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Nanocomposite's features on the basis of correct packings of SiO_2 nanospheres

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Abstract - **Application potentialities of nanocomposites based on perfect SiO_2 nanospheres packings as metamaterials in SHF devices are considered.**

Keywords - **nanocomposites, metamaterials, SHF devices, SiO_2**

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Existence of usual electromagnetic waves with negative group speed is possible for environments with a sufficient strong spatial dispersion of dielectric properties that is caused by existence of non-local dielectric response and is expressed in the dependence of the generalized dielectric tensor ε_{ij} (ω) on the wave vector **k** [1]. Hence, the induction of electric field $D_i = \varepsilon_{ij}(\omega) E_j$ depends not only on the intensity of the electric field E (the local response), but also on the electric field in some vicinity; generally $B_i = \mu_{ij}(\omega) H_j$. A condition of applicability of classical approach (environment is also continuous) $\lambda \geq a$, where a is the parameter of the atomic sizes, for example the lattice constant or the length of electron-free run, etc. In usual materials ε(ω) and μ(ω) poorly depend on the frequency, but when any of structural parameters (a) becomes comparable to the length of a wave in the environment, the standard electrodynamic description of continuous environments becomes not applicable - it is necessary to consider the response of a material depending on coordinates.

Metamaterials are defined as the composites consisting of elements of the various form (nanoblocks), whose geometrical sizes (tens and hundreds nanometers) considerably surpass the atomic sizes. The last means that in μ (ω) it is impossible to neglect the contribution from the dielectric permeability (time-dependent) as the magnetic moment of unit volume is defined by currents of the electric polarization. The usual optical devices used for transfer of images, such as lenses or waveguides, operate exclusively with the extending spatial harmonics radiated by a light source. Therefore the spatial permission of such devices is limited from below by the wavelength – diffraction limit. In 2000 D. Pendri has offered idea of the superlens, capable to transfer a detail of the image much smaller, than the wavelength, on considerable (namely, wave) and the layer of a material with negative μ (ω) has shown distances, and that ε (ω) can create images in a wave zone of the source, possessing the ideal spatial resolution.

Though the superlens represents the basic interest for optics, at present materials with similar properties are created only in the microwave range of frequencies [2–3]. Creation of such environments in the infrared and optical ranges is complicated, as at these frequencies it is difficult to obtain resonant magnetic properties [4–6]. Created composites do not show magnetic properties at high frequencies. However, there is a possibility to transfer images with the superresolution using materials with the forbidden photon band (photonic crystals) as, under certain conditions, fading harmonics with corresponding polarization in such environments increase in the direction from a source as it takes place in metamaterials.

It is possible to assume that nanocomposites on the basis of correct packing nanospheres of SiO_2 (opal matrices) can find application in the range of centimeter and millimeter waves, namely, at much higher frequencies. The basic attention involves the range of frequencies and magnetic fields near the conditions of magnetic resonance that creates preconditions to use the given class of materials in operated devices. Effective interaction of electromagnetic waves of the millimeter range with *3D*-nanocomposites, consisting of opal matrices, both containing nanoparticles of nickel-zinc and manganese-zinc ferrite (Fig. 1) has been experimentally shown.

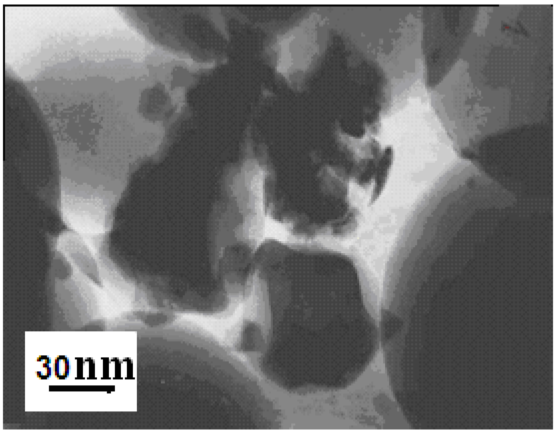
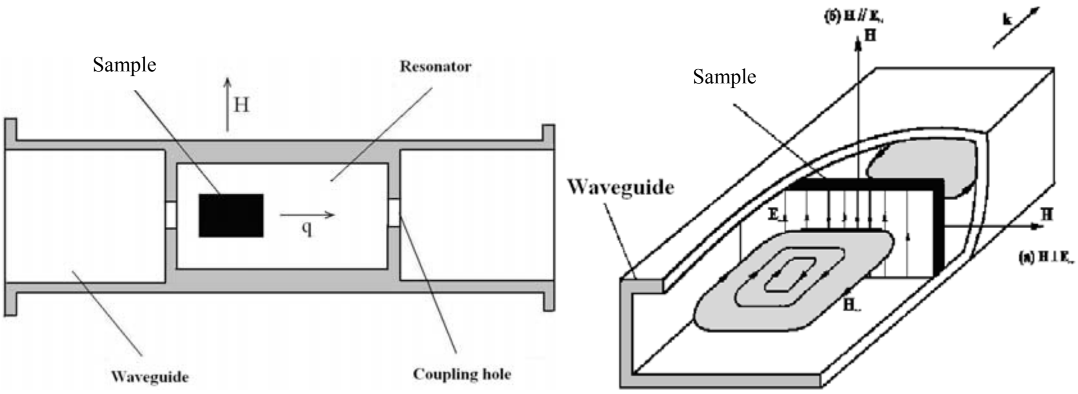


Fig. 1. Nanocomposites structure containing nickel-zinc spinel

The dependence of transfer factor of microwaves on the intensity of a magnetic field is defined by the magnetic resonance in magnetic nanocomposites. It is established that spectra of magnetic resonance contain an acoustic branch, and also separate resonances out of the specified branch are fixed. Interaction of electromagnetic waves of the millimeter range in rectangular resonators and in a waveguide operating on mode TE_{10}, with the specified opal matrices is studied in detail. It is proved that changes of the microwave signal, passed through the resonator with the sample of the matrix containing nickel-zinc ferrite, reach

60 %. Frequency dependence of microwave changes is measured. For orientation of fields $\boldsymbol{H} \perp \boldsymbol{H}_{\sim}$ the usual frequency dependence of amplitude of the resonant peak, when the amplitude increases with frequency growth, was observed. For orientation $\boldsymbol{H} // \boldsymbol{H}_{\sim}$ in a matrix containing nickel-zinc ferrite, the abnormal reduction of the resonance amplitude with increase in the frequency of used waves was observed.

Microwave measurements have been performed in the frequency range of 26–38 GHz with use of rectangular resonators and the standard waveguides working on TE_{10} mode. For performing microwave measurements the sample was located in the rectangular resonator or in a waveguide (Fig. 2). Thus the sample was placed along the SHF-path axis at placing in the resonator and across a path at placing in a waveguide. The external constant magnetic field $\boldsymbol{H}$ created by an electromagnet was put perpendicularly to the wave vector $\boldsymbol{q}$ if the sample is placed in the resonator. In the case when the sample is in a waveguide, the external magnetic field lays in a plane of the sample either in parallel or perpendicularly to the microwave electric field $\boldsymbol{E}_{\sim}$.



a) b)

Fig. 2. The scheme of arrangement of the sample in the resonator (a) and in the waveguide (b).

Simultaneously, the frequency dependence of coefficients of transmission and reflection from nanocomposites in the absence of an external magnetic field (Fig. 3) has been measured. It is established that in the range of frequencies from 26 to 38 GHz the reflection cofficient as a whole decreases, and the transmission coefficient as a whole increases with the increase in the frequency. The frequency dependence for nanocomposites with entered nanoparticles of nickel-zinc ferrite is expressed more strongly. The share absorbed in the nanocomposite without an external magnetic field makes capacities from 5 to 20 %.

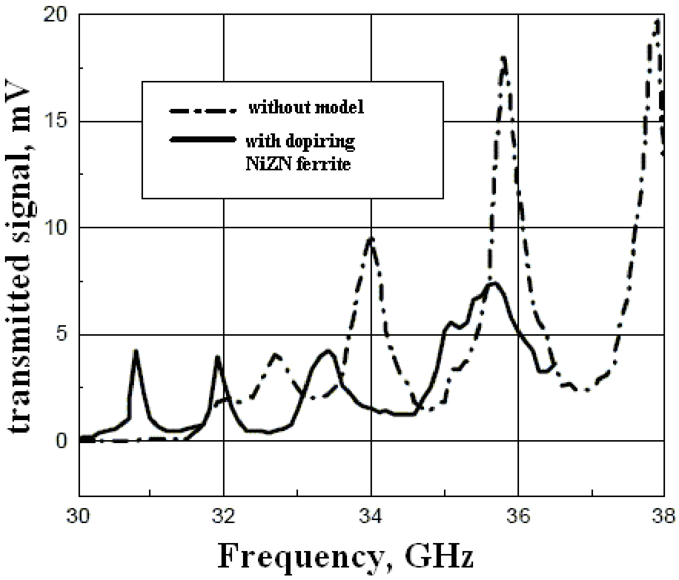


Fig. 3. Frequency dependence of the signal passed SHF-path with the resonator.

Thus, nanocomposites with forbidden photon bands and regions of abnormal increase of density of photon state represent doubtless interest from the point of view of control of wave characteristics and creation of new effective sources of the electromagnetic radiation. Interest is caused, first of all, by opportunities of application of such structures for creation SHF-waveguides and tiny SHF-devices of various type which can be used for transfer of processing of the information.

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