Magnetic Field Influence on Some Microwave Characteristics of Rubber Based Thin Films

R.I. Shtarkova[1], I.V. Petrova[2], N.T. Dishovsky[3], G.I. Krunev[4]

Abstract **- Thin films based on chloroprene rubber (CR) unfilled and filled with magnetite have been produced by magnetic modification method. Reflection and attenuation coefficients of the experimental films obtained were measured in the 8 - 12 GHz frequency range.**

Keywords **- Microwave Absorber, Magnetic Modification**

I. INTRODUCTION

The development and wide spread usage of microwave absorbers starts in the middle 30s of the previous century. The first absorber was patented in 1936 in Holland. In the Second World War absorbing materials were used for camouflage of military objects, especially submarines. After 1955 microwave absorbers start their market penetration. Nowadays microwave absorbers are mainly used for:

- protection of the environment and people from the adverse influence of high frequency electromagnetic radiation due to industrial and other sources;
- technical purposes like eliminating undesired signals and noise in radio- and television technique; in anechoic chambers;
- antiradar camouflage of mobile and fixed military structure and objects for reducing or altering the radar signature.

The main microwave absorbers' requirements are minimum reflection and maximum absorption of the electromagnetic energy. The ideal absorber has broad frequency range of the absorbing energy, excellent weather stability, light weight, characteristic reliability and capability to work in a broad temperature range.

Most of the contemporary microwave absorbers are produced of dielectric polymer matrix and specific functional fillers with high values of the imaginary part of the complex dielectric permittivity and magnetic permeability that absorb high frequency energy.

Nowadays in the making of microwave absorbers a lot of methods for physical impact exist, which help improving the properties of the final material. Such a method is so called magnetic modification, which modifies the properties of the material using external magnetic field. In our previous paper [1] a lot of properties of magnetically modified CR based films were investigated.

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The purpose of the present paper is to investigate the magnetic field influence on the reflection and attenuation coefficients of unfilled and magnetite filled CR based films.

II. SAMPLE PREPARATION

Chloroprene Rubber Baypren 320 (product of Bayer) was used as rubber matrix. Natural magnetite (particle size below 10 μ) was used as absorption active filler. The mixing process of the rubber with the filler was carried out by Brabender Plasticorder at 50ºC.

The rubber-filler ratio was 10-60 phr. The films (average thickness of 100 μ) were prepared from 2 mass % 1,2-dichloroethane solution of the rubber-filler composition. A paper with special treated surface was used as a substrate. Magnetic field with an induction of 0,60 T were applied for the period of 20 minutes during the film formation process. The magnetic field induction was controlled by teslameter. The samples were placed parallel and perpendicularly to the magnetic field lines of force.

Special experimental equipment was used for creation of constant magnetic field (Fig.1). The samples were conditioned for the period of 72 hours (for evaporation of the solvent and achievement of constant weight of the samples) before starting the measurement procedure.

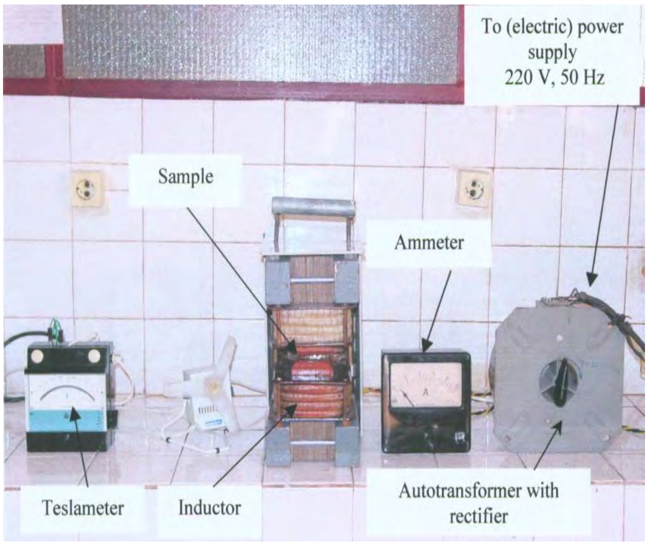


Fig.1. Experimental equipment for creation of constant magnetic field

III. SAMPLE TESTING

The scheme used to perform the measurements of the reflection coefficient (Fig.2) consists of:

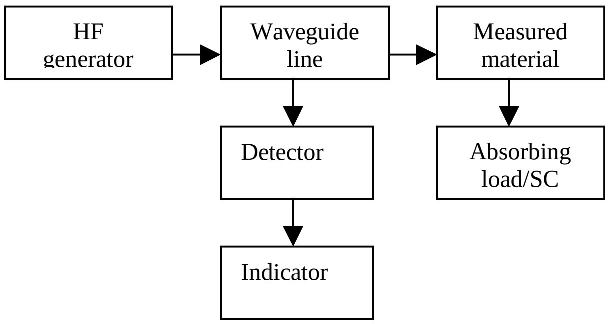


Fig.2. Experimental equipment for measurements of the reflection coefficient

The usage of short circuit (SC) is caused by the fact that most of the materials will be used over metal surfaces. In the same time measuring of the radio transparent materials (with few attenuation and suitable characteristic resistance) with short circuit at the end of the line will cause a lot of reflection coefficient. To avoid this the same measurement should be performed with absorbing load at the end of the line.

Measurements of the attenuation coefficient were performed in waveguide line (Fig.3):

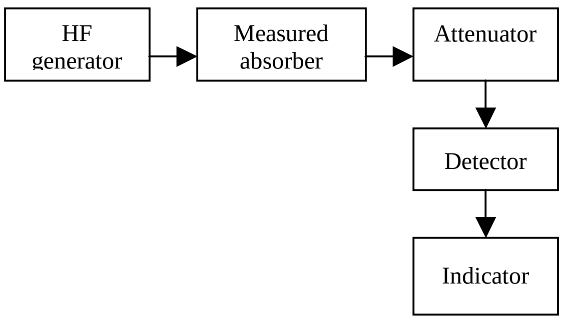


Fig.3. Experimental equipment for measurements of the attenuation coefficient

Measurement steps:

1. Without any absorber and using etalon power of the generator is measured the zero level of the indicator.
2. The absorber is placed and the level of the indicator changes.
3. The absorber is removed and using an attenuator the power of the generator's electromagnetic radiation is reduced while reaching the same level of the indicator.
4. The transition factor can be calculated using the attenuator's scale:

$$g = 10\lg\frac{P_1}{P_2}[dB] \qquad (1)$$

Here P_1 is the passed through the absorber power and P_2 is the generated initial power.

The attenuation of the absorber can be calculated using the following formula:

$$\Delta\alpha = 10\lg\frac{P_1}{P_2\left(1-p^2\right)}[dB] \qquad (2)$$

Here p is the reflection coefficient.
The relative attenuation depending on the thickness of the absorber is:

$$\alpha = \frac{\Delta\alpha}{d}[dB/mm] \qquad (3)$$

Here d is the thickness of the absorber in millimeters.

IV. RESULTS AND DISCUSSION

The external magnetic field influence on the polymer matrix properties is shown measuring test simples of CR without active fillers introduced in the matrix. Two types of samples were measured – the first one - magnetically modified and the second - with the same composition, but without magnetic treatment. In the 8 - 12 GHz frequency range the reflection and absorption coefficients of the samples are shown in figures 4-5:

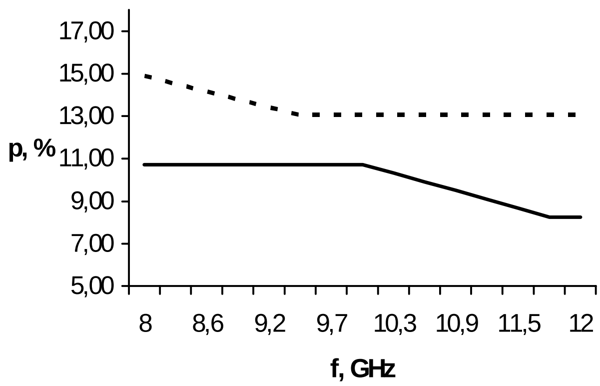


Fig.4 Reflection coefficient frequency dependence for the samples prepared without (…..) and with (____) magnetic field application during their preparation

It may be seen from the figure that the reflection coefficient of the magnetically modified CR is 20% lower than the coefficient of the control matrix.

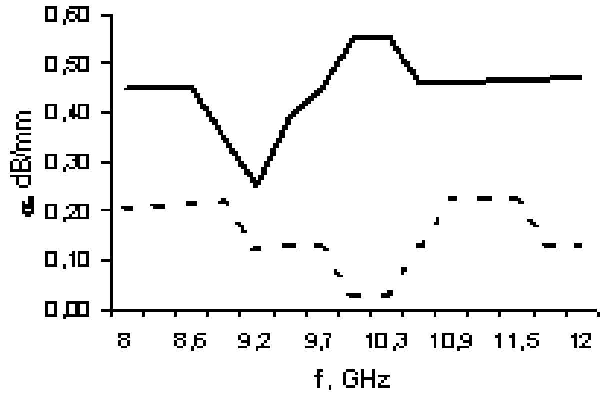


Fig.5. Absorption coefficient frequency dependence for the samples prepared without (…..) and with (____) magnetic field application during their preparation

The absorption coefficient of the magnetically modified matrix has increased two times in compared to those of the control matrix. It is clear that the magnetic field demonstrates an orientation activity on the rubber macromolecules, containing polar functional groups and sensitive to magnetic field action chemical bonds. It is due to the fact that macromolecules containing such type of structures have exactly fixed values of their magnetic susceptibility [2]. The applied external magnetic field changes the susceptibility of these macromolecules and as a result the macromolecules may be easily orientated in the direction of magnetic field lines of force [2]. The orientation effects, described also in our previous publications [1] cause structural and supermolecular microheterogeneities strongly influencing on all properties of the rubber [3], including the ratio between crystal and amorphous phase. In the absence of magnetic field the amorphous phase is localized in large areas, irregular distributed. When an external magnetic field is applied the dimensions of crystal and amorphous domain decrease and increase their numbers. A higher degree of organization and an increasing of the amount of the crystal phase may be observed as a final result. This is the reason for the changes observed in the values of the absorption and reflection coefficients.

The influence of the magnetic modification on the microwave absorbers may be assessed also measuring CR based samples filled with magnetite. The effects here mainly concern the influence of the magnetic field on the magnetite distribution in the rubber matrix. That material is magnetically soft and its particles orientation is highly dependant on external magnetic fields. The measurements were performed in a waveguide line. There were three measured absorbing samples - one control and two magnetically modified. For the first modified sample the direction of the external magnetic field is parallel with the H_{10} wave in the waveguide. For the second sample it's perpendicular (Fig.6).

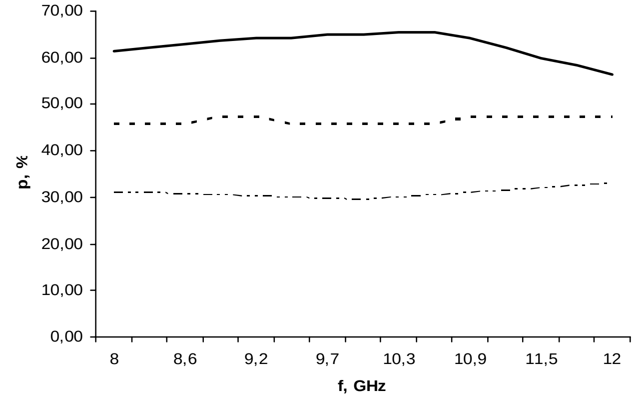


Fig.6. Reflection coefficient frequency dependence for the samples prepared without (…..) and with magnetic field application parallel (.._.. _..) and perpendicular (____) during their preparation.

The reflection coefficient of the sample modified with perpendicular field is higher than those of the non modified simple. The reflection coefficient of the sample modified with parallel field is lower than those of the non modified sample.
The absorption coefficient - frequency dependence of the samples investigated is shown on Fig. 7.

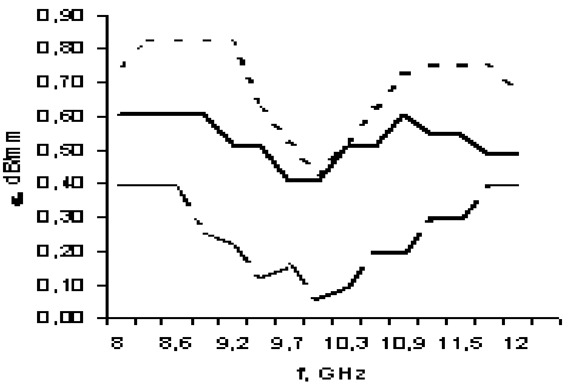
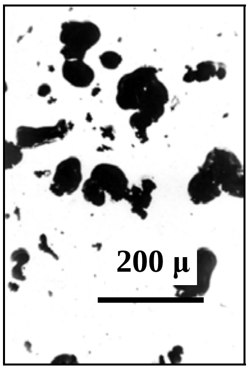


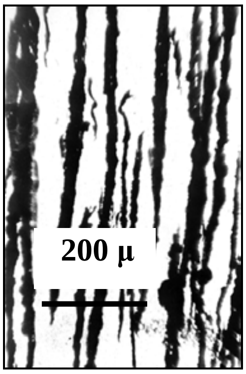
Fig.7 Absorption coefficient frequency dependence for the samples prepared without (…..) and with magnetic field application parallel (.._.. _..) and perpendicular (____) during their preparation.

The absorption coefficient of the no modified sample is the highest. The sample modified with a parallel magnetic field has the lowest absorption.
The application of magnetic field during sample preparation affects the filler particles ordering causing secondary structures formation guided by the direction of the magnetic field lines of force (Fig.8). That way the properties of the

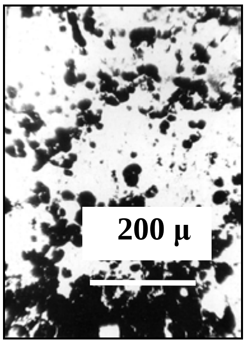
material (including microwave ones) could be changed in a direction assigned in advance.



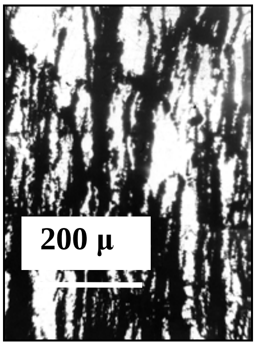
a) 10 phr Fe_3O_4, H=0



b) 10 phr Fe_3O_4, H>0



c) 50 phr Fe_3O_4, H=0



d) 50 phr Fe_3O_4, H>0

Fig.8. Optical microscope pictures (x 70) of CR films, containing different concentrations of magnetite (H=0, without magnetic field application; H>0- with magnetic field application)

V. Conclusion

All measurements performed illustrate how dependable are the properties of the rubber investigated from the direction of the external magnetic field applied during their modification. It causes artificial structuring of the dispersed particles of the filler in chain structures oriented in the direction of the magnetic field. This change the properties of the composite material and it assessed as anisotropy. More complete interpretation of these processes is possible in the case of measure the imaginary part of the complex dielectric permittivity and magnetic permeability in different directions, but that is out of sphere of this work.

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