Material, Smart device

Fabrication of elastic carbon aerogels from crab-shell-derived nanochitin for smart microwave absorption

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Abstract

As concerns about electromagnetic pollution increase, the importance of high-performance electromagnetic-wave absorbers also increases. In this study, we first prepared carbon aerogels from a water dispersion of crab-shell-derived nanochitin as a raw material through unidirectional freeze-drying and subsequent carbonization. This carbon aerogel showed excellent electromagnetic wave absorption performance due to the microscale honeycomb-channel structure formed by unidirectional freeze-drying and the moderately defective carbon molecular structure formed by carbonization. We also found that this carbon aerogel had an elasticity that could be reversibly compressed in a direction perpendicular to the microscale honeycomb-channels. By controlling the compression strain of this elastic carbon aerogel, we could tune the absorption frequency of electromagnetic waves and even switch between absorption and transmission of electromagnetic waves. The frequency tunability and electromagnetic-wave absorption/transmission switching capability are reversible and repeatable for at least 60,000 cycles of compression and recovery.

Background & Results

The increasing use of microwaves in wireless communication has caused severe electromagnetic pollution. As the frequency range for wireless communication expands, it is desired to develop a microwave absorber that can smartly and reversibly tune its absorption and transmission characteristics on demand to transmit desired frequencies and absorb unrequired frequencies.

In this study, we first prepared a carbon aerogel with a microscale honeycomb-channel structure from a crab-shell-derived nanochitin/water dispersion by freeze-drying and the subsequent carbonization at 800°C. We found that the microscale honeycomb structure and the appropriate defect N and O-doped carbon structures can provide good impedance matching and moderate dielectric loss characteristics, affording strong electromagnetic wave absorption.

In addition, this carbon aerogel could deform elastically in the direction perpendicular to the microscale honeycomb channels up to a compression strain of 80% (Fig. 1). Therefore, we controlled the compression strain of this elastic carbon aerogel to tune the absorption frequency of electromagnetic waves and to switch between absorption and transmission (Fig. 2). The maximum absorption frequency could be tuned from 10.4 to 11.0, 11.5, and 12.1 GHz by changing the compression strain from 0 to 20, 40, and 60%, respectively, while maintaining the maximum absorption intensity around -40 dB. This frequency tunable absorption was achieved by reducing the thickness of the carbon aerogel while maintaining its moderate dielectric loss tangent. Further compression from 60 to 80% witched the carbon aerogel from a microwave absorber to a transmitter, by providing an impedance mismatch and a low dielectric loss tangent. Such frequency tuning and absorption/transmission switching were reversible and repeatable for at least 60,000 cycles.

Significance of the research and Future perspective

This study can add new value to nanochitin, which is a sustainable bionanomaterial derived from crustaceans such as crab shells, as a smart and robust electromagnetic-wave absorber. It can help overcome electromagnetic pollution in a wireless communication society. We will continue to promote research to further add value to sustainable bionanomaterials.

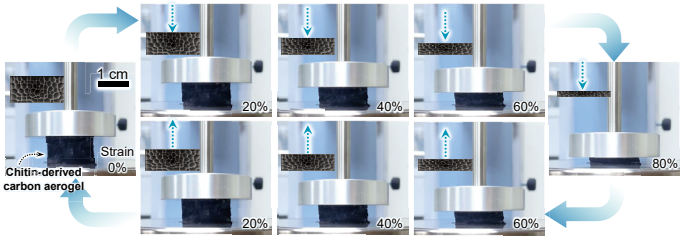

Fig. 1

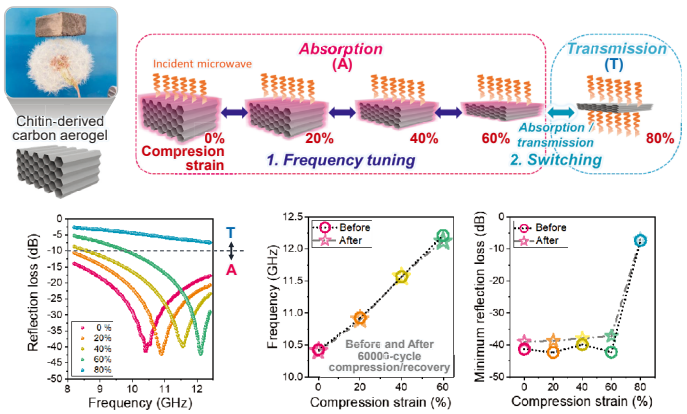

Fig. 2

Patent

Treatise

Li, Xiang; Koga, Hirotaka et al. Frequency-tunable and absorption/transmission-switchable microwave absorber based on a chitin-nanofiber-derived elastic carbon aerogel. Chemical Engineering Journal, 469, 144010. doi: 10.1016/j.cej.2023.144010

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URL

Keyword nanochitin, elastic carbon aerogel, microwave absorption