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53rd Internationales Wissenschaftliches Kolloquium
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S.V. Drobot, V.K. Berezovsky, V.N. Rusakovich

Determination of Complex Permittivity of Nanocarbon Composites using S-parameter Measurements in Rectangular Waveguide

NANO MATERIALS AND PROCESSING

Carbon-based structures play an important role in designing of materials which effectively absorb and shield electromagnetic radiation [1]. It is caused by unique properties of carbon. Tuning of an electromagnetic response of the composite in a wide frequency range has been achieved by inclusion of ensembles of nanostructured elements of the various sizes into the dielectric matrix [2]. A recently discovered form of nanocarbon – onion-like carbon (OLC) – possesses a unique structure, satisfying the criterion of hierarchical assembly with tunable conductivity and ability to absorb EM radiation in a wide frequency band [3]. OLC in comparison to other carbon structures has a higher potential for development of shielding materials for a microwave range (2−38 GHz) [4-5]. Design of coating with the specified parameters of microwave shielding and absorption requires knowledge of the complex dielectric permittivity of the initial material – onion-like carbon.

Waveguide methods for determination of substances permittivity used at present are based on measurement of complex S-parameters and require the expensive equipment – vector network analyzers [6].

A novel technique is presented in which the complex permittivity of the OLC powder is determined by results of measurements in the waveguide only magnitudes of S-parameters. A sensor as a rectangular waveguide section containing a three-layer structure is used by the method. The rectangular waveguide section between two dielectric plates which are located perpendicularly to waveguide walls is filled by the tested material – OLC powder. Determination of the complex permittivity is an inverse electrodynamic problem [7]. A solution of the inverse problem is extraction of the complex permittivity $\dot{\varepsilon} = \varepsilon' + j\varepsilon''$ from its indirect displays – measured magnitudes of the reflection coefficient $|\dot{S}_{11M}|$ and the forward transmission coefficient $|\dot{S}_{21M}|$ of the sensor containing the tested material. The inverse problem is formulated as the problem of search of criterion function minimum

$$U(\dot{\varepsilon}) = \left(\left|\dot{S}_{11C}(\dot{\varepsilon})\right| - \left|\dot{S}_{11M}(\dot{\varepsilon})\right|\right)^2 + \left(\left|\dot{S}_{21C}(\dot{\varepsilon})\right| - \left|\dot{S}_{21M}(\dot{\varepsilon})\right|\right)^2,$$

where $\left|\dot{S}_{11C}\right|$, $\left|\dot{S}_{21C}\right|$ – magnitudes of the coefficients of a wave scattering matrix of the sensor, which are calculated by use of the expressions obtained on the basis of an exact solution of a direct boundary electrodynamic problem of diffraction for the sensor.

The software was designed for realization of the technique. Numerical experiments for definition of efficiency and accuracy of operation of computational algorithms on a test geometry of the sensor which is intended for measuring of the complex permittivity of hypothetical material in 8-mm band of wavelengths were carried out. Obtained results have shown a stability of operation of the computing procedures and a possibility of definition of the complex permittivity with a required error.

We would like to thank Prof. Sergey Maksimenko and Dr. Polina Kuzhir for helpful discussions.

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