdot 10^{-10}$	$2.29 \cdot 10^{-12}$	$9.744 \cdot 10^{-8}$
Resistivity ρ_v, Ohm × cm	60 Hz	$3.987 \cdot 10^{9}$	$7.87 \cdot 10^{11}$	$2.419 \cdot 10^{15}$
	100 Hz	$3.059 \cdot 10^{9}$	$2.11 \cdot 10^{12}$	$1.362 \cdot 10^{15}$
	1000 Hz	$1.175 \cdot 10^{9}$	$4.35 \cdot 10^{11}$	$1.026 \cdot 10^{15}$
Impedance Z_p, Ohm	60 Hz	$1.270 \cdot 10^{8}$	$6.26 \cdot 10^{9}$	$3.851 \cdot 10^{13}$
	100 Hz	$9.738 \cdot 10^{7}$	$1.68 \cdot 10^{10}$	$2.167 \cdot 10^{14}$
	1000 Hz	$3.740 \cdot 10^{7}$	$3.46 \cdot 10^{9}$	$1.633 \cdot 10^{13}$
Capacity C_p, F	60 Hz	$2.627 \cdot 10^{-11}$	$2.56 * 10^{-11}$	$2.256 \cdot 10^{-7}$
	100 Hz	$2.252 \cdot 10^{-11}$	$2.65 \cdot 10^{-11}$	$2.363 \cdot 10^{-7}$
	1000 Hz	$1.683 \cdot 10^{-11}$	$2.65 \cdot 10^{-11}$	$2.349 \cdot 10^{-7}$

Tabel 1
DIELECTRIC PARAMETERS FOR TRANSFORMER BOARD (TB), RECYCLED POLYETHYLENE AND RECYCLED POLYETHYLENE WITH 20% WOOD POWDER

It can be concluded that composite material with 20% wood powder is closest to the values of transformer board. In these conditions and other dielectric properties were investigated for composite material containing 20% of wood powder, which are presented in table 1.

Dielectric characteristic values for composites with 20% wood powder, which are comparable to those of transformer board, but because European law requires the use of recycled materials in various sectors, these materials can be a viable technical solution to cardboard partially replace transformers and transformer design electric cars, given that TB technology, which is very selective with the timber used has implications on the environment and biodiversity [7].

Conclusions

Increased demand for plastics in various sectors, coupled with continuous decrease of resources, lead researchers to consider any possibility of recycling waste plastic top.

Dielectric spectroscopy is a very powerful method to investigate in detail the dynamic processes of composite materials and development of new materials. Dielectric properties have significant changes in the frequency range 0-100 Hz. Additions RPE matrix materials having strong polar (wood powder min. Lignin 20% or min. 30%), significantly influence the permittivity and dielectric loss of composites. Noteworthy is that in the frequency range between 10 and 10^5 Hz dielectric constant is compared with the values of transformer board.

Dielectric characteristics obtained for composite materials studied by 20% wood powder have similar values, but also high stability frequency to TB, which indicates that a viable technical solution to partially replace the transformer cartoon transformers and electrical machines construction, given that TB technology, which is very selective with the timber used has implications on the environment and biodiversity.

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