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Enhanced microwave absorption properties of samarium-doped $BiFeO_3$ Composites: Structural and electromagnetic analysis

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ABSTRACT

The increasing use of electromagnetic (EM) technologies has raised concerns about electromagnetic interference (EMI), which can affect electronic systems and human health. Bismuth ferrite, $BiFeO_3$ (BFO), is a promising material for microwave absorption due to its multiferroic properties, but it faces several limitations that affect its performance. This study aims to enhance the microwave absorption efficiency of BFO composite by modifying its structure and electromagnetic properties through samarium (*Sm*) doping. The undoped BFO and *Sm*-doped BFO samples were prepared using solid-state reactions and then incorporated into an epoxy resin polymer matrix with a ratio of 70:30 wt% to create a composite. The magnetic and dielectric testing demonstrated enhanced magnetization and improved dielectric properties, which significantly contributed to better impedance matching and a higher attenuation constant, leading to greater microwave absorption efficiency. Microwave absorption tests conducted in the 8–18 GHz range demonstrated significant improvements for *Sm*-doped BFO composites compared to the undoped BFO sample. Notably, the *Sm*-doped BFO sample with 0.2 *Sm* concentration and a thickness of 2 mm achieved a significant reflection loss (*RL*) of −22.3 dB at 12.8 GHz. It also had a broader effective bandwidth compared to undoped BFO, showing improved microwave absorption due to samarium doping. These results demonstrate that *Sm*-doped BFO can improve the limitations of current MAMs by offering better absorption, broader bandwidth with a single layer and optimal thickness.

1. Introduction

Microwave absorbing materials (MAMs) are specifically designed to absorb incident electromagnetic (EM) radiation and minimize the reflection of EM waves by converting them into heat or other forms of energy. By minimizing reflectivity, MAMs are widely used in various applications, including stealth military systems to avoid radar detection during warfare and in civilian sectors to protect manpower and equipment from EM hazards. For such applications, efficient MAM should possess a lightweight structure, strong absorption ability across a wide frequency range, thin thickness, tunable absorption frequencies, ease of processability, and cost-effectiveness [1,2]. Significant research efforts have been dedicated to designing materials that meet these requirements, and various absorbing materials have been developed for effective EM wave absorption [2–5].

Ferrite-based MAMs have garnered significant interest due to their combination of magnetic and dielectric properties offering promising performance to absorb electromagnetic radiation in the microwave frequency range. These materials offer significant advantages, including a wide frequency absorption range, tunable electromagnetic parameters, high reflection loss, and good impedance matching [6,7]. Despite these advantages, ferrite absorbers are restricted by their high density, thick required matching layers, and poor environmental stability [8]. Combining ferrites with polymers can improve absorption by enhancing dielectric and magnetic losses. Ferrite-polymer composites result in better impedance matching and broader absorption bandwidths [9,10]. These materials offer better microwave absorption, mechanical strength, and thermal stability [1,11] and can be easily adjusted by

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