New radio-absorbing flexible materials based on a carbon matrix with various synthetic fillers and evaluation of their absorbing properties in the microwave range

Anton V. Kryukov, Alexander S. Eremeev

A.I. Berg Institute of Physics and Technology, http://www.mipt.ru/
Moscow 107078, Russian Federation
E-mail: minyyc@yandex.ru, eremeewalex@yandex.ru
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Abstract: A comprehensive analysis of the absorption coefficient of polymer composites with nonmagnetic carbon inclusions was carried out depending on their complex dielectric constant, material thickness in the frequency range 26-37 GHz. It has been experimentally established that corrugated composite surfaces lead to a significant increase in the absorption coefficient, and their filler is not the main obstacle to absorption, in terms of the possibility of improving their absorbing properties by changing the direction of the matrix structure and adding various fillers in the manufacture of microwave devices.

Keywords: carbon-based composites, absorber, contact impregnation, liquid surface tension, van der Waals forces, carbon filaments, amplitude-frequency characteristic (AFC), frequency ranges of GHz, elastic modulus, radio absorbing materials (RFM), microwave devices, impregnation under pressure

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1. INTRODUCTION

When developing microwave modules for their stable operation, radio absorbers are usually used, placed in a sealed module case (Fig. 1). Despite the existence of a wide range of such materials, the problem of obtaining an inorganic absorber remains urgent [1]. A large number of works are devoted to the study of the electromagnetic properties of composite materials based on various forms of carbon [2,3]. The interaction of electromagnetic radiation with nanocarbon composites shows the promise of their use for scientific and practical applications. Composites with carbon and nanocarbon inclusions are especially attractive as absorbers of electromagnetic radiation, for solving a number of practical problems, such as structural materials with absorbing properties in the microwave range in microelectronic cases.
Traditional shielding, absorbing materials are usually highly conductive and serve to block, absorb or redirect scattered (parasitic) radiation. As the operating frequency rises, the wavelength decreases, and the existing gaps between the material and the housing deteriorate the quality of the shielding.

Absorbers solve the problem of shielding at high frequencies of absorption of scattered radiation. When it comes to electronics, both consumer and specialty, designers strive to ensure the highest possible speed of operation with the widest possible functionality, which requires an increase in the number of components located in the most compact cases. When more components are enclosed in small spaces, developers have great difficulty. Such as incompatibility of certain components, the need to supply more power, which, in particular, leads to problems in terms of EMC caused by an increase in power and a high level of radio interference. As a result of all of the above, there are problems of EME oscillations in the resonator. The use of microwave energy absorbers helps to solve these problems [4]. That fully meets the requirements of OST 4G0.010.224-82 "Integrated microwave modules design".

2. PROCESSES OF MANUFACTURING ABSORBENT MATERIALS AND THE FACTORS THAT DETERMINE THEIR CHARACTERISTICS, DEPENDING ON THE FILLER

As the analysis showed, sheet absorbers of electromagnetic waves are most widely used as radio-absorbing coatings. Their important advantage is the possibility of joint use of several sheet layers with different characteristics of dielectric and magnetic permeability, as well as different values of transmission and absorption of an electromagnetic wave to create the effect of interlayer re-reflection. In addition, ferrite volumetric absorbers are used, which, due to the geometry of their construction, ensure maximum interaction of electromagnetic waves with the absorbing layer due to re-reflection and diffraction on periodic absorbing structures. Both methods show significant characteristics of absorption of electromagnetic waves in the radio range [6]. The disadvantages of these materials are the large thickness of the applied coating, the complexity of the application on parts of complex configuration (Fig. 2). In microelectronics, materials, which include carbonyl iron and...
ferrite, are mainly used as an absorber of microwave waves.

Based on this, the tasks of the study included obtaining prototypes of composite radio-absorbing coatings formed on the basis of existing materials using a polymer binder and using carbon fabric as a matrix on which the material was applied. In addition, in order to increase the absorbing characteristics, the coatings must have the following properties [7]:

1) the presence of a developed electrically conductive nano-network in the polymer matrix;

2) the presence of isolated from each other nanoparticles of a magnetic substance;

3) providing additional attenuation of electromagnetic radiation due to dielectric losses;

4) the presence of structural elements that contribute to the formation of Rayleigh scattering structures and zones where the waves are added in antiphase;

5) achieving a minimum difference in wave impedances at the radio-absorbing material / air interface.

As is known, low concentrations of carbon inclusions in composites make it possible to change the values of the complex dielectric constant of the polymer matrix and obtain a material with controlled absorption [5].

3. MANUFACTURING OF A NEW ABSORBING MATERIAL BASED ON A CARBON MATRIX WITH VARIOUS FILLERS

The process of obtaining a product includes several stages. The main stage should be the impregnation of a functional radio-absorbing filler with a polymer binder. URAL-N-100 carbon threads [8], (Fig. 3) were taken as a filler. The advantage of HCs for absorbing coatings is the strong shielding caused by the effect of depolarization. In composites based on nanocarbon inclusions, it is necessary to reach the percolation threshold to ensure substantial absorption [3]. When using carbon fibers with a regular cylindrical shape and a high ratio of transverse dimensions, the effect of depolarization can be neglected. The conductivity of the shock wave is sufficiently high, but the thickness of the skin layer in the Ka-zone exceeds the diameter of the fibers, so they interact with radiation with their entire volume. This makes it possible to create a composite with a high absorption coefficient at an inclusion concentration below the percolation threshold.

Two materials were used as a binder: 1) epoxy resin grade ED-20 GOST 10587-84, with a content of 0.8-1% (by weight) of the impregnated material and PEPA hardener TU2413-357-00203447-99; 2) adhesive sealant Elasil 137-180 grade B TU 6-02-1214-81. The carbon fabric was impregnated by the contact pressure method (Fig. 4). When impregnated with this method, the binder fills mainly the large pores, the spaces between the individual filaments, and also between the
filaments. Since the size of the tubules of elementary fibers is small in comparison with the size of the molecules of binding substances, the possibility of penetration of the impregnating solution into these tubules is excluded [9].

The impregnated material was dried at room temperature, after final polymerization, composite specimens were cut out of it (Fig. 5), and holes were made for fixing in a mandrel.

4. LABORATORY TESTS

Tests of the absorbing material were carried out to ensure the electrical tightness and shielding of solid-state microwave modules [10]. Carbon fabric impregnated with the method of contact pressure with a polymer binder was used as a spacer between the nickel-plated casing and the module's screen cover; fastening was carried out with screws. The tests were carried out on two types of microwave modules. The first was a 1x2 wideband power switch with an amplifier (≈20 dB) in the common path. The second one was a narrow-band noise signal generator, providing signal shaping and amplification to the required power level.

In Fig. 6 shows the decoupling of the switch arms without shielding covers (blue), with a shielded metal cover (purple) installed, with a carbon spacer and a shield cover (red) installed. The transmission coefficient measurements were carried out on a P2M-18A series scalar network analyzer. The use of a carbon spacer made it possible to increase the isolation of the switch arms by an average of 10 dB, which indicates the efficiency of using carbon fabric as an absorbing material to ensure the electrical tightness of microwave modules.

Due to the high gain of the noise generator module (about 110 dB), the stability of the module is low and without proper shielding leads to excitation. The irregularity of the spectrum without the use of a spacer, with the installed screen cover, is shown in Fig. 6. The transmission of the switch arms using different shielding options is demonstrated in Fig. 5.
cover indicates insufficient shielding of the module (Fig. 7, view a). The shape of the signal spectrum of the noise generator with the installed carbon spacer and the screen cover without irregularities demonstrates the stability of the module (Fig. 7, view b) Thus, the use of a carbon fabric impregnated with a polymer binder as an absorbing material for shielding microwave modules is justified.

5. CONCLUSION

The research results showed that a material based on a carbon matrix with various fillers as an absorbing material makes it possible to ensure internal and external electromagnetic compatibility in microwave devices. However, the question of material preservation and durability remains open. Research in this area is ongoing.

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