P.6: Absorbing material development for RF and Microwave systems

Electromagnetic interference (EMI) and electromagnetic compatibility (EMC) represent significant challenges in contemporary high-power Radio-Frequency (RF) systems. As RF power levels increase, unintended radiation and signal reflections can adversely affect system performance, induce instability, and disrupt the operation of adjacent electronic devices. Electromagnetic absorbing materials offer an effective mitigation strategy by attenuating stray electromagnetic waves. These materials are essential for ensuring compliance with EMI/EMC standards and for maintaining the stability of RF amplifier systems. However, conventional microwave absorbers are often bulky and exhibit limited efficiency due to suboptimal impedance matching. This limitation has motivated the development of advanced magneto-dielectric composites, which provide advantages such as reduced weight, mechanical flexibility, and enhanced broadband absorption, making them highly suitable for applications in electromagnetic shielding, anechoic test chambers, and RF amplifier integration. This work was carried out under a BRNS-funded project through a collaborative effort between CMET Trissur (MeitY) and RRCAT, highlighting the strength of interdisciplinary and inter-institutional cooperation. The project was successfully completed in December 2025 and received favorable evaluation and commendation from the BRNS review committee, underscoring its technical merit and application relevance.

This article presents a magneto-dielectric composite absorber laminate engineered for EMI/EMC mitigation in RF systems. The composite incorporates carbonyl iron, barium hexaferrite, and polyaniline within a silicone matrix to achieve combined magnetic and dielectric loss mechanisms. Surface functionalization of the fillers using silane coupling agents enhances interfacial compatibility, environmental stability, and hydrophobicity. Barium hexaferrite was synthesized via solid-state reaction and sintering, followed by nanoscale size reduction through ball milling at CMET Thrissur (Fig. P.6.1)

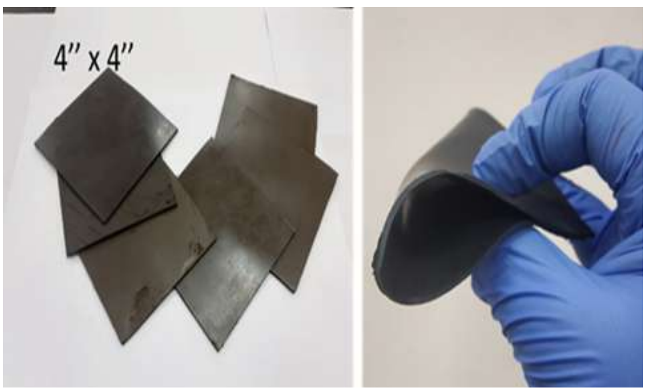

Fig. P.6.1: The developed microwave absorber

Polyaniline was prepared by oxidative polymerization. The silane-treated fillers exhibited improved dispersion within the matrix. Composite laminates were fabricated using controlled mixing, two-roll milling, and thermo-lamination, resulting in uniform and structurally robust materials.

The laminates were characterized using XRD, Raman spectroscopy, SEM, and IR analysis to confirm structural integrity and surface modification. Its electromagnetic performance was evaluated using an automated RF test bench (Fig.P.6.2). Two identical 1-5/8″ EIA coaxial airline test jigs were designed and fabricated, with the absorber sample positioned between them for measurement. The average insertion loss (S21) and return loss (S11) were measured as 0.35 dB and 23.53 dB, respectively, over the DC to 4 GHz frequency range. High-power RF characterization was conducted using indigenously developed solid-state amplifiers. The calculated absorption exceeded 88%. The material exhibited no signs of degradation under both low-power and high-power excitation. During high-power operation, the sample temperature remained stable in the range of 28–30 °C, indicating good thermal stability.

Fig. P.6.2: Automated RF Test bench for testing absorber sample at high power

This work demonstrates the potential of advanced composite materials to significantly enhance the reliability and operational stability of RF and microwave systems while effectively mitigating electromagnetic interference across diverse RF applications within DAE environment. The proposed approach offers a robust and scalable solution for EMI/EMC management, with clear advantages in terms of performance, adaptability, and material efficiency. Furthermore, the developed composites exhibit strong potential for deployment in both defense and commercial sectors, where stringent electromagnetic compliance and high-power handling capabilities are critical.

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