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Physical Chemistry

Radio Wave Absorbing Polymer Composites with Electric Conducting and Magnetic Particles

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ABSTRACT. High (5-8 GHZ) frequency radio waves (RW) absorbing properties of the polymer composites on the basis of epoxy and silicone resin with fine dispersed graphite and ferrite were investigated. It is shown that the ability of absorption of these radio waves depends on the wave length, type of the filler and its concentration. Relatively high absorption is manifested for composites containing 40-50 wt % filler. It is established that high frequency absorption capability of the investigated materials essentially increases with the degree of homogeneity of filler particles distribution in the polymer matrix. It is shown that heterogeneity of the microstructure plays essential role in the absorption process. There is made the assumption that in micro-regions of the composites the resonance structures contributing to diffraction-interference phenomena exist – which is the main reason of absorption properties of the polymer composites. For the composites with ferrite and graphite the synergistic effect (non-additive increasing of some parameters at definite proportion of two or more fillers) was observed. The sandwich type samples containing three layers of absorbing materials differ one from another with different concentration of one and the same filler and with sequence of these layers in the sandwich with increased RW absorbing properties © *2019 Bull. Georg. Natl. Acad. Sci.*

Key words: polymer composite, electric and magnetic fillers, absorption of radiofrequency waves, synergistic effect, sandwich type absorber

Currently the problem of the absorption of high and ultrahigh frequency radio-waves, by different materials is the subject of great interest. It is significant for solution of many practical tasks [1, 2].

The absorbers of radio-waves (RW) present the structures or construction materials with established sequence of dielectric and magnetic properties. These absorbers are characterized with absorption of RW in definite interval of the frequencies at low energy of reflection and scattering [1]. These materials in the form of thin plates are often used in design of the cameras without echo with radio-engineering destination, for the protection of communication equipments and staff, etc [2, 3].

In the published scientific technical literature there is information about investigations of the RW absorbing properties of the polymer materials containing different type fillers (graphite, carbon black, carbon fiber, metal fine dispersed powders and their oxides) [4-6]. High effectiveness is reached in the coatings, in which the average diameter of the powder particles/fibers is nano-sizes [7,8].

The aim of the presented work is creation of the materials on the basis of new polymer composites containing electric conducting and magnetic fine dispersed powders, effectively absorbing RW.

Experimental. The composites based on Diane epoxy resin and fine dispersed graphite and ferrite (average size of the particles <50 mc) were selected. The composites were obtained by following manipulations: 1) mixing of ingredients in the spatial mixer; 2) formation of the blends in the cardboard forms with sizes 70x50x2 mm (in case of the sandwiches: 70x50x1 mm; 3) solidification of blends during 24 h at room temperature; 4) 3-fold sandwich type absorbers preparation by gluing the plates with thickness 1 mm.

The study of radio wave absorption by the obtained composites on RW was carried out on the installation presented in Fig.1.

and after reflection from it transfers to the second wave guide, oriented in rectangular direction to the first one, from which transmits through the receiver antenna 4 to the detector 6 and fixes as signal on the zero-indicator (measured in decibels). So the device gives possibility for RW intensity measuring of reflected waves with different frequencies from the range 4.5-7.5 GHz. After that, the sample is placed on the surface of the reflector plate and the manipulations described above repeat. By comparison of the intensities (in decibels) reflected from reflector without and with the sample one estimate the ability of the absorption properties of the composite. Test was provided in the following sequence: 1) switching of the device; 2) after 15-20 min the measuring of the intensity of reflected waves intensity from plate without sample; 3) displacement of the sample on the plate; 4) measuring of the wave intensity reflected from sample; 5) establishment of the absorption ability of the composite by comparison of intensities reflected from plate without and with sample.

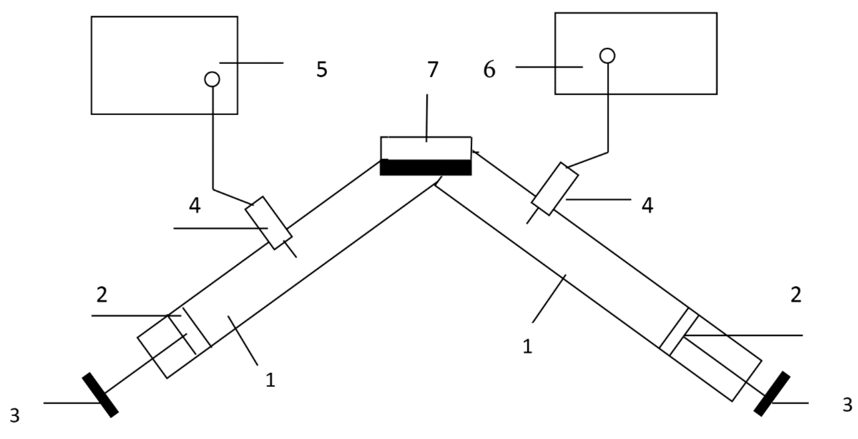

Fig. 1. The scheme of EMW absorption measuring device. 1 – waveguide of made from a brass sheet; 2 – agreeable piston; 3 – its handle; 4 – transmission and receiving antennas (the right includes the detector); 5 – super-high frequency generator; 6 – registrator of EMW intensity reflected from sample; 7 – copper plate reflector with sample (black rectangle).

The principle of working on the device is the following: RW generated on the generator 5 with use of the transmission transfers to the waveguide and falls on the reflector plate 7 (without sample)

Results and Discussion

The curves in Fig. 2 show that the value of the RW absorption depends both on composite composition and on the frequency of RW. Here one can see different extremes on the curves. The location of the minimums on the curves and their depths are dependent on the type and concentration of the fillers. Namely, the composite containing 20 wt% graphite is characterized by one minimum near 6.2 GHz and 7.2 GHZ frequencies, which correspond to 5 and 3 Db, respectively. The composite with 30wt% of graphite is characterized by analogical minimum near 6.3 GHz (8 Db), while for composites with 40 and 50 wt% such minimums (10.5 and 9.5 respectively) appear at one and the same frequency (6.2 GHz). The sample containing 50% of graphite show the similar minimums (9.5 Db at 5.5 and 6.2 GHz respectively). Composite with 40 wt% graphite appears the maximum of the RF absorption (10.5 Db).

The character of the considered dependences is based on the known phenomenon, which is responsible for the extremes of the properties at fixed concentration of the filler – on two competing processes (absorption and reflection of EMW). One of them increases at relatively low concentrations of the filler and the second one at relatively high concentrations, which is due to gradation of the filler absorption-reflection processes: at high concentrations the proportion of reflection in the reflected intensity increases, which leads to decreasing of the global absorbed intensity RW.

The main reason of absorption of the EMW can be ascribed to interference-diffraction phenomena, which usually take place in the heterogeneous composites. In this case high heterogeneity of the investigated materials and based on it heterogeneous character of the composite structure must be foreseen. It is admissible that the separate region of the composite can be differed structurally from the neighboring one. Respectively, the physical properties of the latter must depend on the region coordinates. In this case the RF absorption properties of separate regions differ one from another in result of realization of the individual diffraction – interference processes in these regions. Therefore the absorption properties of one and the same composition can be changed by monitoring of the material microstructure, in the other words by technological manipulations. The dependences of the absorption properties on the frequency of RW presented in Fig. 2. are expressed not only with the value of absorption but also with its dependence on the frequency of RW. This phenomenon probably is described in terms of difference in local microstructure, partially by the local resonances of diffraction-interference phenomena.

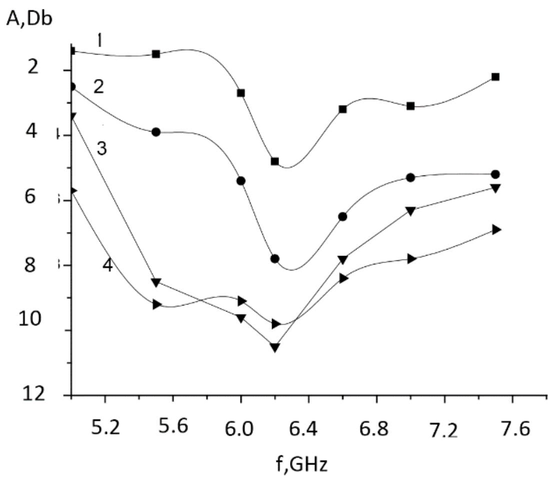

Fig. 2. RW absorption ability of the composites based on epoxy resin and graphite for following concentrations of the filler (in wt%): 20 (1), 30 (2), 40 (3), 50 (4).

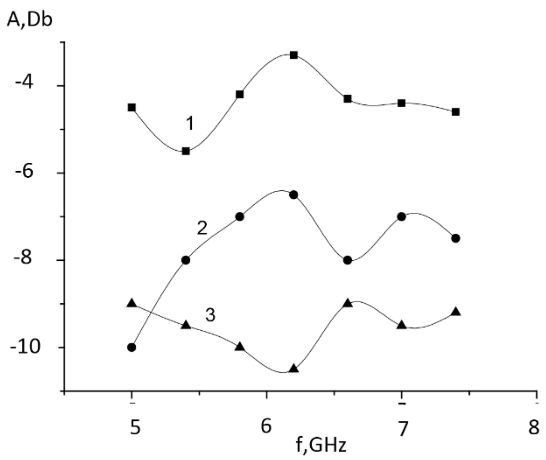

Fig. 3. RW absorption ability of the composites based on silicon rubber and graphite for following concentrations of the filler (in wt%): 30 (1), 50 (2), 40 (3).

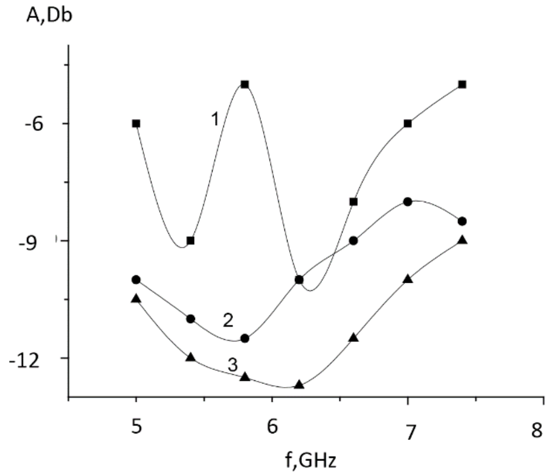

Fig. 4. RW absorption ability of the composites based on epoxy resin and binary fillers for following proportions graphite/ferrite of the filler concentrations (in wt%): 15/35 (1); 2 – 30/20 (2); 25/25 (3).

The data obtained in Fig. 4 allow us to express the opinion that the EMW absorption ability of the composites with binary filler essentially depends not so much on filler concentration but on the proportion of the components included to this combined filler. Here so called synergistic effect appears (the extreme dependence of the composite properties on the proportion of concentrations of two or more fillers, which is unreached in case of one component with any concentrations [9]). The best result (maximal absorption EMW) is reached for composite with 25 -25 wt% of the graphite and ferrite powders blend.

Table. RF EMW absorption ability of the sandwich type absorbers (f = 5.6 GHz)

Packing index	The sequence of the plates in the package (concentration of graphite in the plates) (the wave falls on the package from left side -plate with less content of the filler)	EMW absorption (in dB)
A	30 - 40 -50	-14.1
B	30 - 50 - 40	-12.3
C	40 - 30 - 50	-10.7
D	40 - 50 - 30	-10.1
E	50 - 30 - 40	-9.8
F	50 - 40 - 30	-9.5

It was interesting to establish the EMW absorption by polymer materials of sandwich type. In the Table there are presented the EMW absorption properties of such composites assembled from three plates filled with graphite at concentrations 30, 40, 50 wt%, respectively. Thickness of each plate was 0.5 mm. The plates in the package were located with a change in sequence.

In accordance with the Table the maximal absorption shows the package with index A, on which the wave falls from left side. The gradation of the absorption value presented in the Table is determined by following terms. In the first sample (package A) the wave will pass relatively "easy" package firstly through the plate with less content of the filler because of low concentration of the one (the processes of the wave absorption-reflection processes are relatively weak). The passing of the waves through the second plate, containing more (in comparison with the first plate) concentration of the graphite will absorb more amount of the EMW energy. The passing of EMW through the third plate will be characterized with more intensive absorption-reflection properties than in case of previous plates. The waves falling on the metal surface (after passing through the third plate) reflect with weakened energy from the latter and undergo repeated absorption-reflection processes and therefore the energy of the waves exiting from package will be essentially lower than that falling initially on the package. In case of wave falling on the package from the reverse side the energy of waves exiting from the package is more than in the first case because in the second case the wave falling on the third plate (with relatively high concentration of the filler) is reflected from it more intensively and therefore the part of absorbed energy is much less than in the first case.

Conclusions

In result of the study of the ability of RF EMW absorption composites based on epoxy resin with graphite and ferrite it is established that the composite composition (type and concentration of fillers as well as combination of lasts) is the main factor determining of the absorbing properties of polymer material. Partially it is shown that the composites with 40 and 50 wt% graphite are distinguished from others (20 and 30 wt%) with more high absorbing ability. Analogical conclusion may be made for composites based on silicones with the same fillers. They are characterized with extreme dependence of the EMW absorption level on the RF, which is due to peculiarities of the micro structure. The sandwich type samples (packages of thin plates) allow us to obtain effective absorbers of EMW by variation of the type and concentration of fillers in the plates taking into account the variation in the sequence of the plates.

ფიზიკური ქიმია

რადიოტალღების მშთანთქმელი პოლიმერული კომპოზიტები შევსებული ელექტროგამტარი და მაგნიტური ნაწილაკებით

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შესწავლილია გრაფიტისა და ფერიტის შემცველი ეპოქსი და სილიკონური ფისების საფუძველზე მიღებული კომპოზიტების მაღალი (5-8 გჰც) სიხშირის რადიოტალღების (რტ) შთანთქმის პროცესები. ნაჩვენებია, რომ მასალების მიერ რტ შთანთქმითი უნარიანობა მნიშვნელოვნადაა დამოკიდებული როგორც ტალღის სიგრძეზე, ასევე შემვსების ტიპსა და კონცენტრაციაზე.შედარებით მაღალი აბსორბციული თვისებებით გამოირჩევა კომპოზიტები, რომლებიც შეიცავს 40-50 მას.% შემვსებს. დადგენილია, რომ საკვლევი მასალების რტ შთანთქმითი უნარიანობა არსებითად იზრდება პოლიმერულ მატრიცაში შემვსები ნაწილაკების თანაბრად განაწილების ხარისხის ზრდასთან ერთად. ნაჩვენებია, რომ მიკროსტრუქტურის ჰეტეროგენულობა მნიშვნელოვან როლს ასრულებს აბსორბციულ პროცესებში. დაშვებულია, რომ კომპოზიტების მიკროუბნებში არსებობს რეზონანსული სტრუქტურები, რომლებიც განაპირობებს დიფრაქციულ-ინტერფერენციულ მოვლენებს და შესაბამისად რტ შთანთქმას. გრაფიტისა და ფერიტის შემცველი კომპოზიტებისთვის შემჩნეულია ე. წ. სინერგიული ეფექტი (ზოგიერთი პარამეტრის არაადიტიური გაძლიერება ორი ან სამი შემვსების გარკვეული

თანაფარდობით შემცველობისას). რტ შთანთქმის მაღალი მახასიათებლებით გამოირჩევა სენდვიჩური ტიპის ნიმუშები, რომლებიც ერთმანეთისგან განსხვავებული შემცველობის მშთანთქმელი მასალებისგან დამზადებული ფირების ერთობლიობას წარმოადგენს.

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