# Epoxy-Barium Titanate Nanocomposite Fabrication Process and Dielectric Properties at S and G Band

*Nurulfadzilah Hasan[1]*, Nurul Hazlina Noordin[2], Mohamad Shaiful Abdul Karim[2], Nurhafizah Abu Talip Yusof[2], Mohd Ruzaimi Mat Rejab[3]*

[1]*Faculty of Electrical and Electronics Engineering Technolgy, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia.* [2]*College of Engineering, Universiti Malaysia Pahang, Gambang, Pahang, Malaysia,* [3]*Faculty of Mechanical & Automotive Engineering Technology, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia.*
**nurulfadzilah@ump.edu.my*

**Keywords**: PERMITTIVITY, NANOCOMPOSITE, DIELECTRIC MEASUREMENT

## Abstract

This paper focused on the fabrication of epoxy-barium titanate nanocomposite and its dielectric properties at S-band (2 to 4GHz) and G-band frequencies (4 to 6 GHz). The nanocomposite is fabricated by mechanically mixing the two materials and curing agent together. Then the mixture is let to cure in a controlled environment. Permittivity and loss tangent of the nanocomposites were measured using dielectric probe technique. Results show that both the permittivity and loss tangent of the nanocomposite increases as the filler content increases. The highest permittivity is achieved at 40 vol.%, which is around 16. However, agglomeration of filler particles in the matrix is a problem that must be overcome, when fabricating the nanocomposite, especially in higher filler concentration.

## 1 Introduction

With rapid growth of electronics communication system today, the demands for high permittivity dielectric polymer-ceramic nanocomposite is increasing. Composite materials are produced by combining two or more materials, by means of mechanical mixing, which will change the materials' electrical and mechanical properties [1]. One of the attractive features of composite material is that its electrical and mechanical properties can be tailored to fulfil the specific needs of the intended applications. Besides, composite material is reported to exhibit high performance, but maintains low cost, small size and weight [2].

Epoxy resin is a type of low-cost thermoset polymer, formed through step-wise or chain-wise polymerization reactions [3]. It has high stiffness and good adhesion, which makes it widely used in automotive, aerospace and electronics industries [4]. However, it has low permittivity value of around 2 to 5 [5], which makes it unsuitable for some electronics applications such antenna substrate, in capacitors, energy storage applications, microelectronics packaging and others. To increase the permittivity, epoxy resin is often mix with high permittivity ceramic nanopowder, to form epoxy-ceramic nanocomposite. Barium titanate, BaTiO3 (BT), is the most common filler used in epoxy-ceramic composite, and is widely used in many electronic components [6]–[18]. The permittivity of nanosized BT at room temperature is between 3,500 to 6,000 [5]. The resultant nanocomposite's permittivity depends on many factors, such as the filler grain size, shape and size of the polymer crystals, impurities, and the type of processing techniques used [19] [3].

There are two primary methods of fabricating epoxy-barium titanate (epoxy-BT) nanocomposite. The first technique is by using solvent methods, in which both matrix and fillers, are disperse in organic solvent. Then the mixture is thoroughly mixed either using ball milling method or ultrasonic agitation. The solvent is then evaporated before epoxy curing agent is added and finally, the mixture is let to cure inside mold [1]. Researchers that applied this method claim that homogeneous dispersion of nano powder filler inside the matrix is achievable. Another way is by thoroughly mixing solid filler into liquid form matrix using mechanical mixer, before adding curing agent. The composite mixture is then let to cure in the appropriate environment [2]–[6]. The later method is an easier and direct approach compared to the former method, since the matrix is already in liquid form. However, careful, and thorough mixing is needed to ensure homogeneous dispersion of nano powder filler into the matrix. The later method is applied in this paper and will be explained more later in the article.

The focus in this paper is to fabricate epoxy-BT nanocomposite and investigate the dielectric properties of epoxy-BT nanocomposite at 2 to 6 GHz. The electrical properties of interest are the permittivity and loss tangent (dielectric loss). Permittivity of a dielectric material, is expressed using complex number as shown in equation (1) below:

$$\varepsilon = \varepsilon_r{}' + \varepsilon_r{}'' \quad (1)$$

Where $\varepsilon_r$' is the real part and $\varepsilon_r$" is the imaginary part of complex permittivity.

The imaginary part of complex permittivity indicates the amount of energy loss from the material because of an external electric field, whereas the real part represents the amount of