ON THE INTERACTION BETWEEN RUBBER BASED COMPOSITE MATERIALS AND MICROWAVE RADIATIONS

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Abstract

The present paper is focused on the clarification of the role of the rubber matrix nature and fillers crystal structure on the level of interaction between electromagnetic waves and rubber based microwave absorbers.

1. INTRODUCTION

The environmental impact assessment of microwave radiation is a very important activity in many branches of science, connected with the protection of human health, biological objects and environment. Electrical and electronic industrial or military equipments and devices can all be sources of unintentional electromagnetic radiation. As selected examples of the typical uses of equipment generating microwave radiation may be considered TV, radars - meteorological, air and ship-born, navigation, satellite communication, radio-broadcasting centers, microwave ovens, etc. In the same time in the last years reassuring evidences for the hazards of the electromagnetic waves action have been categorically provided. Taking in consideration the above mentioned, the objectives of the present paper may be formulated as follows:

On the base of a better understanding of some factors, influencing on the level of interaction between microwaves (as a technological hazard resulting from technological development) and solid materials (consisting of rubber matrix and solid dispersion system) to develop improved rubber based coatings for protection.

The investigations in the present paper are focused on the clarification of the role of the fillers structure and the rubber matrix on the level of interaction.

2. FUNCTIONAL FILLERS

A number of functional fillers may are added to the rubber for specific property improvements such as electrical conductivity, magnetic characteristics, microwave absorption, etc. Specifically, in our investigations, barium and strontium ferrites have been introduced in rubber matrices at very high loadings in order to improve the

magnetic or microwave properties and to make possible their application for prevention of electromagnetic pollution, microwave protection of humans, etc. The manufacture of rubber-based magnetic materials involves compounding of the ferrite with the rubber to achieve a uniform filler dispersion, followed by vulcanization to convert the raw composite material into the desired product. A knowledge on the vulcanization mechanisms of composite materials, containing hard magnetic substances as fillers is essential for proper equipment design, specifying the processing conditions, improvement of the microwave performance of the final products and for trouble-shooting. Problems arise in this specific case due to the existence of constant magnetic field around the hard magnetic filler particles (Figure1).

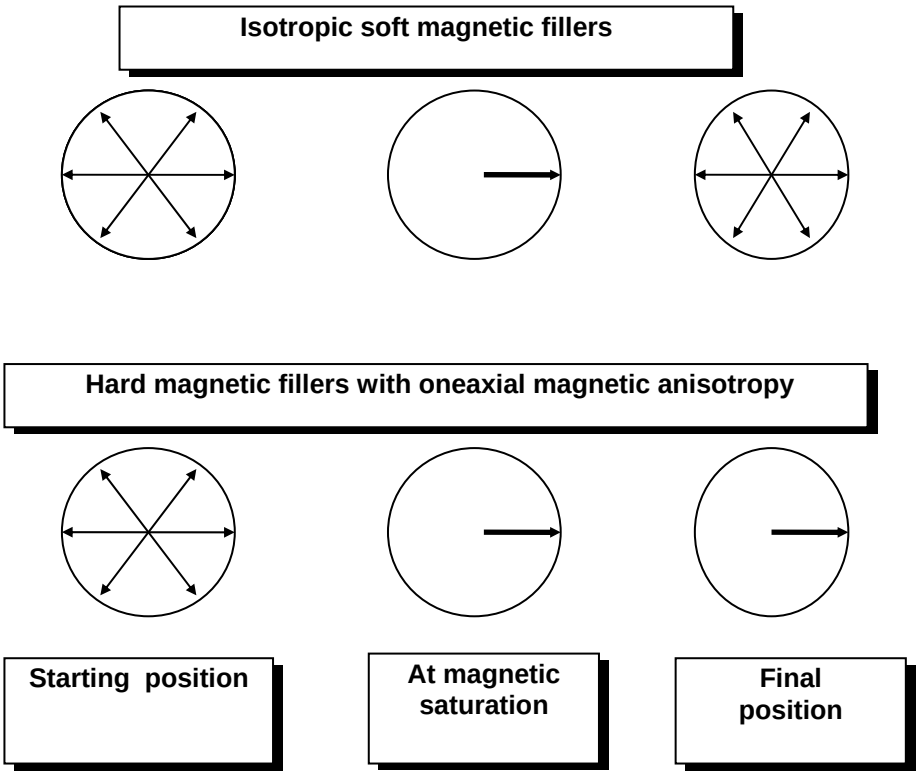
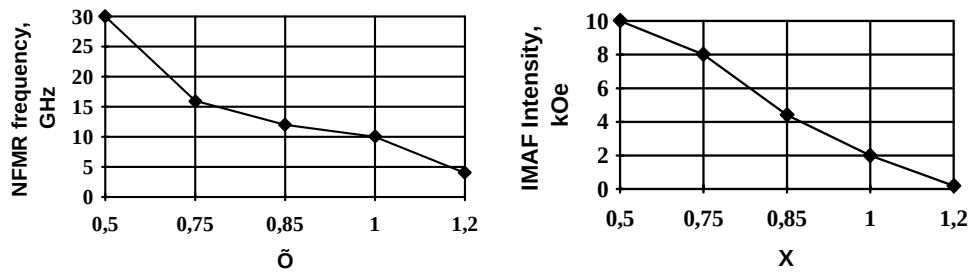


Figure 1. Distribution of magnetic moments vectors in isotropic soft magnetic fillers and in hard magnetic fillers with oneaxial magnetic anisotropy

The reason for these problems is the role of the interface phenomena and interface interactions at the rubber matrix - filler phase boundary, which are very important for all properties of the composite. In this connection the fillers with possibilities for purposeful changes in the structure as a way for interface phenomena and interactions managing have serious advantages in comparison with traditional ones in developing and formulation of specific rubber composites. Barium and strontium ferrites are one of the most suitable functional fillers with possibilities for structural changes, because

these changes may be easily realized by different extent of substitution of Fe^{3+} ions in ferrites crystal structure with Co^{2+} and Ti^{4+} ions during the fillers synthesis[1]. The substitution of the Fe-ions is based theoretically on the existing of three types of their positions in barium hexaferrites crystal structure in which the Co^{2+} or Ti^{4+} ions may be introduced. By the substitution of Fe^{3+} in the hexaferrite crystal structure one can change both the frequency of natural ferromagnetic resonance (NFMR) and the internal magnetic anisotropy field (IMAF) intensity (Fig.2) [1, 2]. It gives an opportunity for managing of these main hexaferrite fillers characteristics strongly influencing on rubber composites microwave and technological properties[3].



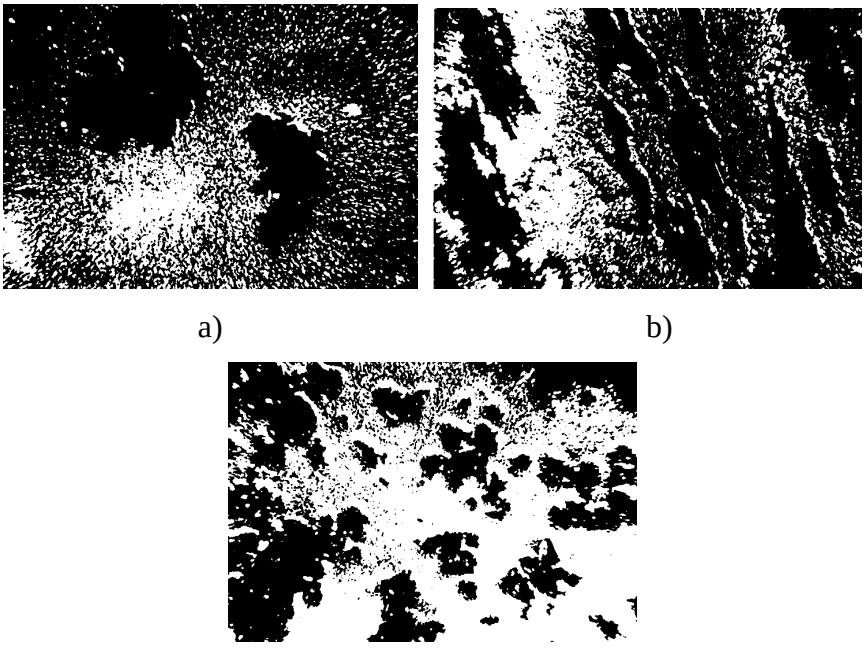
a) b)

Figure 2. NFMR frequency (a) and IMAF intensity (b) dependencies on the extent "X" of Fe^{3+} substitution in barium hexaferrites with general formula $BaCo_xTi_xMn_{0,1}Fe_{[12-(2x+0,1)]}O_{19}$

3. RUBBER MATRIX

In our investigations it was found also that the filler internal magnetic anisotropy field leads to structural microheterogeneities in the rubber matrix. The effects are especially well observed in the rubber layers located on and near the filler surface and cause differences in an optical activity in a polarized light due to differences in the structure ordering and the process of crystallization between these layers and another parts of the rubber matrix. The effects observed increase with the increasing of internal magnetic anisotropy field intensity (Fig.3).

It is clear from the optical microscopy pictures that the filler field of internal anisotropy demonstrates an orientating activity on the containing polar functional groups and sensitive to magnetic field action chemical bonds rubber macromolecules. It is due to the fact that the rubber macromolecules, containing polar functional groups, double and triple bonds have an exactly fixed values of their magnetic susceptibility.



a) b)

c)

Figure 3. Optical microscopy photographs in polarized light of rubber films, containing as fillers different in internal magnetic anisotropy field intensity substituted barium hexaferrites

The filler particles internal anisotropy magnetic field changes the susceptibility of the macromolecules, containing such kind of groups and bonds. In a result under the influence of the internal magnetic anisotropy field the polar rubber macromolecules may be easily orientated in the direction of the magnetic field action. The rising in a result specific effects of orientation in the rubber matrix layers, located near the interpface boundary cause structural and supermolecular microheterogeneities. By changing the internal magnetic anisotropy field intensity we can change on one hand the distance of the field influence on the rubber macromolecules and on the other hand we can manage the interface phenomena and rising in a result microheterogeneities, strongly influencing on all composite properties, including the vulcanization mechanisms and capability to absorb electromagnetic waves.

4. CONCLUSION

The hard magnetic fillers magnetic field influences not only on the macromolecules of the polar elastomers, but also on rubber to filler interactions and on the vulcanization mechanisms, due to the polarity of the vulcanizing system components and their location around and on the filler particles surface.

It is possible to manage the interaction between the rubber based protective coatings and microwave radiations by the managing of the field of internal magnetic

anisotropy of the hard magnetic fillers and the rubber matrix chemical nature and it may be considered as a promising technique both for improving of the polymer composites microwave performance and development of new protective rubber based coatings.

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