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Research article

Preparation of nanocarbon and metal oxide based composite material for X-band electromagnetic absorption

Bang Quoc Ha[1], Tuong Manh Nguyen[1], Canh Van Nguyen[1], Hoanh Dac Trinh[1], Hoa Thi Nguyen[1], Hoanh Van Ngo[1], Hieu Trung Le[1], Tri Minh Le[2,*]

ABSTRACT

Electromagnetic waves are believed to be highly effectively absorbed by composite materials based on nanocarbon and magnetic oxides. In this study, $NiFeMgO_x$ multi-metal oxide nanoparticles were prepared by homogeneous precipitation process and then, CNT fibers were chemically vapor deposited onto $NiFeMgO_x$ to obtain the CNT/$NiFeMgO_x$ material. SEM, XRD, and BET techniques were used to characterize the composition of composite materials, and electromagnetic properties such as conductivity, coercivity, and saturation magnetic moment were also investigated. The findings of the study indicated that CNT fibers grew effectively on the surface of $NiFeMgO_x$ nanoparticles. Multi-metallic oxide composed of NiO, FeO and MgO covered with highly graphitized CNTs fibers. The resulting composite material exhibited a concentrated pore distribution ranging from 10 to 50 nanometers and a specific surface area of 90 m^2/g. The micro-structured material includes hollow carbon nanotube (CNT) fibers measuring approximately 50 nm in diameter and 2 nm to 4 nm in wall thickness. The CNTs/$NiFeMgO_x$ material showed low coercivity (Hc = 1500 Oe) and high magnetic saturation (Ms = 11.5 emu/g), which makes it a great candidate for the fabrication of materials that absorb electromagnetic radiation. On the basis of CNT/$NiFeMgO_x$ composites, magnetic powder, carbon black, and adhesives, electromagnetic wave-absorbing materials are produced. The results suggest that an X-band material with a thickness of 1.5 mm and an adhesive content of 20% may successfully reduce electromagnetic wave reflection by up to to be -35 dB. The CNTs/NiFeMgOx composite material has a lot of opportunities to develop to a novel electromagnetic wave adsorbent material system with numerous outstanding characteristics.[1–21]

Key words: CNT/NiFeMgOx, composite material, electromagnetic absorption

[1]*Institute of Chemistry and Materials, 17 Hoang Sam, Nghia Do, Cau Giay, Hanoi, Vietnam*

[2]*Department of Science and Technology, 17 Hoang Sam, Nghia Do, Cau Giay, Hanoi, Vietnam*

Correspondence

Tri Minh Le, Department of Science and Technology, 17 Hoang Sam, Nghia Do, Cau Giay, Hanoi, Vietnam

Email: leminhtri19751977@gmail.com

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INTRODUCTION

Electromagnetic-absorbing materials (EMA) are widely used in instrumentation, technical inspection, communication, and medical equipment[1]. In the field of defense, EMA is one of the most effective means to prevent radar detection of flying devices. They make it easier for aircraft and missiles to move through the gaps of enemy air defenses and anti-missile lines and protect fixed targets on the ground and at sea from radar detection by the enemy[2]. Therefore, the research and fabrication of electromagnetic absorbing materials have attracted great research attention.

In 1991, carbon nanotubes (CNTs) were initially found by Iijima. Since the discovery of CNTs, substantial progress has been made in the development of applications for coatings that absorb electromagnetic radiation. The coatings have good ability to absorb electromagnetic waves, which can be applied as camouflage materials in the fields of security, medical, electronics and military defense[3].

As we know, electromagnetic waves consist of two components: an electric field and a magnetic field. Materials can absorb electromagnetic waves through different mechanisms depending on their properties. Typically, the magnetic component of an electromagnetic wave interacts with a magnetic material, whereas the electric field component interacts with dielectric materials. CNTs absorb electromagnetic waves mainly based on the dielectric loss mechanism. Because of the lack of magnetic attenuation ability and advantageous dispersion, it is extremely difficult to produce great absorption efficiency for single-component CNTs absorbent. CNTs were combined with other loss materials to improve permeability and interface contact in order to achieve a greater absorption effect. Actually, CNTs-based metal composites are mainly concerned with developing novel nanomaterials by fabricating magnetic nanoparticles on CNTs to satisfy impedance matching while developing special microstructures, whereas multi-component alloys are frequently attached to

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the surface of CNTs.. The transition metal oxide like Fe_3O_4 [4], Co_3O_4 [5], $CoFe_2O_4$ [6], $NiFe_2O_4$ [7], are capable of absorbing electromagnetic waves on the magnetic loss mechanism, and when combined with CNTs, it is possible to obtain electromagnetic wave-absorbing materials according to both above-mentioned mechanisms. SWCNTs and $CoFe_2O_4$ nanocrystal were combined by Li et al., and the resulting composite material had an RL value of -30.7 dB at 12.9 GHz[8]. Cao and coworkers effectively created the Fe_3O_4/MWCNTs nanocomposite, which exhibits exceptional microwave absorption capability and wide absorption bandwidth[9,10]. Reduced GO/MWCNTs/$ZnFe_2O_4$ was easily fabricated by Shu et al. using a 3D conductive network, and it exhibits a minimum RL value of -22.2 dB at the Ku band with a thickness of just 1.0 mm[11]. Using a simple one-step process, Shu et al. developed a 3D net-like MWCNTs/$ZnFe_2O_4$ hybrid with a mass of conductive networks[12].

Here in, we described a simple one-step CVD method for creating high-performance EMAs made of hybrid composites of CNTs and NiFeMgOx nanoparticles. he results showed that the MWCNTs/NiFeMgOx hybrid composites were much better at absorbing electromagnetic waves (EMWs), with less reflection loss and a wider absorption bandwidth. Additionally, it explained the potential mechanism of EMW absorption as well as the synergistic effect and interfacial interactions between magnetic NiFeMgOx microspheres and carbon nanotubes.

MATERIALS AND METHODS

Chemicals and Materials

$Fe(NO_3)_3.6H_2O$, $Ni(NO_3)_2.4H_2O$, $Mg(NO_3)_2.9H_2O$, glycine were supplied by Fisher Chemical Co. Methane were commercially available from Vietnam Pure Gases JSC.

Experimental methods

Preparation of CNT/NiFeMgO$_x$ composites

A mixture of 1 mol $Fe(NO_3)_3.6H_2O$, and 1 mol $Ni(NO_3)_2.4\ H_2O$, 1 mol $Mg(NO_3)_2.9\ H_2O$ and 20 g of glycine were dissolved in 20 mL of water. The solution was heated above 50^{o}C and magnetically stirred for 30 minutes. Place the above mixture in an inert gas furnace and heat it to 500 ^{o}C at a rate of 5 ^{o}C per minute. Continue maintaining this temperature for 60 minutes to obtain $NiFeMgO_x$ oxide.

CNT/$NiFeMgO_x$ composite was fabricated by pyrolysis of methane gas on $NiFeMgO_x$. Place the crucible containing 1g of NiFeMgOx inside the CVD furnace. N_2 was blown into the furnace for 30 minutes at a rate of 100 mL/min. Heat the mixture at a rate of 5°C per minute to reach 700°C gradually. Switch the gas from N_2 to methane gas and maintain the methane gas rate of 100 mL/min for 10 minutes. The results obtained were CNT/$NiMgO_x$ products with a CNT yield of 3g CNT/1g $NiFeMgO_x$.

Characterization of CNT/NiFeMgOx

Using X-ray Bruker D8-Advance diffractometer with a Cu Kα anode (λ = 0.1542 nm) to characterize the crystal structure of materials with operating condition of 40 kV and 30 mA and the angle range 2θ from 10° to 70° with a step size of 0.05° per step. The specific surface area and porosity distribution were investigated by N_2 isotherm adsorption-desorption method on the Tri Start 3000 at 77 K and degassing temperature of 200 C for 5 h.

Field emission scanning electron microscopy (FE-SEM; HITACHI S-4800) at an accelerating voltage of 15 kV and High-resolution transmission electron microscopy (HRTEM; JEM 2100) at an acceleration voltage of 200 kV were used to characterized the structural properties of materials.

Electromagnetic Properties Measurement

The electromagnetic wave absorbent material is made on the basis of CNT/$NiFeMgO_x$ composites, with the ratio of components as follows: 100 parts by weight of chlorinated polyvinyl chloride resin and CNT/$NiFeMgO_x$, and 50 parts of cyclohexanol solvent. The above ingredients are ground by a planetary ball mill for 1 hour and then evenly coated on a 200 mm by 200 mm aluminum sheet. The coating thickness is 150 nm. The electromagnetic properties were measured at a frequency of 8-12 GHz on a keysight RF analyzer.

RESULTS AND DISCUSSION

Figure 1 exhibit the N_2 gas adsorption-desorption isotherm and pore distribution of CNT/$NiFeMgO_x$ composite. The N_2 gas adsorption-desorption curve can be classified into type II model which is characteristic for macro-porous materials. The N_2 adsorption volume at the low P/P° area show that a significant overlapping of monolayer adsorption and the beginning of multilayer adsorption. The increase of adsorption volume at the P/P°=1 due to macro-porous pore and multilayer N_2 diffusion and adsorption behavior. The analysis of the specific surface area of CNT/$NiFeMgO_x$ showed quite high value (90 m^2/g). The pore distribution diagram demonstrates that the

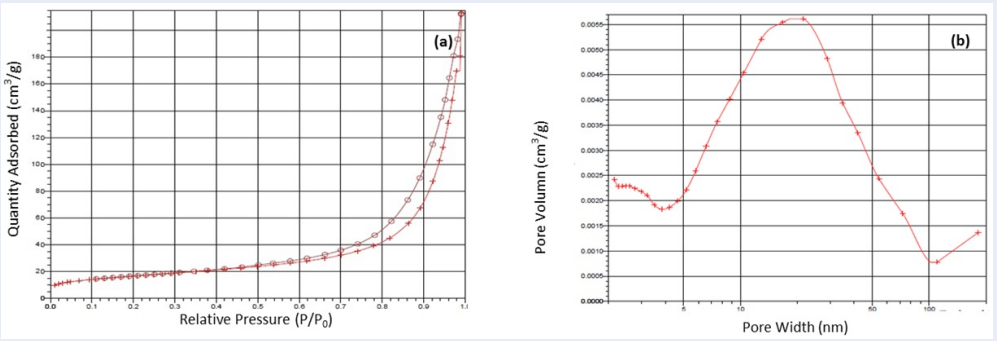

Figure 1: N_2 adsortion-desorption isotherm (a) and pore distribution (b) of CNT/NiFeMgO$_x$.

material has minimal pores of over 100 nanometers in size. The porosity of these samples primarily originates from openings ranging from 10 to 50 nm.

Illustrated in Figure 2 are the SEM and TEM images of CNT/NiFeMgO$_x$. The SEM image shows that, the CNTs were successfully fabricated on NiFeMgO$_x$ nano particles. The average diameter of CNTs was about 50 nm. It can be clearly observed that the NiFeMgO$_x$ nanoparticles are well-distributed on the surface of CNTs with some degree of the aggregation. The majority of NiFeMgO$_x$ nanoparticles were approximately 30 nm in diameter. The semitransparent of the CNTs implies that the CNT's wall consist of several layers with the thickness of 2-4 nm.

The results of X-ray diffraction (XRD) were employed to analyze the properties of the phase composition of CNT/NiFeMgO$_x$. The XRD patterns of NiFeMgO$_x$ nano particles and CNT/NiFeMgO$_x$ are shown in Figure 3a and Figure 3b, respectly. XRD pattern of NiFeMgO$_x$ shows that the crystallite peaks appearing at 2θ= 30.1°, 35.0°, 37.2°, 43.2°, 53.5°, 56.9°, 62.6°, 75.2°, and 78.7° are characteristic of FeO, MgO and NiO as well as the formation of rock salt NiFeMgO$_x$ solid solution [13].

The diffraction peaks mentioned above can also be seen on the CNT/NiFeMgO$_x$ XRD pattern, but their intensity has been noticeably reduced. The diffraction peak at position 2θ = 26° is typical for the graphitic carbon of CNTs. XRD result demonstrates that the produced CNTs growth on NiFeMgO$_x$ exhibits high graphitization degree [14,15].

The magnetization curve (Figure 4) displays the relation of the mass magnetization M with the magnetic field Hc of CNT/NiFeMgO$_x$ composite. The curve of is similar to others composites reported in the literature [16,17]. The curve is typical for soft magnetic materials with a large value of saturation magnetization (Ms=11.5 emu/g) and a low coercivity (Hc=1500 Oe). According to the magnetic property measurements, CNT/NiFeMgO$_x$ is suitable for the production of electromagnetic absorption materials [10].

The electromagnetic wave absorption characteristic of the material is shown by the attenuation of wave reflection intensity at frequencies from 8 to 12 GHz. It is clear that the samples attained reflection intensity has been attenuated between 10 and 11 GHz. Samples with 15%, 20%, and 25% CPVC compared to CNT/NiFeMgO$_x$ demonstrated the best attenuation of 32 dB, 35 dB, and 28 dB. With a film-forming ratio of 20%, the material can absorb up to 99.9% of electromagnetic waves with wide absorption bandwidth. The optimal amount of the film-forming agent allows consistent film formation without having a significant impact on the electromagnetic wave absorption properties of CNT/ NiFeMgO$_x$

Compared to previous reports on CNT based material for electromagnetic wave absorption application, this result was quite favorable (Table 1). Using the CVD technique, CNT is directly deposited onto a metal oxide substrate to fabricate the material. As a result, the material possesses an interlaced, multi-layer porosity structure with uniformly sized CNT fibers. Due to the combination of the magnetic properties of metal oxide and the electrical conductivity of CNT, CNT/NiFeMgO$_x$ showed good electromagnetic wave absorption efficiency [3,18].

CONCLUSIONS

CNT/NiFeMgO$_x$ composite was fabricated by pyrolysis of petroleum gas process at high temperature and neutral atmosphere. The average diameter of CNTs was about 50 nm. The NiFeMgO$_x$ nanoparticles with approximately 30 nm in diameter are well-distributed on the surface of CNTs with some degree of the aggregation. The obtained composite exhibit soft magnetic materials properties with a large

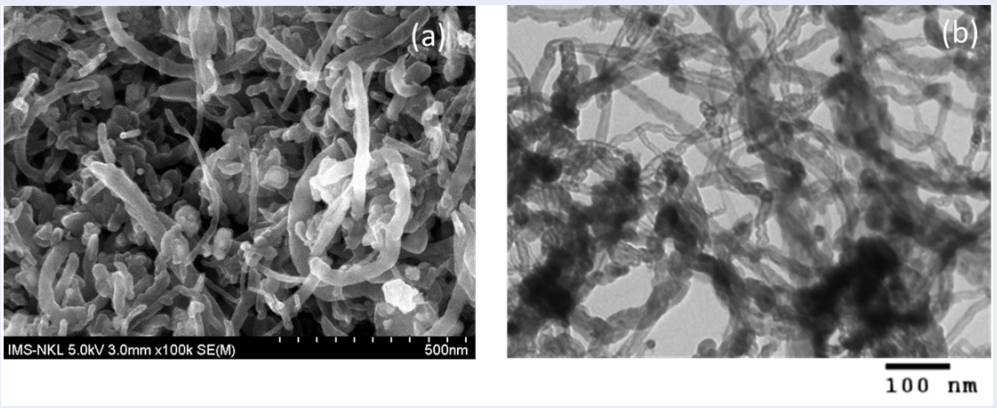

Figure 2: SEM image (a) and TEM image (b) of CNT/NiFeMgO$_x$.

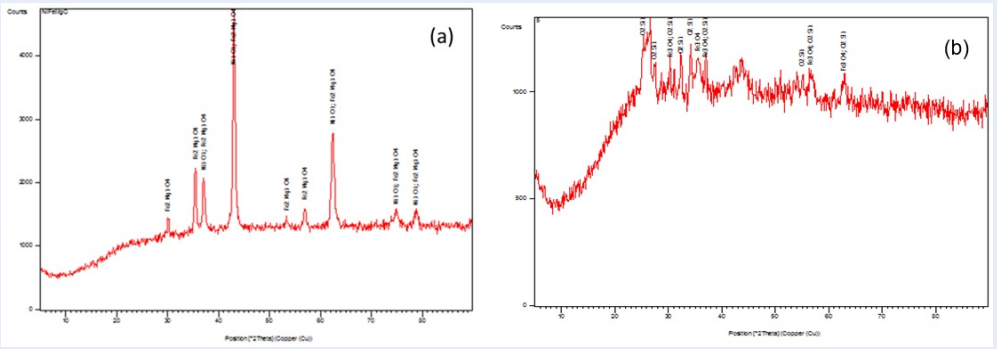

Figure 3: XRD pattern of NiFeMgO$_x$ (a) and CNT/NiFeMgO$_x$ (b)

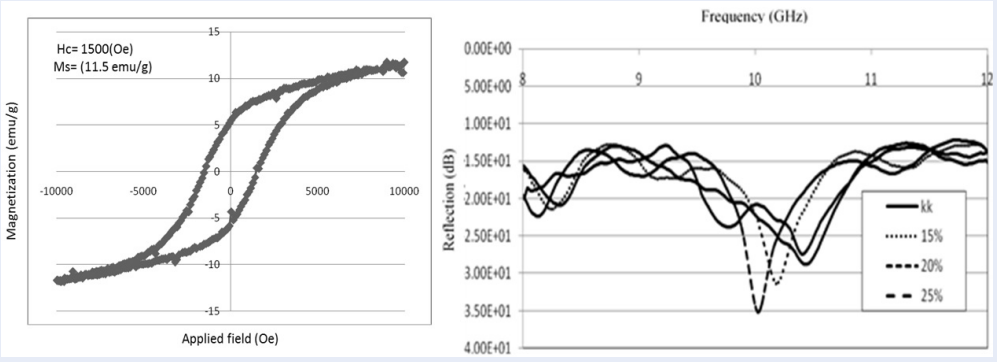

Figure 4: Magnetization curve at 298 K and Electromagnetic reflection of CNT/NiFeMgOx

Table 1: Comparisons of electromagnetic wave absorption effects of CNT based composites

Materials	Electro-magnetic wave absorption	References
10 μm CNTs/epoxy composite	18 dB (4-12 GHz)	[14]
4 mm of CNT/SiCf composites	62. 5 dB (2-18 GHz)	[15]
3.5 mm CNTs paraffin composite	-22 dB (0-18 GHz)	[16]
2.0 mm Fe3O4@Ti3C2Tx/CNTs composite	40.1 dB (2-18 GHz)	[17]
2.0 mm CNT/NiFeMgOx composite	35 dB (8-12 GHz)	This work

value of saturation magnetization (Ms=11.5 emu/g). The CNT/NiFeMgOx exhibited high of microwave absorption performance with RL of - 35 dB.

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DECLARATION OF COMPETING INTEREST

Declaration of competing interest. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

B.Q.Ha: Material preparation, data interpretation, analysis and writing-original draft preparation; H.T.Nguyen, H.V.Ngo, H.D.Trinh: Data analyzing, writing-reviewing and editing;
C.V.Nguyen, H.T. Le: Discussion and data curation;
T. M. Nguyen; T.M. Le: Review and editing, supervision.
All authors have read and approved the final manuscript.

REFERENCES

1. Lv H, Yang Z, Pan H, Wu R. Electromagnetic absorption materials: Current progress and new frontiers. Prog Mater Sci. 2022;127:100946;Available from: https://doi.org/10.1016/j.pmatsci.2022.100946.
2. Zhang M, Cao MS, Shu JC, Cao WQ, Li L, Yuan J. Electromagnetic absorber converting radiation for multifunction. Mater Sci Eng R Rep. 2021;145:100627;Available from: https://doi.org/10.1016/j.mser.2021.100627.
3. Chen X, Liu H, Hu D, Liu H, Ma W. Recent advances in carbon nanotubes-based microwave absorbing composites. Ceram Int. 2021;47:23749-23761;Available from: https://doi.org/10.1016/j.ceramint.2021.05.219.
4. Zhuo C, Yu Y, Lei F, Hu D. A lightweight and flexible CNT/Fe3O4 composite with high electromagnetic interference shielding performance. Carbon Lett. 2020;31:1-5;Available from: https://doi.org/10.1007/s42823-020-00152-y.
5. Abdalla I, Shen J, Yu J, Li Z, Ding B. Co3O4/carbon composite nanofibrous membrane enabled high-efficiency electromagnetic wave absorption. Sci Rep. 2018;8:12402;PMID: 30120335. Available from: https://doi.org/10.1038/s41598-018-30871-2.
6. Yuan Y, Wei S, Liang Y, et al. Solvothermal assisted synthesis of CoFe2O4/CNTs nanocomposite and their enhanced microwave absorbing properties. J Alloys Compd. 2021;867:159040;Available from: https://doi.org/10.1016/j.jallcom.2021.159040.
7. Guo L, He Y, Chen D, et al. Hydrothermal Synthesis and Microwave Absorption Properties of Nickel Ferrite/Multiwalled Carbon Nanotubes Composites. Coatings. 2021;11:534;Available from: https://doi.org/10.3390/coatings11050534.
8. Li G, Sheng L, Yu L, An K, Ren W, Zhao X. Electromagnetic and microwave absorption properties of single-walled carbon nanotubes and CoFe2O4 nanocomposites. Mater Sci Eng B. 2015;193:153-159;Available from: https://doi.org/10.1016/j.mseb.2014.12.008.
9. Cao MS, Yang J, Song WL, Zhang DQ, Wen B, Jin HB, Hou ZL, Yuan J. Ferroferric Oxide/Multiwalled Carbon Nanotube vs Polyaniline/Ferroferric Oxide/Multiwalled Carbon Nanotube Multiheterostructures for Highly Effective Microwave Absorption. ACS Appl Mater Interfaces. 2012;4:6949-6956;Available from: https://doi.org/10.1021/am3021069.
10. Sun L, Zhu Q, Jia Z, Guo Z, Zhao W, Wu G. CrN attached multi-component carbon nanotube composites with superior electromagnetic wave absorption performance. Carbon. 2023;208:1-9;Available from: https://doi.org/10.1016/j.carbon.2023.03.021.
11. Shu R, Zhang G, Zhang J, et al. Fabrication of reduced graphene oxide/multi-walled carbon nanotubes/zinc ferrite hybrid composites as high-performance microwave absorbers. J Alloys Compd. 2018;736:1-11;Available from: https://doi.org/10.1016/j.jallcom.2017.11.084.
12. Shu R, Zhang G, Wang X, Gao X, Wang M, Gan Y, Shi J, He J. Fabrication of 3D net-like MWCNTs/ZnFe2O4 hybrid composites as high-performance electromagnetic wave absorbers. Chem Eng J. 2018;337:242-255;Available from: https://doi.org/10.1016/j.cej.2017.12.106.
13. Awadallah A, Abdel-Mottaleb M, Aboul-Enein A, Yonis M, Aboul-Gheit A. Catalytic Decomposition of Natural Gas to CO/CO2-Free Hydrogen Production and Carbon Nanomaterials Using MgO-Supported Monometallic Iron Family Catalysts. Chem Eng Commun. 2013;202:836631;Available from: https://doi.org/10.1080/00986445.2013.836631.

14. Singh P, Sharma K, Kumar A, Shukla DM. Effects of functionalization on the mechanical properties of multiwalled carbon nanotubes: A molecular dynamics approach. J Compos Mater. 2016;51:671-680;Available from: https://doi.org/10.1177/0021998316649781.
15. Baghel P, Sakhiya AK, Kaushal P. Ultrafast growth of carbon nanotubes using microwave irradiation: characterization and its potential applications. Heliyon. 2022;8:10943;PMID: 36276756. Available from: https://doi.org/10.1016/j.heliyon.2022.e10943.
16. Moosavi S, Molla-Abbasi P, Aghajani Z. Photo-catalyst CoFe2O4-TiO2: application in photo-degradation of organic dyes and magnetic nanocomposite preparation. J Mater Sci Mater Electron. 2016;27:4879-4886;Available from: https://doi.org/10.1007/s10854-016-4371-2.
17. Zheng X, Tang J, Cheng L, Yang H, Zou L, Li C. Superhydrophobic hollow magnetized Fe3O4 nanospheres/MXene fabrics for electromagnetic interference shielding. J Alloys Compd. 2023;934:167964;Available from: https://doi.org/10.1016/j.jallcom.2022.167964.
18. Savi P, Giorcelli M, Quaranta S. Multi-Walled Carbon Nanotubes Composites for Microwave Absorbing Applications. Appl Sci. 2019;9(5):851;Available from: https://doi.org/10.3390/app9050851.
19. Xu J, Xia L, Luo J, et al. High-Performance Electromagnetic Wave Absorbing CNT/SiCf Composites: Synthesis, Tuning, and Mechanism. ACS Appl Mater Interfaces. 2020;12(18):20775-20784;PMID: 32282186. Available from: https://doi.org/10.1021/acsami.9b19281.
20. Qi X, Xu J, Hu Q, et al. Metal-free carbon nanotubes: synthesis, and enhanced intrinsic microwave absorption properties. Sci Rep. 2016;6:28310;PMID: 27324290. Available from: https://doi.org/10.1038/srep28310.
21. Zhang C, Wu Z, Xu C, Yang B, Wang L, You W, Che R. Hierarchical Ti3C2Tx MXene/Carbon Nanotubes Hollow Microsphere with Confined Magnetic Nanospheres for Broadband Microwave Absorption. Small. 2022;18(3):2104380;Available from: https://doi.org/10.1016/j.jallcom.2022.167964.

Tạp chí Phát triển Khoa học và Công nghệ – Engineering and Technology 2024, 6(SI3):46-52

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Vật liệu composit hấp thụ sóng điện từ băng X trên cơ sở nano cacbon và oxit kim loại

Hà Quốc Bảng[1], Nguyễn Mạnh Tường[1], Nguyễn Văn Cành[1], Trịnh Đắc Hoành[1], Nguyễn Thị Hòa[1], Ngô Văn Hoành[1], Lê Trung Hiếu[1], Lê Minh Trí[2,*]

TÓM TẮT

Vật liệu composit trên cơ sở nano cacbon và oxit kim loại từ có khả năng hấp phụ tốt sóng điện từ. Trong nghiên cứu này, hạt oxit đa kim loại nano oxit $NiFeMgO_x$ được chế tạo bằng phương pháp đồng kết tủa và sợi CNT được phủ lên bề mặt các hạt bằng phương pháp lặng đọng hơi hóa học, thu được được vật composit $CNTs/NiFeMgO_x$. Sử dụng các phương pháp hiện đại như SEM, XRD, BET để khảo sát thành phần cấu trúc và đặc tính bề mặt của vật liệu, ngoài ra đặc tính từ cũng được nghiên cứu làm rõ. Kết quả nghiên cứu cho thấy sợi CNTs đã mọc thành công trên bề mặt hạt nano $NiFeMgO_x$. Oxit đa kim loại dạng tổ hợp giữa NiO, FeO và MgO được bao phủ bởi các sợi CNTs có độ graphit hóa cao. Vật liệu composit thu được có diện tích bề mặt riêng là 90 m^2/g, phân bố lỗ xốp tập trung trong khoảng 10 nm- 50 nm. Vật liệu có vi cấu trúc là các sợi CNTs rỗng có đường kính khoảng 50 nm, độ dày thành ống khoảng 2 nm- 4 nm. liệu $CNTs/NiFeMgO_x$ có đặc tính từ mềm với từ độ bão hòa cao đạt Ms=11.5 emu/g và lực kháng từ thấp Hc=1500 Oe, rất phù hợp cho chế tạo vật liệu hấp phụ sóng điện từ. Vật liệu hấp thụ sóng điện từ được chế tạo với thành phần chính là composit $CNT/NiFeMgO_x$, than đen, chất kết dính. Kết quả cho thấy, khi sử dụng 20% hàm lượng chất kết dính, vật liệu vật liệu dày 1,5 mm cho độ suy giảm phản xạ sóng điện từ tới 35 dB trong dải băng tần X. Kết quả nghiên cứu cho thấy vật liệu composit $CNTs/NiFeMgO_x$ có nhiều triển vọng để phát triển thành hệ vật liệu hấp phụ sóng điện từ mới với nhiều đặc tính vượt trội.

Từ khoá: CNT/NiFeMgOx, vật liệu composit, hấp thụ sóng điện từ

[1]*Viện Hóa học - Vật liệu, số 17 Hoàng Sâm, Nghĩa Đô, Cầu Giấy, Hà Nội*

[2]*Phòng Quản lý Khoa học, số 17 Hoàng Sâm, Nghĩa Đô, Cầu Giấy, Hà Nội*

Liên hệ

Lê Minh Trí, Phòng Quản lý Khoa học, số 17 Hoàng Sâm, Nghĩa Đô, Cầu Giấy, Hà Nội

Email: leminhtri19751977@gmail.com

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