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Composites Based on Dielectric Materials for Microwave Engineering

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Abstract—Composites provide possibilities to combine the properties of different materials in order to obtain materials with the necessary parameters (low loss, absorbing, reflective materials, etc.). According to their structure, composite materials are conventionally divided into the microtextures and macrotextures. In turn, these materials may be passive or active. The properties of passive composite materials are invariable, and the properties of active ones can be altered using different effects: electric, magnetic, thermal, etc. In this article we present the results of theoretical and experimental investigations of various microwave dielectric-based composite structures. Particular attention is given to high-Q microwave structures with electrical control.

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1. INTRODUCTION

Achievements of microwave microelectronics are based on the results of radiophysical investigations of the interaction of electromagnetic waves with the dielectric, semiconductor and magnetic materials. Through years of researches there were implemented physical fundamentals for the creation of a new class of frequency-selective structures based on dielectric resonators, which provided a new way to solve the problem of miniaturization of microwave equipment and to design the devices with previously unattainable performance.

In order to expand the potential capabilities of microwave devices based on them one needs to carry out further investigations on a comprehensive study of physics of phenomena occurring in dielectric materials in order to design high-Q, thermally insensitive, linear and nonlinear materials with high value of permittivity, as well as absorbing and reflecting materials. Also there are such actual problems as the tuning of resonance frequencies holding high quality factor, high thermal stability, the thinning of eigenoscillations spectrum, obtaining and removing of degenerating oscillation modes. One way to solve these problems is the utilization of composite materials.

Composite dielectrics can combine the properties of different materials to obtain the required characteristics. Therefore, the purpose of this article is the investigation of properties of various composite materials and structures based on dielectrics for their further application in the design of microwave devices.

Filled polymers are the most widespread in the microwave applications. For example, by mixing the polymer, whose $\varepsilon = 2$ and $\tan(\delta) \sim 10^{-5}$ (Teflon), with a fine-dispersed ceramics, that have $\varepsilon = 100$ and $\tan(\delta) \sim 10^{-3}$ (rutile), we can obtain composite microwave dielectrics with $\varepsilon = 2$–40 and $\tan(\delta) \sim 10^{-3}$. These materials are widely used in the devices of centimeter and decimeter wavelength bands. On the other hand, the matrix composites of Teflon with miniature quartz spheres allow one to obtain dielectrics with low value of $\varepsilon = 1.3$–2, which are used in the millimeter range devices.

Hereinabove we present the examples of microtextured microwave dielectric composites, in which the dimensions of the inhomogeneities are considerably less than the wavelength of the electromagnetic wave (Fig. 1, the left branch). The flexibility, relatively simple technology, low dielectric losses and tailored permittivity $\varepsilon = 1.1$–50 are the distinctive features of these microtextured composites.