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Broadband microwave absorbing honeycomb core material with active carbon as delegates

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Abstract

Honeycomb is a two-dimensional periodic cellular material that is relatively strong and stiff normal to the microstructure. Due to the normal aramid paper honeycomb core (NAPHCM) was microwave transparent material, the absorber of microwave absorbing honeycomb-core materials plays an important role on the absorbing property. In this study, we choose the active carbon as the absorber, and the aramid paper honeycomb as the base materials. We also investigated the influence of the surface area of active carbon and the thickness, cell dimension and density of microwave absorbing honeycomb core materials (MAHCMs) on the reflectivity of MAHCMs. The results showed that the higher thickness of honeycomb, the MAHCMs had lower reflectivity. The honeycomb cell dimension of 2 mm of MAHCMs had lower reflectivity than that of the honeycomb cell dimension of 3 mm.

Keywords: Microwave absorbing honeycomb, active carbon, broadband absorbing

1. Introduction

With the development of the radar detecting technology, the stealth technology of the weapon and equipment is important in the military area.1 In aerospace, some absorbing microwave structures are required load carrying property. An efficient way is to combine the electromagnetic behavior and mechanical into a structure. Except these, the light weight is also an important factor which should be achieved.2 Honeycomb is a two-dimensional periodic cellular material that is relatively strong and stiff to the normal microstructure. Honeycomb materials have a wide range of applications such as aerospace, rolling stock, automotive, building, marine, electronics and packaging, as core in sandwich panels.3,4 Usually, the honeycomb core materials are parepared through dippting method. Hence, the microwave absorbing honeycomb can be prepared through mixed the microwave absorber into the dipping resin solution, and will be a good choice as microwave absorbing core materials in stealth technology.5

Due to the normal aramid paper honeycomb core material (NAPHCM) was microwave transparent material (as shown in Figure 1), the absorber of honeycomb-core materials play an important role on the absorbing property of microwave absorbing honeycomb-core materials (MAHCMs). Hence, in order to achieve high efficiency of the reflection loss of the MAHCMs, the absorber with excellent absorbing efficiency of electromagnetic waves need be used. The absorber of honeycomb-core materials is usually non-magnetic materials, especially carbon material. A good absorber is based on two basic conditions. First, the absorber must exhibit impedance matching, such that electromagnetic waves can enter the material without reflection as much as possible. Second, the absorber must exhibit attenuation matching, such that the electromagnetic wave can be consumed as much as possible and has close contact with the complex permittivity and complex permeability. The electrochemical activity of amorphous carbon (such as carbon black, active carbon and so on) is primarily originated from numerous graphitization areas within the whole carbon matrix, which also play a key role on their dielectric properties.6,7

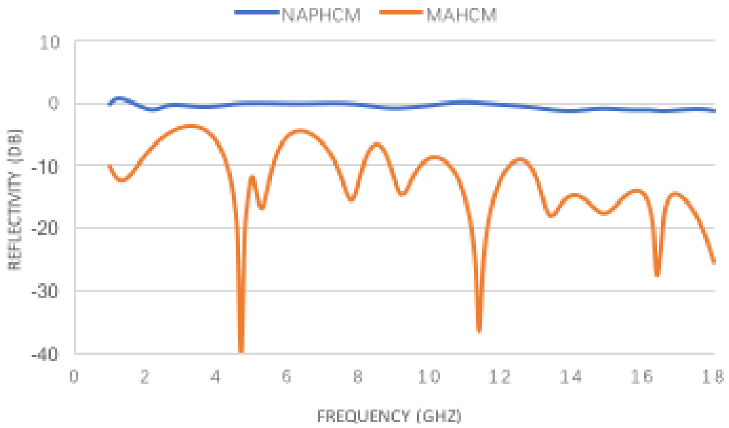

Figure 1 The reflectivity of NAPHCM and MAHCM

Compared with the carbon black, the active carbo has large surface area and porosity. From the reported of the literatures, 8-14 porous and large amount of interface may contribute to the higher electromagnetic wave absorption capability due to their interfacial polarization and multi-reflection. Meanwhile, this special structure is benefit for its lower density. Therefore, the active carbon may be a proming absorber of MAHCMs. In this work, a novel MAHCMs was prepared with the NAPHCM and phenolic resins as the base materials and the active carbon as the absorber.

2. Experimental

The aramid paper honeycomb was prepared from foil through the procedure as follows. Firstly, the foil goes through the printed the adhesive lines. Then the foil is cut into a set size and stacked into piles using the stacking machine. Secondly, the stacked sheets of foil are pressed through heated press to allow the adhesive to cure and bond the sheets of foil together, forming a block. The block can be cut into slices according to the thickness of honeycomb. Finally, the honeycomb core was expanded to the degree of regular hexagon.

The honeycomb core is then coated with microwave absorbing materials through dipping the microwave absorbing solutions. The absorbing solutions contains phenolic resins (≥70 wt%) and active carbon powers (≤ 30 wt%). The active carbon powers were mixed with phenolic resins solution using a high-speed mixer. The honeycomb core was dipped into the absorbing solutions. Then the honeycomb core was taken out of the absorbing solutions and putting it on the desk in order to dry the solvent. This process would be repeated until the density was achieved the given value, and the honeycomb core materials would be put into oven and cured under 180 °C for 2 h. Then the MAHCMs were obtained (Figure 2(b)).

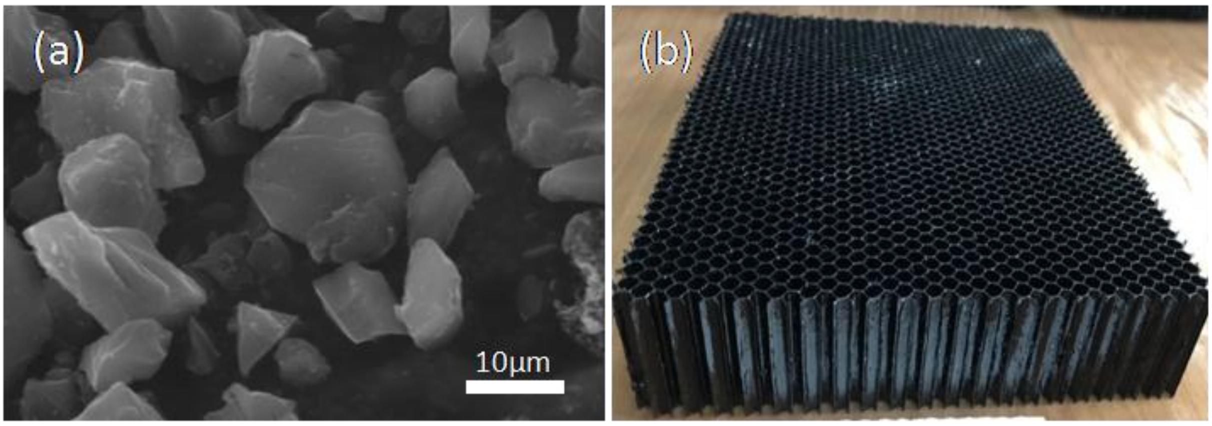

Figure 2 (a) The micro-morphology of active carbon and (b) the picture of MAHCM

The morphology of active carbon as measured through SEM. The surface area of active carbon was measured through BET method. The surface area of active carbon used in this work is about 2000 g/m^2. The microwave absorbing property was measured through the Radar Cross Section (RCS) method according to the national standard GJB 2038-94. In order to measure the normal incidence reflectivity, the antennas are located as close as possible. 2-PF-20-120, the name of MAHCM sample means that the cell dimension of honeycomb is 2 mm, the dipping resin is phenol formaldehyde resin (PF), the thickness of honeycomb is 20 mm and the density of the MAHCM is about 120 kg/m^3.

3. Results and discussion

The morphology of active carbon was showed in Figure 2 (a) and the diameter was about 5~30 μm. The shape of active carbon was irregular, which might be advantage to the scattering of microwave, and this would increase the interfacial polarization, multi-reflectivity and absorbing of microwave in the honeycomb cell which could enhance the attenuation of electromagnetic waves. What's more, the large surface area was also good for the reflectivity and attenuation of electromagnetic waves. These indicated that the active carbon might be a promising MAHCMs absorber.

Usually, the surface area of active carbon absorber and the thickness, cell dimension and density of honeycomb are the important factors of the MAHCMs, which play important roles on the absorbing property. Hence, in this study, we investigated the influence of these factors on the absorbing property of the MAHCMs. Figure 3 showed the influence of different surface area of active carbon on the reflectivity of MAHCMs. The result indicated that the MAHCMs with the active carbon with higher surface area as absorber have lower reflectivity, and this might attribute to the higher interfacial polarization and multi-reflection due to higher surface area of active carbon.

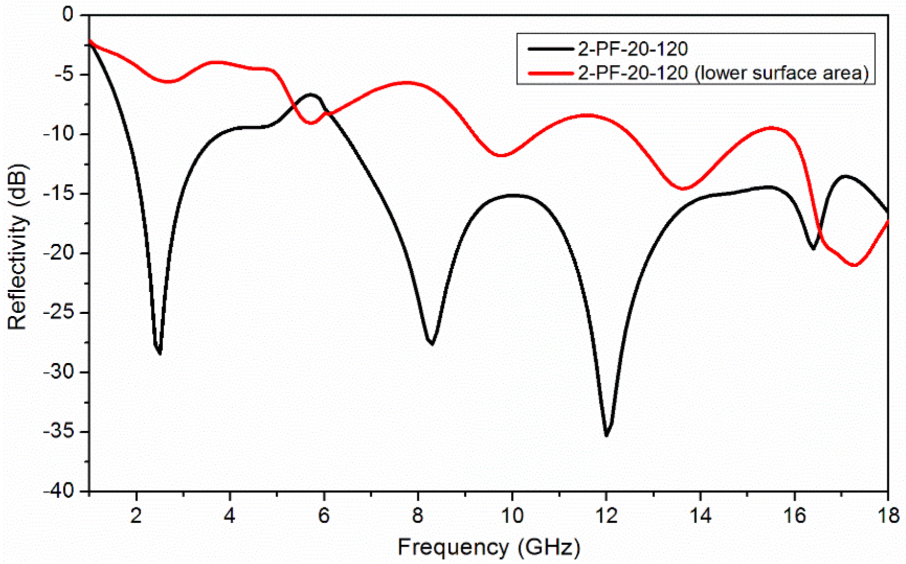

Figure 3 The influence of surface area of active carbon on the reflectivity of MAHCMs

The thickness of the honeycomb is one of the most important factors for the absorbing property of the MAHCMs. From the results of Figure 4, with the increasing of the thickness, the effective absorption bandwidth (WAB) which means the reflectivity below -10 dB (>90% electromagnetic wave is attenuated) is increasing. And when the thickness is 35 mm, the effective absorption bandwidth can achieve 14 GHz. This might attribute to the higher thickness, the more multi-reflectivity and absorbing. Therefore, the MAHCMs with higher thickness, the reflectivity will be lower.

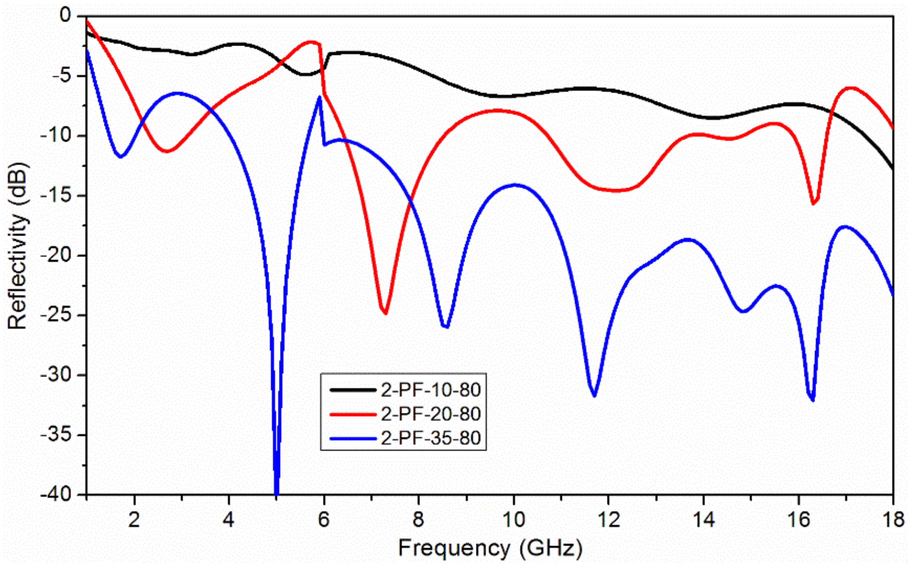

Figure 4 The influence of the thickness of honeycomb on the reflectivity of MAHCMs

The MAHCMs with different cell dimension have different reflectivity. Here we compared the reflectivity of MAHCMs with the cell dimension as 2 mm and 3 mm (Figure 5). The results showed that when the cell dimension was 2 mm, the MAHCM had lower reflectivity. This might because of the more honeycomb cell, more interfaces and more absorber in the same area which would bring more reflective-attenuation, and then resulted in more absorbing and lower reflectivity. Therefore, to some extent, the MAHCMs with smaller cell dimension may have lower reflectivity of electromagnetic wave.

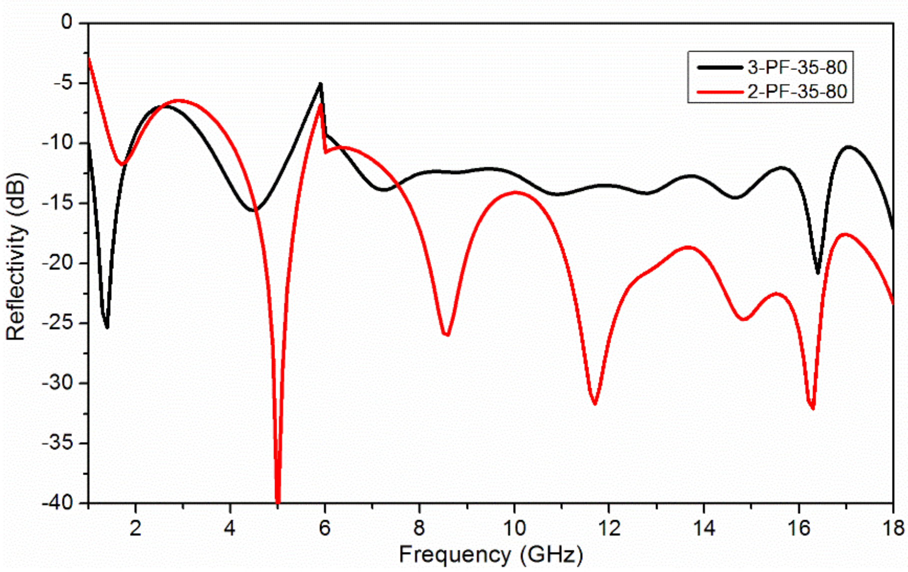

Figure 5 the influence of the cell dimension on the reflectivity of MAHCMs

When the base honeycomb cores have the same density, the different density of MAHCMs means the MAHCMs consisting different content of absorber. Figure 6 showed the reflectivity of MAHCMs with different density. The MAHCMs with the density of 120 kg/m^3 have the largest effective absorption bandwidth, which can achieve about 14 GHz, which was higher than the effective absorption bandwidth of the MAHCMs with the density of 80 kg/m^3 and 190 kg/m^3. The indicated that there was an optimum density of MAHCMs, and we should find the best density in order to obtain the MAHCMs with lowest reflectivity. In the further work, we will investigate the more MAHCMs with different density, and do our best to find the best ones.

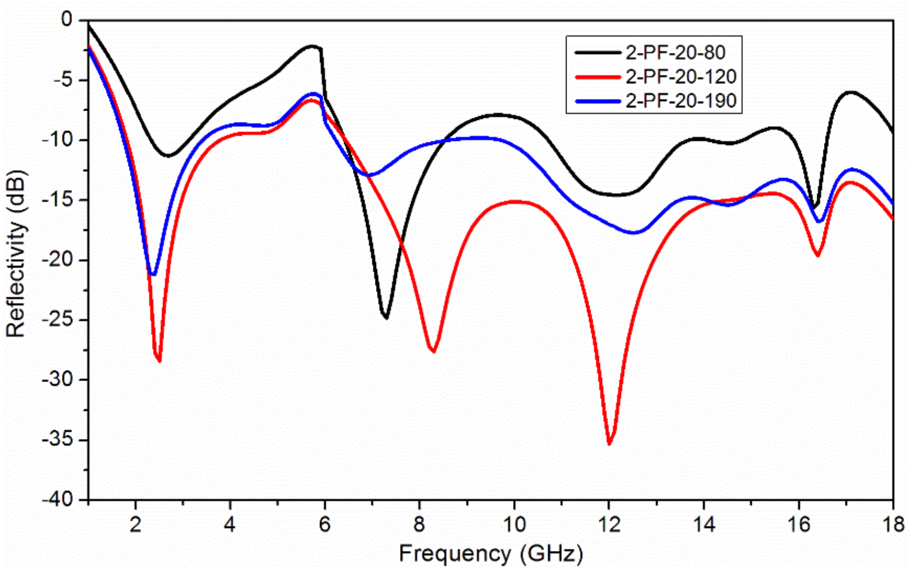

Figure 6 The reflectivity of MAHCMs with different density

4. Conclusions

In this work, we have prepared the microwave absorbing honeycomb-core materials with the porous active carbon as the absorber, and these microwave absorbing honeycomb-core materials have good absorbing property and low reflectivity. The results showed that with the increasing of the thickness of the MAHCMs, the effective absorbing frequency bandwidth is increasing. When the thickness is 35 mm and the density is about 80 kg/m3, the effective absorption bandwidth can achieve 14 GHz. With the density of MAHCMs increasing, the effective absorbing frequency bandwidth will be increasing and then decreasing, which indicated that there was an optimum density of MAHCMs, and the appropriate density should be find during the application. What's more, the cell dimension of MAHCMs should be not too large.

References

[1] Choi, W.-H., Kim, C.-G. Broadband microwave-absorbing honeycomb structure with novel design concept [J]. Composites Part B, 2015, 83: 14-20.

[2] Shen, L., Pang, Y., Yan, L., Quan, L., Qu, S. Multifunctional sandwich structure designed for broadband reflection reduction [J]. International Journal of Electronics and Communications [J]. International Journal of Electronics and Communications, 2018, 96: 75-80.

[3] Luo, H., Chen, F., Wang, F., Wang, X., Dai, W., Hu, S., Gong, R. Preparation and microwave absorption properties of honeycomb core structures coated with composite absorber [J]. AIP Advances, 2018, 8:056635-1-7.

[4] Xie, S., Ji, Z., Yang, Y., Hou, G., Wang, J. Electromagnetic wave absorption properties of honeycomb structured plaster boards in S and C bands [J]. Journal of Building Engineering, 2016, 7: 217-223.

[5] Wang, P., Zhang, Y., Chen, H., Zhou, Y., Jin, F., Fan, H. Broadband radar absorption and mechanical behaviors of bendable overexpanded honeycomb panels [J]. Composites Science and Technology, 2018, 162: 33-48.

[6] Liu, X., Wang, L.-S., Ma, Y., Zheng, H., Lin, L., Zhang, Q., Chem, Y., Qiu, Y., Peng, D.-L. Enhanced Microwave Absorption Properties by Tuning Cation Deficiency of Perovskite Oxides of Two-Dimensional LaFeO3/C Composites in X-Band [J]. ACS Applied Materials & Interfaces, 2017, 9: 7601-7610.

[7] An, Z., Zhang, J. Facial large scale preparation and electromagnetic properties of silica-nickel-carbon composite shelly hollow microspheres [J]. Dalton Transactions, 2016, 45:2881-2887.

[8] Zhou, C., Geng, S., Xu, X., Wang, T., Zhang, L., Tian, X., Yang, F., Yang, H., Li, Y. Lightweight Hollow Carbon Nanospheres with Tunable Sizes Towards Enhancement in Microwave Absorption [J]. Carbon, 2016, 108:234-241.

[9] Bychanok, D., Li, S., Sanchez-Sanchez, A., Gorokhov, G., Kuzhir, P., Ogrin, F. Y., Pasc, A., Ballweg, T., Mandel, K., ASzczurek, A., Fierro, V., Celzar, A. Hollow carbon spheres in microwaves: Bio inspired absorbing coating [J]. Applied Physics Letters, 2016, 108:013701.

[10]Zhou, J.-g., Zhu, X.-l., Zhang, L., Qiao, W.-m., Long, D.-h., Ling, L.-c. Mechanical and dielectric properties of mesoporous carbon microsphere/phenolic resin composites [J]. New Carbon Materials, 2016, 31: 301-306.

[11]Qiang, R., Du, Y., Wang, Y., Wang, N., Tian, C., Ma, J., Xu, P., Han, X. Rational design of yolk-shell C@C microspheres for the effective enhancement in microwave absorption [J]. Carbon, 2016, 98: 599-606.

[12]Li, D.-P., Sun, Y.-C., Wang, X., Wu, S., Han, S.-C., Yang, Y. Development of a hollow carbon sphere absorber displaying the multiple-reflection effect to attenuate electromagnetic waves [J]. RSC Advances, 2017, 7: 37983-37989.

[13]Xu, H., Yin, X., Zhu, M., Han, M., Hou, Z., Li, X., Zhang, L., Cheng, L. Carbon Hollow Microspheres with a Designable Mesoporous Shell for High Performance Electromagnetic Wave Absorption [J]. ACS Applied Materials & Interfaces, 2017, 9: 6332-6341.

[14]Lv, H., Guo, Y., Yang, Z., Guo, T., Wu, H., Liu, G., Wang, L., Wu, R. Doping Strategy to Boost the Electromagnetic Wave Attenuation Ability of Hollow Carbon Spheres at Elevated Temperatures. ACS Sustainable Chemistry & Engineering. 2018, 6 1539-1544.