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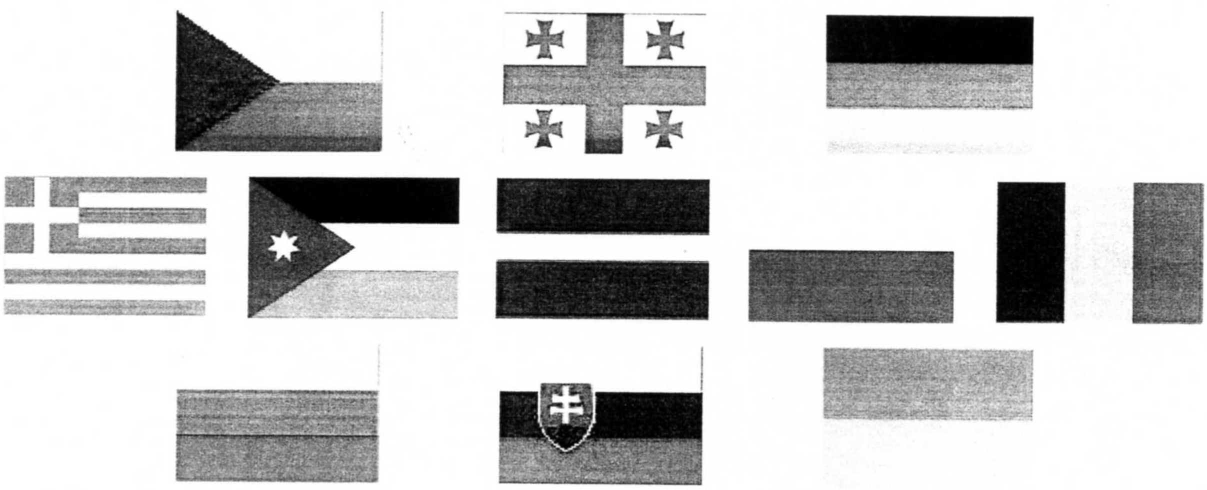

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MAGNETIC POLYMER-FERRITE NANOCOMPOSITES: STRUCTURE, PHYSICAL AND MECHANICAL PROPERTIES

MERIJS MERI Remo[1] – KALNINS Martins[1] – KALKIS Valdis[2] – SHUTKA Andris[1] – STRODE Santa[1]

[1] Riga Technical University, Institute of Polymer Materials, Azenes street 14/24, Riga, LV 1048, Latvia, ☎ +371 6 708 9252; 💻 zicans@ktf.rtu.lv

[2] University of Latvia, Department of Chemistry, Kr. Valdemara street 48, Riga, LV 1013, Latvia

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Abstract

This research is devoted to the investigation of the ferrite modified polymer matrix nanocomposites. Auto-combustion route has been utilized for the manufacturing of the ferrite nanoparticles. The effect of initial chemical composition and most important processing parameters on the fineness of the ferrite nanopowder have been cleared out. Obtained ferrite nanoparticles have been introduced in a polycarbonate matrix by melt mixing. Most important technological parameters of the melt processing have been defined. Certain stress-strain, calorimetric and structural properties of the polycarbonate/ferrite nanocomposites has been investigated.

Keywords: ferrite, polycarbonate, combustion synthesis, nanocomposite

1. INTRODUCTION

Materials modified with magnetic particles have attracted great interest of scientists and industrialists already for many years because of their wide use potential in medicine, electronics, information technology and other branches of national economy. Among other magnetic materials, ferrites have obtained special interest. In comparison to traditional magnetic materials (metals, metal alloys), magnetic properties of ferrites usually are lower. However, ferrites usually are cheaper and more resistant in oxidative environments. Besides it, due to the isolating role of oxygen ions in the crystal lattice of ferrites, they possess higher electrical resistivities and thus are especially useful at high frequencies [Magnetics, 2000]. It is well recognized that optimum level of magnetic properties of the ferrites are attainable when the dimensions of it particles are well below domain sizes (580 nm in the case of $BaFe_{12}O_{19}$ as calculated for spherical particles with an axial magnetic anisotropy) [Gubin, 2005; Skomski, 2003] and when the dimensions of it particles decrease to an extent where the ratio of the number of surface atoms to the total number of atoms in the particle approaches 0.5 [Gubin, 2005]. At such particle dimensions, ferrites possess several specific properties such as supermagnetism and macroscopic quantum tunnelling, which are not characteristic for particles with larger diameter particles. Additional advantageous properties to the material can be assigned if ferrite submicro- and nanoparticles are introduced in the matrixes of other materials such as metals, ceramics and polymers. Consequently this investigation is devoted to manufacture of ferrite modified polycarbonate nanocomposites and investigating of it structure, as well as certain physical properties.

2. MATERIALS AND METHODS

$C_6H_8O_7 \cdot H_2O$, $Ba(NO_3)_2$ and $Fe(NO_3)_3 \cdot 9H_2O$ were used as starting materials for ferrite preparation. The molar ratio of Ba to Fe was fixed at 1:12. Certain amount of ammonia solution was also added to adjust the pH to 7. Obtained mixture of nitrates and citric acid in a sufficient amount of water was intensively mixed and evaporated at 90°C. Obtained gel was dried at 80°C and thermally treated that lead to self combustion. Subsequently material was calcinated yielding nanopowder, which was used for modification of polycarbonate (PC). Modification of PC with barium ferrite nanofiller (BaF) was performed on a two roll mills at 210°C. Weight content of ferrite in a PC matrix was 2, 5 and 10 %.

Thermogravimetric and calorimetric investigations were performed on a *Mettler Toledo TGA1/SF* thermogravimetric analyzer, X-ray analysis - on a *Rigaku Ultima +* X-ray diffractometer; stress-strain characteristics at the movement of upper crossbar 10 mm/min. – on a *Zwick BDO-FB020TN* universal testing machine.

3. RESULTS AND DISCUSSION

The BaF gel was obtained as an intermediate in the citrate-nitrate process. In order to determine optimum auto-combustion temperature of the BaF gel, thermogravimetric and calorimetric investigations were performed. Results of the subsequent scans are shown in Fig. 1.

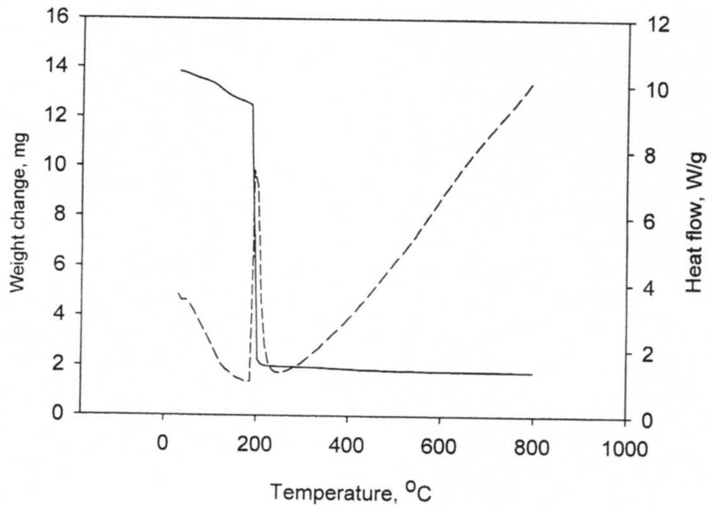

Fig. 1. Thermogravimetric and calorimetric scans of the dried ferrite gel

As one can see, auto-combustion of the dried BaF gel proceeds between 200°C and 250°C. Consequently auto-combustion of the BaF gel was carried out at 250°C. Obtained material was grinded in a powder form with a mortar and pestle and subsequently calcinated at 800°C for 2 hours, thus yielding the BaF nanopowder.
Structure of the BaF nanopowder was characterized by X-ray diffractometer. As clearly shown in Fig.2, after auto-combustion and calcination pure $BaFe_{12}O_{19}$ is formed.

Crystallite sizes of the synthesized nanoparticles were calculated by using we known *Scherrer's* equation:

$$t = \frac{K \cdot \lambda}{FWHM} \cdot \cos\Theta ,$$

where K is the constant close to unity, FWHM corresponds to the full width at half maximum of the peak and θ the Bragg angle of the reflection. According to the calculations it was revealed that crystallite sizes of the synthesized ferrite nanoparticles are close to 30 nm. Thus measured crystallite/nanoparticle sizes of the synthesized ferrites were well below dimensions of the single domains (580 nm), that according to several researches allow optimizing it magnetic properties [Gubin, 2005]. From other hand it should be mentioned that with X-ray analysis it is only possible to estimate the size of coherent X-ray scattering areas, corresponding to the average crystallite, but not particle, size. At such crystallite/particle sizes, however, many other material properties, such as modulus of elasticity and tensile strength can be improved.

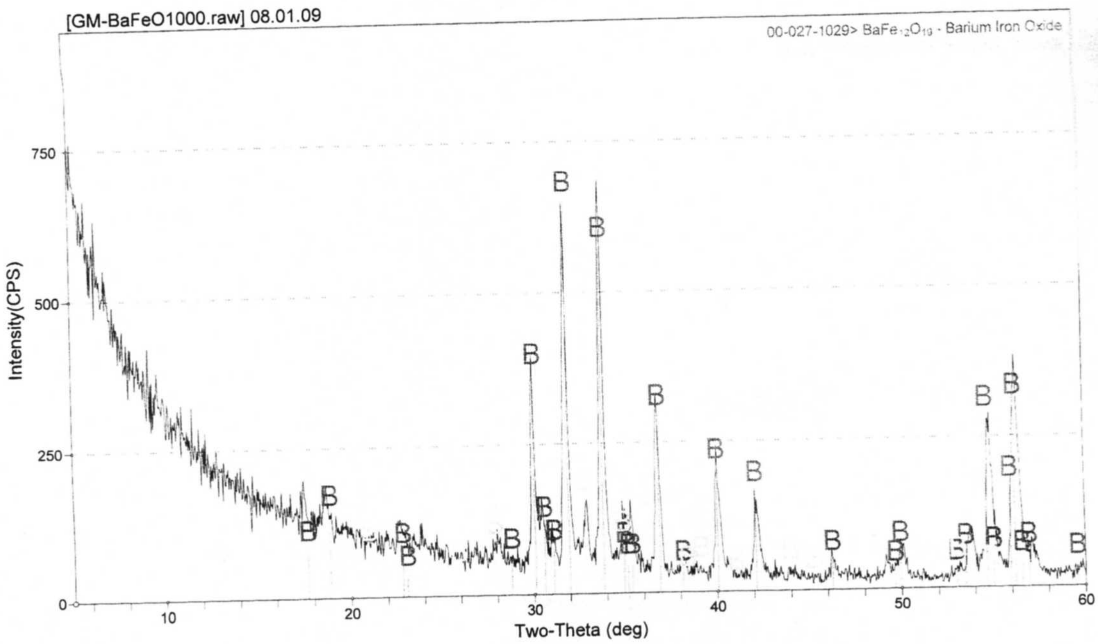

Fig. 2. X-ray diffractogram of synthesized ferrite nanopowder.

Characteristic stress-strain curves as well as selected mechanical properties of the investigated ferrite nanocomposites are shown in Fig. 3a-b. As one can see, with addition of ferrite nanofiller yield strength and ultimate strength of the composites is increased, while the respective relative deformations are influenced only insignificantly.

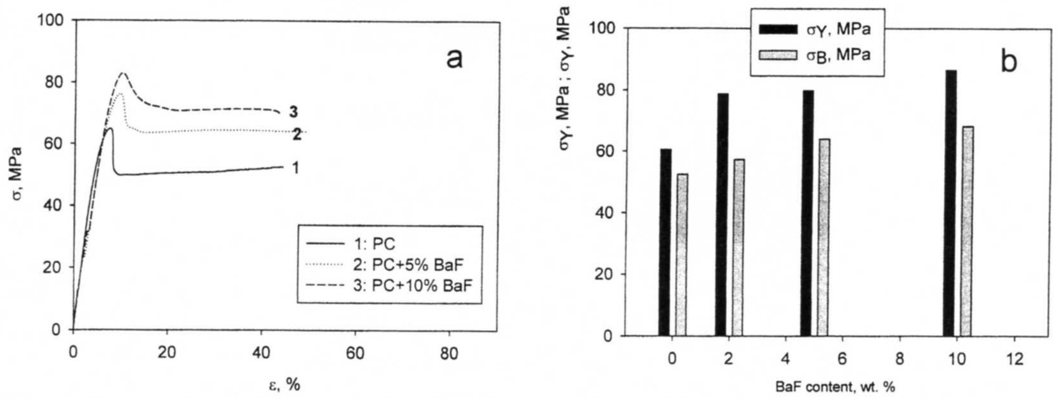

Fig. 3a-b. Stress-strain characteristics of ferrite nanofiller (BaF) reinforced PC nanocomposites: a- characteristic stress-strain curves of selected compositions; b- yield strength σ_Y and ultimate strength σ_B of the nanocomposites as functions of ferrite nanofiller content.

4. CONCLUSION

In this research Ba ferrite modified polycarbonate matrix nanocomposites were investigated. Auto-combustion route has been utilized for the manufacturing of the ferrite nanoparticles. By thermogravimetric investigations it was determined that recommended auto-combustion temperature of Ba ferrite (BaF) is 250°C. Obtained ferrite nanoparticles after calcination at 800°C have been introduced in the polycarbonate matrix by melt mixing. Structure and mechanical properties of the investigated nanocomposites were investigated. It was determined that crystallite sizes of the synthesized ferrite nanoparticles are close to 30 nm that is well below dimensions of the single BaF domains (580 nm). As a consequence mechanical properties of the nanocomposites were improved.

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