

Seminar

Institute for Plasma Research

Title: MXene Quantum Dot–Ni@NCS Hybrid Composite for High-Efficiency X-Band Microwave Absorption

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Abstract

The X-band region of the electromagnetic spectrum is very crucial for communication based technologies like radar systems, satellite communication, and advanced wireless technologies etc; however, achieving strong and broadband electromagnetic absorption (EMA) within this band remains challenging due to limitations in impedance matching and energy-attenuation mechanisms of conventional materials. In this study, we develop a highly efficient X-band absorber based on epoxy-resin-embedded $\text{Ti}_3\text{C}_2\text{T}_x$ MXene quantum dots (QDs) and Ni-loaded nitrogen-doped carbon sheets (Ni@NCS). $\text{Ti}_3\text{C}_2\text{T}_x$ MXene was first synthesized from Ti_3AlC_2 MAX phase using a LiF/HCl solution-etching route, followed by the preparation of MXene QDs through an ammonium hydroxide-assisted hydrothermal method. These QDs were subsequently integrated with Ni@NCS-derived from pyrolyzed ZIF precursors-to fabricate the qM_Ni@NCS/Epoxy composites.

The synergistic incorporation of conductive MXene QDs, defect-rich N-doped carbon sheets, and magnetic Ni nanoparticles enhances dielectric loss, magnetic loss, interfacial polarization, and multiple scattering pathways. Consequently, the qM_Ni@NCS-5_2mm sample delivers exceptional performance, achieving an RL_{min} of -56.7 dB at 2 mm thickness and an effective absorption bandwidth (EAB) of 3.1 GHz with 45 wt% loading. These findings validate the material's outstanding promise for advanced X-band stealth and EMI-shielding technologies. Furthermore, this work opens pathways for future development of thermoplastic polyurethane (TPU)-based auxetic composite foams incorporating the same hybrid absorber system, enabling multifunctional applications that combine microwave absorption with mechanical impact attenuation for next-generation protective structural systems for electronics and subsystems from unwanted electromagnetic radiation.

Keywords: Microwave Absorption, Zeolite Imidazole Framework (ZIF).
