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Processing–Structure–Electromagnetic Property Relationships in Tannin-Derived Carbon Xerogel/Carbonyl Iron Composites for X-Band Microwave Absorption

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Introduction

Tannin-derived carbon xerogels are promising bio-based materials for microwave absorption applications due to their tunable dielectric properties. When combined with carbonyl iron in a silicone rubber matrix, these materials form hybrid composites that integrate dielectric and magnetic loss mechanisms. Understanding how xerogel synthesis conditions, carbonization temperature, and filler concentration influence electromagnetic properties and impedance matching is essential for optimizing microwave absorption performance in the X-band (8.2–12.4 GHz

Objectives

To investigate how xerogel synthesis time, carbonization temperature, and filler loading influence the structural characteristics, complex electromagnetic properties, impedance matching, and X-band microwave absorption performance of tannin-derived carbon xerogel/carbonyl iron composites.

Methodology

Xerogel synthesis: Tannin-derived carbon xerogels prepared using two synthesis times (45 min and 24 h).Carbonization: Thermal treatment at 700, 800, and 900 °C.Composite preparation: Incorporation of 1.0 or 3.5% carbon xerogel and carbonyl iron into a silicone rubber matrix.Structural characterization: Scanning electron microscopy (SEM) and X-ray diffraction (XRD).Electromagnetic characterization: Complex permittivity and permeability measurements in the X-band (8.2–12.4 GHz) using a vector network analyzer and the Nicolson–Ross–Weir method.Microwave absorption analysis: Evaluation of reflection loss, impedance matching, and thickness-dependent absorption behavior through electromagnetic simulations



Figure 1. Tannin powder chemical process



Figure 2. Samples

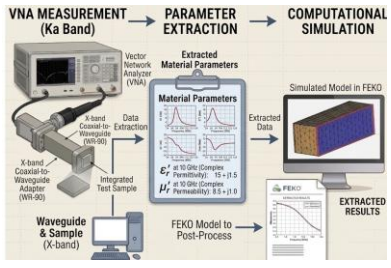


Figure 3. Properties Analysis

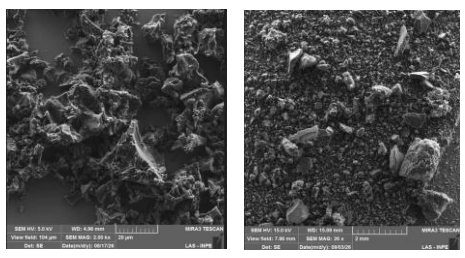


Figure 5. MEV Microscopic characterization

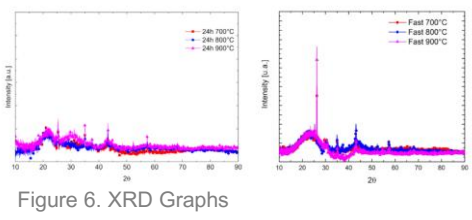


Figure 6. XRD Graphs

Results and Discussion

Increasing xerogel content from 1.0 to 3.5% enhanced dielectric losses. The frequency-dependent permittivity and permeability showed increased properties in the 3.5% composites, specifically in the fast ones. The best performance was obtained for the fast-processed 3.5% composite carbonized at 900 °C, reaching −21.5 dB at 1.9–2.5 mm, with a reported absorption efficiency of 99.3%. These results highlight the combined influence of xerogel loading and processing conditions on microwave attenuation.

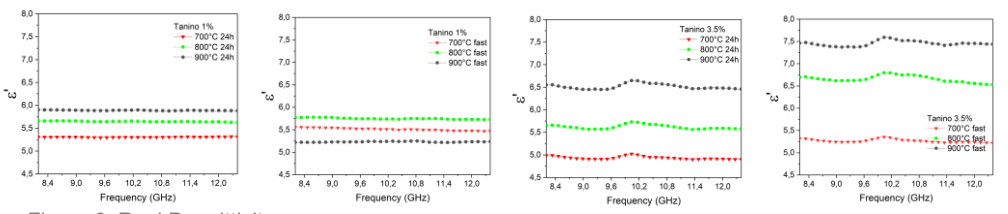


Figure 6. Real Permittivity

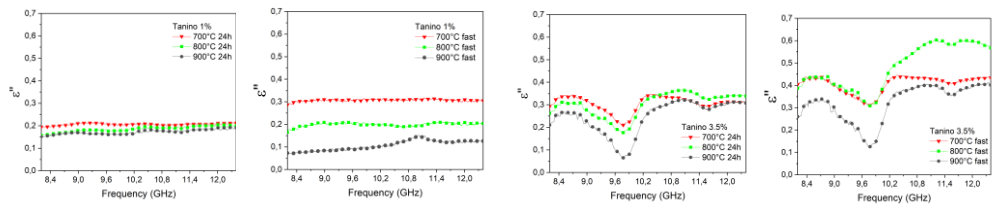


Figure 7. Imaginary Permittivity

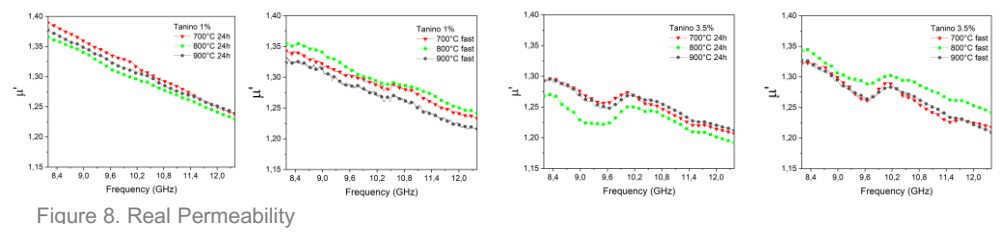


Figure 8. Real Permeability

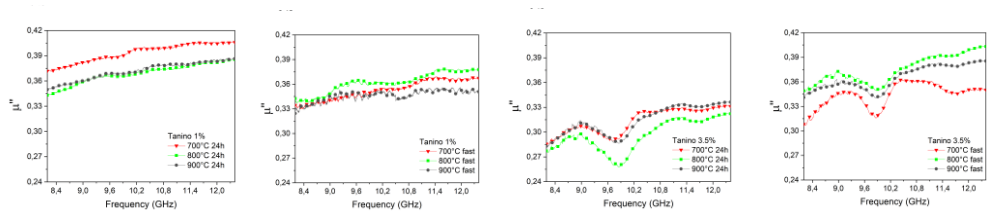
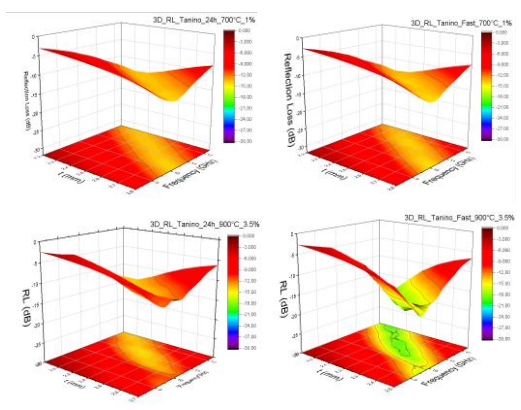


Figure 9. Imaginary Permeability



Sample	Thickness t (mm)	Max Reflection Loss (dB)	Absorption Efficiency (%)
1%, 24h, 700°C	2.2 – 2.8	~ -12.5 dB	~ 94.4%
1%, Fast, 700°C	2.2 – 2.8	~ -13.0 dB	~ 95.0%
3.5%, 24h, 900°C	2.1 – 2.7	~ -15.0 dB	~ 96.8%
3.5%, Fast, 900°C	1.9 – 2.5	~ -21.5 dB	~ 99.3%

Figure 10. Best sample response for RL, 3D Graphs

Conclusions

Microwave absorption depends on the interplay between complex permittivity, permeability, frequency, and thickness, which jointly govern impedance matching and attenuation. The 3.5% xerogel composites achieved better matching and stronger absorption at lower thicknesses than the 1.0% composites at the same frequency. The 45 min synthesis route with carbonization at 900 °C provided the most promising thin-absorber performance.

References and Acknowledgements

Lopes et al. Mater. Sci. Eng. B 332 (2026), 119644.
Guan & Chung. Carbon 157 (2020), 549–562.
Chung & Ozturk. J. Mater. Sci. 56 (2021), 9263–9273.

Acknowledgements: