博 士 論 文 の 内 容 の 要 旨

氏名	LI FENGYU
学位名	博士（工学）
学位授与年月日	2022 年 09 月 30 日
論文題目	Development of magnetic carbon nanomaterials for high performance microwave absorption （高性能マイクロ波吸収用磁性カーボンナノ材料の創製）

（博士論文の内容の要旨）

The rapid development of communication technology not only brings convenience to life, but also brings electromagnetic radiation pollution, which affects the operation state of precision instruments and may threaten human health. Therefore, research and development on microwave absorption materials has become the focus of attention. Compared with other nanomaterials, carbon materials have become research focus of microwave absorption composites due to their special mechanism and simple synthesis method. But poor impedance results from high dielectric constant matching makes carbon materials remain difficult for preparing excellent microwave absorption materials. Meanwhile, multilayer composites also show potential to regulating microwave absorption performance. However, multilayer composite structure has complex parameters which makes it difficult to optimize properties with simple experimental methods. In order to improve performance of carbon materials and efficiently optimize the structural parameters of multilayer composites, high-performance magnetic carbon-based composites using biomass materials and metal organic framework are prepared, and structures of multilayer composites is optimized by genetic algorithm and finite element analysis. The significant work is as follows:

(1) Biomass derivatives are being extensively studied for microwave absorption because of their simple and environment-friendly preparation process. Herein, we report a facile and low-cost method wherein egg white is used as a carbon and sulfur source for the first time. Meanwhile a trimetallic alloy derived from cobalt nitrate, ferric nitrate, and nickel nitrate is used as the magnetic component to fabricate microwave absorption materials. The amount of alloy can regulate the microwave absorption performance of egg-white-derived carbon. The strongest reflection loss (- 47.09 dB) of the obtained composites can be achieved at 13.8 GHz with an ultrathin thickness (1 mm). The analysis of dielectric and magnetic constant reveals that the introduced alloy affects dielectric loss while increasing the amount of alloy affect magnetic loss more obviously. This study not only evidences that egg-white-derived carbon flakes can absorb microwaves but also reveals the role of alloy introduction in enhancing microwave attenuation capability.

(2) Template-free strategy has been widely used to prepare microwave absorption materials, but it still remains hard to achieve full X band (8.2-12.4 GHz) absorption at a thin thickness. Herein, NiCo alloy and N co-doped carbon with spontaneous three-dimensional network was obtained by preparing precursors using $Ni2+$ and $Co2+$ to be designed into zeolitic imidazolate frameworks (ZIF). The morphology of composites is able to be controlled by regulating Ni/Co ratios in crystallization. During pyrolysis, 3D network structure with N-doped carbon and NiCo alloy can be catalyzed to form under a specific Ni/Co ratio. Excellent microwave absorption performance, the minimum reflection loss is -41.9 dB at 1.5 mm and entire X band absorption at 2.6mm, is achieved. The 3D network structure containing N-doped carbon and NiCo alloy not only provide favorable dielectric and magnetic loss, but also have a crucial impact on reflection and scattering of incident microwave. The mechanism of dielectric loss including polarization relaxation, conductive loss and magnetic loss derived from resonance also is investigated. The chemical components and network structure controlled by ZIF-derived strategy have practical research value to

improve microwave absorption performance.

(3) Multilayer composites can be used to prepare controllable microwave absorption materials by using specific materials or structures. But calculation with complex parameters limits optimization efficiency. Genetic algorithm is used to overcome this problem. The EWC-1 and Ni1Co2@C are used as the database for optimizing multilayer composites, and the results are analyzed by COMSOL finite element method. Firstly, in the single factor variable experiment, multilayer composites composed of a single material is analyzed. thickness of the single layer, number of layers, interval distance, layer and the total thickness of the multilayer composite material all show effect on microwave absorption properties of multilayer composites. Then genetic algorithm is used to optimize multilayer composites. When the number of layers is five and the surface layer is EWC-1, the composite exhibits C-band absorption at 4.71687mm. In analysis of finite element simulation, the result is consistent with the calculated one, which means validity of the model. From the simulation result, it can be seen that power loss of microwave is mainly concentrated in front part of the structure, which indicates that Ni1Co2@C play a more important role in attenuating microwave. The successful optimization of multilayer composites provides a theoretical reference for development of novel microwave absorption materials.

In summary, referring characteristics of carbon materials, the egg white and metal organic framework are used to prepare ultra-thin and X-band absorbing materials, respectively. By analyzing the electromagnetic parameters, the effect of component and morphology on microwave absorption properties is systematically discussed. Then, combined with characteristics of two materials, the genetic algorithm is used to develop multilayer composites with C-band absorption. By finite element method, attenuation mechanism of the multilayer composite is figured out. We believe that this work can provide an important theoretical reference for the design and development of new microwave absorption composites.