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Dynamic and regional constructive electromagnetic protecting materials made by MWNT/Fe3O4/poly pyrrole doped vitrimers

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ABSTRACT

Electromagnetic protection is always an important factor for electrical device. Therefore electromagnetic shielding materials (ESM) with good properties such and easy-processing is desirable. Vitrimer, a kind of material that equipped with advantages of both thermoplastics and thermosets, such as proof of acid and alkaline, mechanical stability, and easy processing was recently discovered. In our research, we use vitrimer as matrix, doped with MWNT/Fe_3O_4 composite, to form a new kind of ESM. MWNT/Fe_3O_4 was prepared by MWNT and $Fe(acac)_3$. Outcome has shown that such ESM is stable at room temperature and suitably deformable at evaluated temperature, making it easy for constructing surface fitted ESM. Also, MWNT absorption of light focus enables its spatial and regional deformation. $Fe(acac)_3$ prepared MWNT/Fe_3O_4 showed a significant improvement in microwave-range reflection loss. Lap-shear test provided almost an equal capacity of self-healing under external force and magnetic force. As a result, the ESM showed promising perspective on wilder usage of electromagnetic protection with greater properties.

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1. Introduction

Electro Magnetic Interference(EMI) is always an important factor taken into consideration for precise performance of electrical device. There are several kinds of magnetic shielding material that are frequently used, which could be concluded into three major classes: metals, conducting polymers and doped polymers. Due to high electrical and magnetic conductivity, metals are the first choice for magnetic shielding. But their high mass density, susceptibility to corrosion and hard to process restrict their application. As for conducting polymers, such as polyacetylene, polypyrrole and polyaniline [1–3], are confined to experimental researches due to their difficulties in processing and reconstruction. Doped polymers are expected to make up the disadvantages of the above two [4–7], but dopants sometimes are not able to overcome the deficiencies of matrix thoroughly. For example, doped polymers with thermoset matrix still have difficulty in processing and reconstructing, and matrixes such as PE and PP do not improve enough in heat-triggered aging and mechanical stability through doping [8,9].

Vitrimers, thermosets with exchangeable covalent bond, were recently discovered [10]. Equipped with mechanical stability and easy processing of thermoplastics, vitrimers have attracted much attention in many applications. Due to its excellent mechanical stability, it has potential of being a good magnetic protecting material if doped with strong wave-absorbing particles. Furthermore, due to its stability at room temperature and suitable deformability (viscosity mildly change so we can process in its solid state without worrying about turning into liquid state suddenly) (Fig. 1a) at evaluated temperature [11–14], it will be a magnetic protecting material capable of dynamic 3D constructing and reconstructing with heat or light [13,15,16] if doped with wave-absorbing particles.

Besides, the doping effect on mechanical properties should also be taken into consideration. Mechanical and reprocessible reinforcement of vitrimers through doping by CNT [17], modified nanosilica particle, metal ligands have been carefully studied by Wang et al. [18–20]. In the meantime, Researches on magnetic shielding were carried out concentrating on multi-doping of metals, oxidized metals, carbon nanotube, graphene and graphite [21–28]. Among most of doping materials, Fe_3O_4 has the advantage of cheapness, stability and commercial available. Some papers have reported great improvements on wave absorption when doping CNT/Fe_3O_4 composites into polymer matrix [24].

Based on the previous research, we dop vitrimer with Fe_3O_4/MWNT, to form a kind of electromagnetic protecting thermoset that is able to self-bonding [29], dynamic 3D construction and

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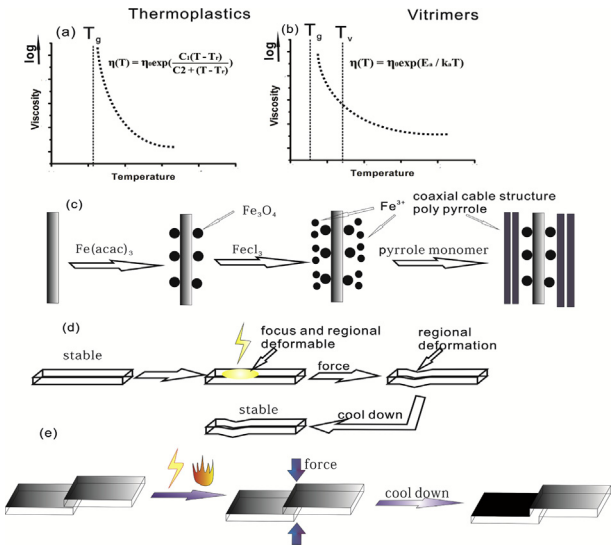

Fig. 1. Temperature-viscosity plot of (a) thermoplastics; (b) vitrimers; (c) Flow chart of the coaxial cable structure polypyrrole formation. (d) Schematic diagram of dynamic and regional construction; (e) Chart of self-bonding.

reconstruction under magnetic force. Compared with conventional EMI materials, the vitrimer EMI material have some significant advantages such as easy reprocessing at mild temperature and mechanical stability, which make it recyclable and of great use.

2. Results and discussion

2.1. Electromagnetic behavior of Fe_3O_4, MWNT and polypyrrole

Fe_3O_4 is a kind of particle absorpting electromagnetic wave which is high cost performance, so it is doped for fabricating ESM. However, according to the experiment, Fe_3O_4 lacks of dielectric loss. Meanwhile, MWNT is excellent in hysteresis losses but insufficient in dielectric loss (ESI, Fig. 1). Therefore MWNT is also added for complementary. Due to both MWNTs and Fe_3O_4 dispersed poorly in vitrimer matrix, we wrapped MWNTs and Fe_3O_4 with polypyrrole (ppy), acquiring satisfying dispersion in vitrimer matrix. In addition, ppy is a kind of conducting polymer, and is probably to be helpful for Reflection loss, thus reducing the addition of Fe_3O_4 and MWNTs.

2.2. SEM image of MWNT/Fe_3O_4/PPy

Considering common-ion effect, we choose $FeCl_3$ as polymerization initiator for ppy [30]. Due to the common-ion effect, Fe^{3+} ion gradually precipitate on the surface of MWNT/Fe_3O_4 (Fig. 1c). As (Fe_3O_4/WMNT): pyrrole ratio is high, the surface of Fe3O4/WMNT could provide sufficient sites for pyrrole monomer to cure completely, leading to a structure of coaxial structure (Fig. 2a); if the ratio is high, pyrrole monomers have to cure elsewhere, thus a cotton-like structure is constructed(Fig. 2b). Taking the electrical conductivity and mechanical strength into consideration, in this study, we use 1:2 ratio coaxial MWNT/Fe3O4/PPy composites to dop vitrimers. To achieve a more even and wildly precipitation of

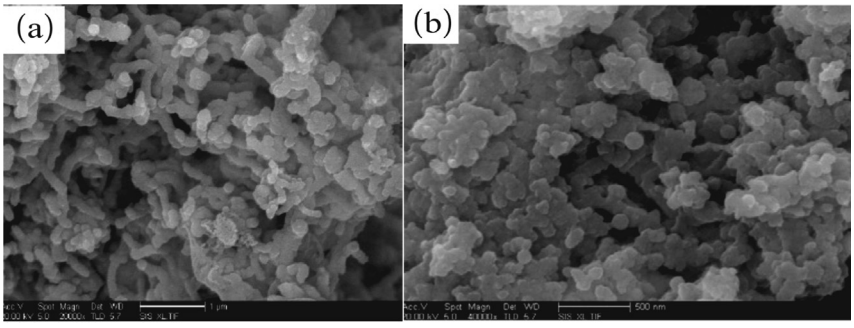

Fig. 2. SEM image of (a) coaxial structure as (Fe_3O_4/MWNT): PPy = 1:2 (b) cotton-like structure as (Fe_3O_4/MWNT: PPy = 1:4).

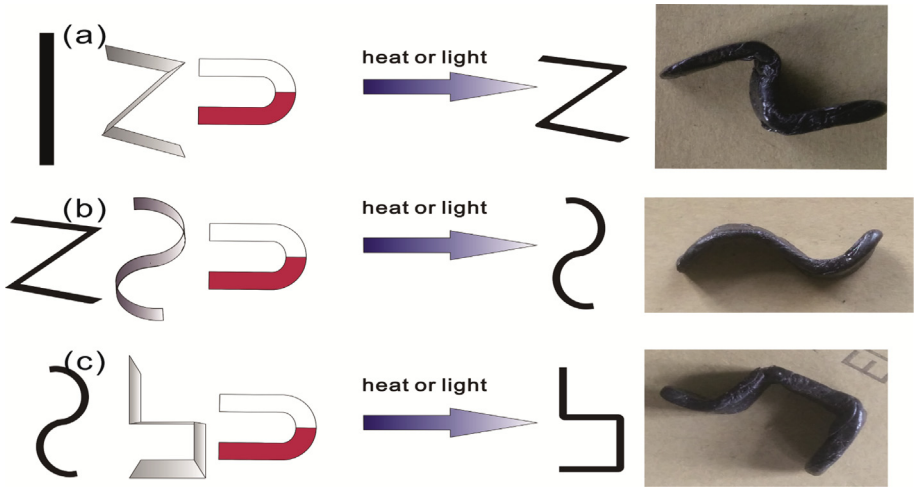

Fig. 3. 2D dynamic construction of Fe3O4/MWNT/ppy vitrimer: (a) straightness to zigzag; (b) zigzag to S-curve; (c) S-curve to Ω-shape.

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