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Study on effect of barium titanate concentration in epoxy-based composite towards dielectric material properties

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ABSTRACT

The properties of dielectric material can be controlled either by combining new composite materials or by altering the composition between the filler and matrix materials. This paper focuses on the development of epoxy-barium titanates composites at different filler concentrations and their relationship with dielectric properties. Epoxy resins are frequently utilized for their affordability, ability to withstand high humidity and resistance to chemicals. Meanwhile, barium titanate is recognized for its high permittivity. When these two materials are combined, they can create a high permittivity value that is advantageous for the design of small and compact antennas. In this work, five samples of different epoxy resin-barium titanate composites are made, at five different volume ratios of filler (5 vol%, 10 vol%, 15 vol%, 20 vol%, and 25 vol%). A low volume of filler results in a lower permittivity value due to the quantity of filler being less than the volume of the matrix base. Adding nano powder barium titanate to the matrix base can increase the permittivity of the composite material. However, when the volume of filler is too high, it may agglomerate, which can adversely affect the electrical performance. In this work, the complex permittivity of composite materials of epoxy resin and filler barium titanate is measured between 4 and 6 GHz using the waveguide technique. The results showed that the permittivity of epoxy-barium titanate grows continuously as the filler volume increases.

1. Introduction

In the past decade, researchers have studied the effect of reflection for medical probes which depend more on the composite material structure rather than the types of metal or group element used. Composites are more effective in insulation performance compared to metals because of their fundamental characteristics [1]. Composite materials are valuable in the medical sector due to their advantageous properties such as lightweight, high stiffness, low-cost, and biocompatibility. Composite materials are created by mixing or combining two or more different materials which have various electrical and physical properties [2,3,4]. One of these materials is known as the matrix and the other main material is reinforcement in the form of fibers or particles to improve the matrix characteristics [1]. Examples of composite matrix that can be used are polymer, metal, environmentally friendly biodegradable filler, or ceramic [5,6,7]. Epoxy resin is used as a polymer matrix in many high-technology applications due to many factors such as low-cost material and high chemical resistance [8,9]. Furthermore, due to their high permittivity, ceramic nanoparticles such as barium titanate ($BaTiO_3$) are considered very promising fillers in improving the dielectric and functional properties of nanocomposites [10,11,12].

Existing composite materials are easy to use since the composite materials already have their own dielectric permittivity values. For example, the previous works [13] and [14] have demonstrated the use of existing composite material Teflon with permittivity of $2.08 - j0.001$ and the result shows that the value of the reflection coefficient, S_{11} are $-$ 25.42 dB and $-$ 9.82 dB, respectively. Since the applicator is not designed with careful consideration of the impedance matching with liver tissues, S_{11} value is slightly high. This is not ideal for effectively radiating microwave power into the very crucial target area. However, in the medical sector, low dielectric permittivity values tend to produce higher characteristics impedance which increases the reflection coefficient value. Several methods have been proposed in the literature to prepare composite materials [9], which involve mixing filler and base material with an overhead stirrer and removing any trapped air bubbles in a vacuum chamber. The composite is then cured in a vacuum oven

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