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EFFECT OF WASTE DISPERSION PHASES FROM THE EXTRACTION METALLURGY ON THE RHEOLOGICAL, ELECTRICAL AND MICROWAVE PROPERTIES OF NITRILE BUTADIENE RUBBER BASED COMPOSITES

D. Grigorova, N. Dishovsky, Vl. Iliev*

University of Chemical Technology and Metallurgy
8 Kl. Ohridski, 1756 Sofia, Bulgaria
** College of Telecommunications and Posts,*
Sofia, Bulgaria
E-mail: dishov@uctm.edu

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ABSTRACT

In the last few years the protection from the ultra high frequency electromagnetic radiations is of a particular importance. This paper presents investigations on the influence of fillers containing waste dispersion phases, generated from the gas cleaning equipment of the extraction metallurgy on the rheological, electrical and microwave properties of nitrile butadiene rubber based composites.

Keywords: rubber, waste powder, rheological, electrical, microwave properties reflection, attenuation.

INTRODUCTION

The biological influence of ultrahigh frequency electromagnetic radiations needs serious attention [1-2]. As a result the measurement, ecological assessment and protection from this type of radiations become very important in the last years due to the human health cares and quality of life and work improvement. In our previous publications [3-4] it has been shown that some waste dispersion phases from the extraction metallurgy rich in magnetite may be successfully used as functional fillers in rubber based composites.

This study focuses on the effect of these kinds of fillers on some electrical, rheological and microwave properties of NBR based composites containing different types of waste dispersion phases from the extraction metallurgy, rich in magnetite.

EXPERIMENTAL

Waste dispersion phases

Two groups of waste powder materials from the extraction metallurgy (obtained in “Kremikovtzi” JSC, Sofia, Bulgaria) have been studied by introduction as functional fillers in nitrile butadiene rubber matrix:

- Waste dispersion phase generated during the technological process as a result of gas cleaning activity in the LD – converter (sample 1),
- Waste dispersion phases generated from the starting materials used in the metallurgical production: blast furnace powders (sample 2) and electrostatic precipitator (ESP) powder from a sinter plant (sample 3).

For comparison an iron ore concentrate from “Krivoy Rog” (Ukraina) was used (sample 4).

The characteristics of the dispersion phases are described elsewhere [3] but all of them are rich in magnetite.

Composite preparation

The formulations of the used rubber compounds are shown in Table 1.Test samples were prepared by a two – roll mill (170 mm roll diameter, 300 mm length, speed of slow roll 16 min^{-1} and gear ratio 1,4) at a carefully controlled temperature, mixing time and gap between the rolls. The NBR (40% content of nitrile groups) was used. The vulcanization process of the rubber compounds was carried out in an electrically heated hydraulic press using a special home – made mold at temperature 160^{0}C and under pressure 12 MPa for 10 min. Samples in sheet form (90 X 60 X 2 mm) were prepared.

Measurements

Specific volume resistivity (ρ_v) of NBR composites was measured by Terraohmmeter Teralin III (made in Germany) both in static (isothermal) and dynamic (gradually increasing and decreasing the temperature) regimes. The measurements were carried out at pressures of 10, 15, 20, 25, 35 kPa on the samples surface [4].

The rheological properties of the green composites were examined by Brabender Plasticorder PLE 651 at speed of 30 min^{-1}. The change of the temperature during mixing process is evaluated by means of thermocouple situated directly in the mixing chamber. The variation of the torque with the time is also studied and used as a measure for the effective viscosity of samples.

The Hewlett-Packard waveguide line containing spectroanalyzer, powermeter, coefficient of reflection meter, and coefficient of attenuation meter, was used for measuring the microwave properties at the frequency of 1 GHz.

RESULTS AND DISCUSSION

Electrical properties

Effect of static pressure on the volume resistivity

The volume resistivity of tested samples as a function of pressure at 25^{0}C is shown in Fig. 1. The effect of increasing pressure on all NBR based composites is similar – the volume resistivity decreases. It may be explained with their type of conductivity, depending on the kind of the filler. As a result of decreasing the rubber layer thickness around the conductive aggregates and/or tunneling effects appearance due to the applied pressure on the samples, the current carriers motion become easier [4]. The difference in ρ_v between the samples containing different fillers is not considerable. It shows that at this filler concentration (100 phr) the percolation threshold where ρ_v decreases rapidly due to the physical contact among the conductive Fe_3O_4 particles is not reached yet.

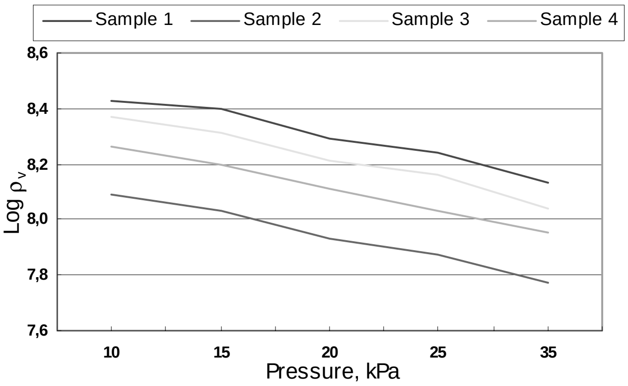

Fig. 1. Volume resistivity (ρ_v) change with pressure applied perpendicular to the surface of the samples.

Effect of temperature on the volume resistivity

Fig. 2 shows the temperature influence on the volume resistivity of nitrile butadiene rubber composites with different waste dispersion phases from the extraction metallurgy. It is clear that the volume resistivity decreases when temperature increases for all tested samples. Ion mobility and ion concentration increase with temperature. In the same time this temperature

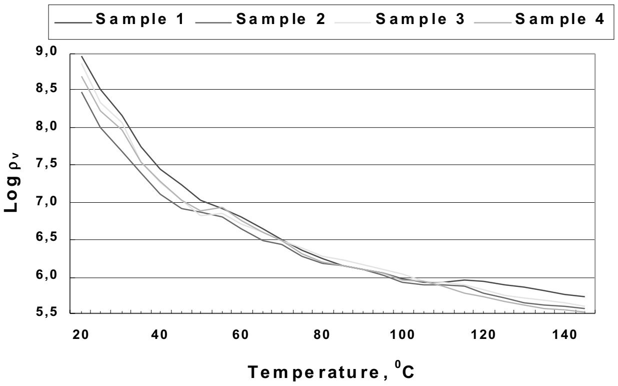

Fig. 2. Volume resistivity-temperature dependences for NBR composites filled with waste dispersion phases.

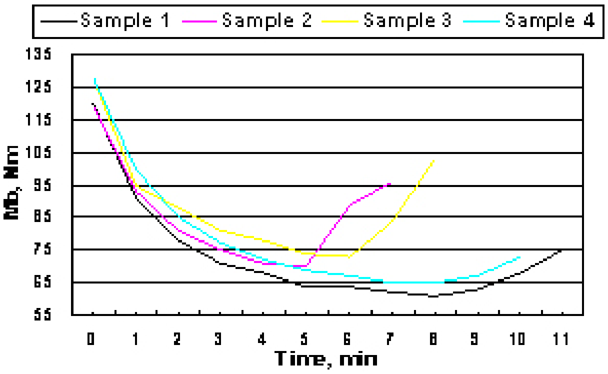

Fig. 3. Torque-time dependences for nitrile butadiene rubber composites filled with waste powders from the extraction metallurgy.

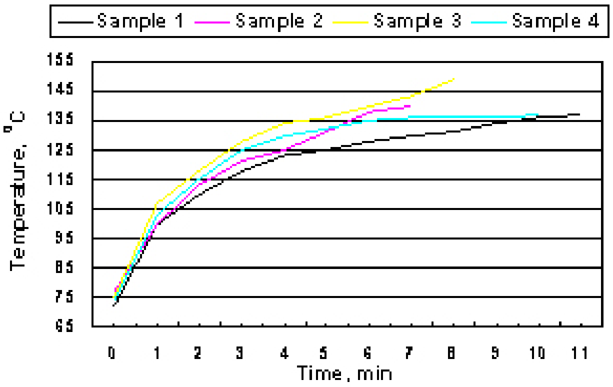

Fig. 4. Temperature time dependences for NBR based samples.

Table 1. Formulation of rubber compounds.

Ingrediens, phr	sample 1	sample 2	sample 3	sample 4
NBR	100	100	100	100
Stearic acid	2	2	2	2
ZnO	5	5	5	5
LDA	1	1	1	1
MBT	0,5	0,5	0,5	0,5
Sulfur	2	2	2	2
Acetylene carbon black	50	50	50	50
Filler	100	100	100	100

Vulkacit LDA, Zinc-N-diethyl dithiocarbamate (produced by Bayer); Vulkacit Merkapto (MBT) – 2-mercaptobenzothiazole (produced by Bayer)

Table 2. Microwave properties of nitrile butadiene based composites filled with waste dispersion phases at 1 GHz.

Microwave properties	sample 1	sample 2	sample 3	sample 4
Attenuation, dB/cm	2	1	2,5	5
Coefficient of reflection, %	15	7	6	4

increase makes the emission of considerable amount of electrons from the valence zone to the conductive zone easier. The difference in ρ_v between the samples is not considerable. It confirms the previous result that at this concentration the percolation threshold is not reached.

Rheological properties

Fig. 3 shows that the initial values of the torque are rather high. This is a result of the polar nature of rubber and high extent of filling. The curves for the different samples are similar – after the initial stage the torque considerably decreases which may be explained with the viscosity decrease when the temperature increases. In these conditions the samples turn into liquid-viscous state – the curves are smooth.

Sample 2 and sample 3 show a rapid increase of the torque after 5-6 minutes, which notices the vulcanization process beginning. For sample 1 and sample 4 the curves keep their fluent behaviour nearly to the end of experiment where they increase slightly. It shows that in these samples the vulcanization process is delayed. The temperature - time dependences for these samples are shown in Fig. 4. Sample 2 and sample 3 values are the highest of all and temperature release takes place.

These differences in the rheological behavior may be explained with some differences in the composition of the investigated fillers containing mainly metal oxides.

Microwave properties

The microwave properties of the vulcanizates, containing as fillers the studied waste dispersion phases are presented in Table 2.

The best from all studied NBR composites is the composite containing “Krivoy Rog “ concentrate (attenuation of 5 dB/cm and reflection of 4 % only at 1 GHz). The most effective from the waste dispersion phases is the ESP powder (attenuation of 2,5 dB/cm and 6% reflection at the same frequency). These two rubber composites may be used for production of protective materials and coatings against harmful influence of the electromagnetic waves at the frequency of 1GHz.

CONCLUSIONS

Some properties of NBR based composites containing waste dispersion phases from the extraction metallurgy used as functional fillers are investigated. The volume resistivity of nitrile butadiene composites filled with filler investigated decreases when the pressure and the temperature increase. The rheological behavior of the composites depends on the specific features in the composition of the studied fillers. Composites containing ESP may be used for production of protective materials against influence of the electromagnetic waves at the frequency of 1 GHz.

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