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Microwave Propagation in Circular Waveguide made of Epoxy and Fused Silica Composite

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Abstract— Epoxy-Fused silica composite was created by mixing the Fused silica and Epoxy using powder processing methods. Fused silica powder has worked as a filler material in the epoxy material. This paper represents the design, fabrication, and testing of the circular waveguide fabricated from Epoxy-Fused Silica polymer-ceramic composite. The dielectric loss of the composite is viewed as 0.0012 at 9.5 GHz, which is lower than the dielectric loss (0.012) of the unfilled epoxy. The dielectric consistency of the composite (€r 2.5) roughly continues as before as the unfilled epoxy. Thus, a new material composite is formed, and the rod is fabricated for X band applications. The rod is sputtered using a silver target as-deposited material. So, a circular waveguide is formed for the low loss microwave propagation. The insertion loss of the circular waveguide was found 0.49 dB. Thus, a circular waveguide is formed with polymer and ceramic composite a new material for low loss microwave applications. The practical value holds good in agreement with the theoretical approaches.

Keywords—ceramics, polymers, composite, microwave, waveguide

1. Introduction

The business is developing at an extremely quick rate and the prerequisite for the recently made material is generally there for the high-recurrence applications. There are different polymers and clay materials and there are composites currently accessible in the business for high-recurrence applications. Nonetheless, they have limits in their utilization on account of the constraint in the mechanical, warm, and electrical properties. Their handling cost is a significant variable for creating gadgets which is usable in the microwave recurrence district. Pottery materials have prevalent microwave dielectric, attractive, warm, and mechanical properties. Notwithstanding, the creation cost of ceramics is high [2]. The weakness and high handling temperature of ceramics lead to trouble in the manufacture of mind-boggling shapes or machining substrates during circuit creation. The significant disadvantage of the polymers is their high worth of the coefficient of warm development, mediocre attractive properties, and low warm conductivity [3-5]. A blending of polymers and clay materials can successfully determine the handling cost as well as handling challenges with adjusted electrical, warm, and mechanical properties [1, 6-8].

Epoxy has been utilized at large scale in numerous sorts of RF and microwave applications like radome, substrates, and tars for conductive surfaces for joining the gadgets. They have fantastic synthetic and consumption obstruction properties. The assembling of epoxy has been less expensive, and it tends to be handled at lower temperatures. The dielectric misfortune (€r 0.012 @10 GHz) of the epoxy has been high and this limits the utilization of the material for different other microwave applications. Their greatest working temperature ultimately depends on 150 °C just [9].

Melded Silica is a fantastic straightforward material in the microwave frequency range for radio transmission and radome applications. They have magnificent thermal properties, and their greatest working temperature depends on 900 °C. Their dielectric consistent is 3.7 in the X band range dielectric misfortune is 0.0004 [10]. Notwithstanding, its handling cost is extremely high, and it required a sintering temperature of 1220 °C roughly.

The blending of the Fused silica and Epoxy makes a polymer ceramic composite that shows excellent machinability, lower powder handling coat, and lower digression misfortune properties. The intertwined silica has been utilized as a filler material in the epoxy tar.

Epoxy-based Silica composite has proactively been explored in different avenues regarding development in its electrical, warm, and mechanical properties. [11-14]. The high-recurrence proliferation in a Circular Waveguide made of Epoxy-Fused Silica Composite has been explored in this paper. This recently made material was utilized as a roundabout waveguide for the microwave engendering at X-band. The inclusion loss of the roundabout waveguide was estimated,

2. Theoretical approach

The roundabout waveguide was planned in HFSS for TEM Mode. The limited component strategy is perhaps the best recurrence space computational technique for electromagnetic recreation. The technique's fundamental benefit is its ability to treat any sort of math and material inhomogeneity without a need to adjust the definition or the PC code. That is, it gives mathematical loyalty and unlimited material treatment. A roundabout waveguide is a cylindrical, roundabout guide. A plane wave spreading through a roundabout waveguide brings about cross-over electric (TE) or cross over attractive (TM) mode.[15]

The plan of the roundabout waveguide is made in the HFSS recreation programming. The determined model arrangement is chosen for the recreation. The design in the HFSS is as below in Fig. 1. The waveguide is filled with the vacuum and the assigned boundary condition is finite conductivity. The excitation is provided at both the wave port.Fig.1 Circular waveguide in HFSS, The Design of a circular waveguide with an inner diameter of 7.383 mm (0.938 in.) In HFSS. The outer wall of the waveguide is assigned a boundary condition called finite conductivity or perfect E. with this assumption, the port is defined within a waveguide. The frequency range for the simulation is 1-18 GHz. The output for the different modes of the port was analysed. In simulations, the dialectic constant of the Epoxy-Fused silica composite was chosen to 2.3 and tangent loss was chosen to 0.00013.

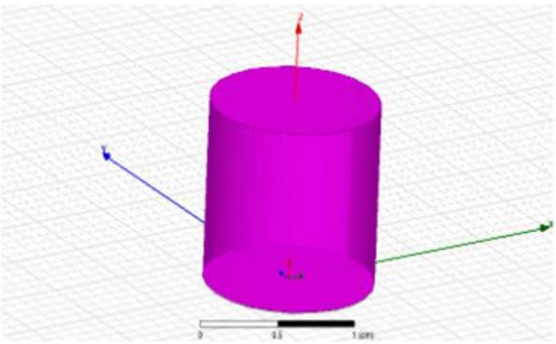

Fig: 1 Circular waveguide Simulation in HFSS

The size of the polymer ceramic composite was found to be approximately 32.2 mm (length0 and 7.4 mm. The metallic layer of silver over the composite was created of 1.5 microns.

In simulation results, the insertions loss of the circular waveguide was found 0.51 dB.

3. Experimental procedure

Epoxy & Fused Silica composite was fabricated using the powder processing technique [1]. The fabricated slab was used to make a circular waveguide of lengths 32, 2 mm, and 7.4 mm. in the machine shop using the surface grinding machines.

The bare rod was then brought to the sputtering area and the following processes were carried out in a closed environment.

- The Epoxy-Fused silica rod was first cleaned in an ultrasonic cleaner for 5 minutes so that deposited dust particles are washed out.
- The rod was then heated to 150 deg° under an oven so that moistures content at the surface of the rod was removed and evaporated.
- The rod was then fitted on a rotating jig a kind of structure that takes that is suitable to provide an earth like rotation. The rod rotates in a circular motion and also rotates around its axes.
- A silver layer of 1.5 microns was deposited over the Epoxy-Fused Silica composite rod. The operations were carried out in a closed chamber under a vacuum of 10e-5 torr.
- The rod was then removed from the chamber and coating of lacquer was done manually to protect the silver layer from the external environments and air contacts.
- The sputtering machine that was utilized in the this operation has been given in Figure:2

Figure 2: Sputtering machine used in making circular waveguide.

(Courtesy, Millman Thin Film Systems, India)

The Fabricated Circular Waveguide made of Epoxy and Fused Silica Composite has been shown in figure: 3.

Fig: 3 Fabricated Circular waveguide using Epoxy & Fused Silica Composite

4. Results & discussion

The fabricated Epoxy-Fused silica composite rod was then tested using the Keysight Performance Network Analyzers. The test setup for the measurement has been shown in figure: 4.

The S parameter testing was done for the fabricated rod. The test setup was calibrated first the nullify the cable and waveguide to coaxial and the test set up losses. The S21 results found for the fabricated waveguide rod is 0.49 dB. S11 and S22 were found to be -9.8 dB. From these results, it is observed that the dielectric material inside the waveguide was entirely changed. Its new material is called Epoxy and Fused silica composite. The composite is behaving properly with respect to microwave propagation. The waveguide is still a low-loss channel to propagate the signal from one end to another end.

The Epoxy and Fused Silica composite material are easier to manufacture, and it has got a better property with respect to the unfilled epoxy. The composite is low-loss material with respect to unfilled epoxy. The tangent loss for the unfilled epoxy was 0.0120 and the tangent loss for the epoxy and fused silica composite was found 0.0012. The Thermal and mechanical properties of the composite are better with respect to the unfilled epoxy the summary of the properties is given in the table below.

Sl. No	Properties of the Bare Polymer	Properties of the Composite
1	Tangent Loss: 0.012	0.0012
2	Density: 1.15 gm/cc³	1.33 gm/cc³
3	Tensile Strength: 70 Pa	47 MPa
4	Coefficient of Thermal Expansion: 60.7ppm/°C	57 ppm/°C

Table1: Properties of the Bare polymer and Composite fabricated.

From the properties given in the table above it is better in terms of thermal and mechanical properties. It can be used as a low lossy material for microwave applications.

5. Conclusion

The Epoxy and Fused Silica composite was used to fabricate the circular waveguide for wave microwave applications. The composite slab was machined to create the bare circular rod. The bare rod was sputtered in a close chamber in the silver target. The sputtered rod creates a circular waveguide that is filled with epoxy-fused silica composite. The measured S –parameter results of the circular waveguide were found satisfactory, and it is found suitable for the low loss microwave propagation.

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