

The Progress of Composites with High Thermal Conductivity and Electromagnetic Shielding

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Abstract: As electronic components develop toward high power, high package density, and device size miniaturization, heat dissipation and electromagnetic interference between electronic components are becoming more and more serious. In order to solve the adverse electromagnetic waves and heat radiation generated by electronic devices, people have high hopes for electronic packaging materials with high thermal conductivity and electromagnetic interference resistance. This paper summarizes the research status of high thermal conductivity composite materials and electromagnetic shielding composite materials. Finally, the latest research results of high thermal conductivity and electromagnetic shielding composites are introduced, and the future development trend of new materials for microelectronic packaging is prospected.

Keywords: Composite Materials; High Thermal Conductivity; Electromagnetic Shielding

Introduction

From slash-and-burn farming to iron plowing in Niu Geng, from age of steam and the electric age to the information age, human beings' insatiability for the present situation has been promoting the continuous progress of science and technology. As far as electronic products are concerned, people have been pursuing more energy-saving, lighter and more efficient. As a result, electronic devices are gradually developing towards high power, miniaturization and high integration. In general, high-speed processors, as the main components of electronic components, will generate a large amount of heat emission when working, which will not only limit the working frequency of electronic components, will also shorten the life of electronic devices^[1-5]. Some studies have shown that when the power density in the hot zone of electronic components exceeds 100 W/cm^[2], the operating frequency of the microprocessor is already difficult to exceed several gigahertz^[6]. Therefore, the problem of heat dissipation in hot areas in integrated circuits has become a bottleneck for the further development of microelectronic technology^[7]; At the same time, the distribution density of electronic components is too high and the problem of electromagnetic interference caused by high-frequency circuits is becoming more and more serious^[8-9], especially with the advent of the era of high-frequency and high-speed 5G, higher requirements are put forward for electromagnetic shielding materials. In order to effectively shield bad electromagnetic waves and dissipate heat, anti-electromagnetic interference materials with high thermal conductivity are urgently needed.

Polymers have the advantages of light weight, corrosion resistance and easy processing, and have broad application prospects^[10] in the field of microelectronic packaging. Generally speaking, polymer composites with good thermal conductivity can be prepared by adding various fillers with high thermal conductivity. In addition, adding filler to polymer matrix is one of the most effective methods to prepare electromagnetic interference shielding materials^[11]. Therefore, the polymer matrix composite prepared by introducing various fillers can endow the material with multiple functions and is expected to become a new type of high thermal conductivity electromagnetic. Shielding Microelectronic

1. High thermal conductivity composite

The polymer matrix composite material consists of a polymer matrix, a heat conducting filler and an interface between the filler and the matrix. The thermal conductivity of polymer matrix composites depends on the synergistic effect of polymer matrix and thermal conductive filler.

1.1 Polymer matrix

The main function of polymer matrix in polymer matrix composites is to bond various heat conducting fillers together to form heat conducting passages in the matrix and endow the materials with certain heat conducting properties. The type and composition of polymer matrix have great influence on the thermal conductivity of composites. Commonly used polymer matrices include plastic, rubber and various adhesives, etc. However, the low thermal conductivity of polymers greatly hinders the application of pure polymers in thermal management.

The intrinsic polymer is designed to change the crystallinity and molecular chain orientation of the polymer to construct phonons in the polymer. Transmission channel is an effective means to improve the thermal conductivity of polymers^[12]. Chen and others reported a high thermal conductivity polyethylene film. The thermal conductivity is as high as 62 W/m, k, which is more than two orders of magnitude higher than that of common typical polymers (about 0.1 W/m, k), which is more than many traditional metal and ceramic materials. Research shows that polymer films with high thermal conductivity can be obtained by highly stretching and orienting the films. In fact, the film is composed of crystalline and amorphous nanofibers. By controlling the morphology of amorphous region, the amorphous region also has very high thermal conductivity (about 16 W/m, k), this is the film material.

1.2 Thermal conductive filler

Since the thermal conductivity of the thermally conductive filler is much higher than that of the polymer matrix, the thermal conductivity of the polymer matrix composite mainly depends on the selection of the thermally conductive filler. In addition, the morphology of the filler, the distribution of the filler in the matrix and the interfacial bonding between the filler and the matrix will directly affect the thermal conductivity of the composite. In recent years, various fillers with high thermal conductivity have been used to improve thermal conductivity, such as stone.

Qin^[20] and others have developed a Shimoene-sponge superelastic bicontinuous heat conduction network in order to effectively control the three-dimensional thermal conductivity of graphene-reinforced polymer nanocomposites. By adjusting the preparation and deformation parameters of the network, the structure and thermal conductivity of the obtained composite material can be effectively controlled. According to the experimental and theoretical simulation results, the heat conduction mechanism is summarized as two-stage transmission of phonons. When the directional compression ratio is increased from 0% to 95%, the in-plane thermal conductivity is increased from 0.175 to 1.68 w/m and k, 70 Enhanced Efficiency Exceeds 300. When the three-way compression ratio is 70%, the content of graphene in the composite material is 4.82 wt%, and the thermal conductivity of the composite material reaches 2.19 w/m, k. In order to improve the heat transfer performance of the composite, Hou^[21] and others constructed a micro reed composite structure with carbon fiber. Polydimethylsiloxane (PDMS) and impregnating under vacuum to obtain composite material. Due to the vertical carbon fiber structure, the in-plane thermal conductivity of the polymer composite material reaches 6.04 w/m, k and k at low filling amount.

2. Electromagnetic shielding composites

Electromagnetic interference (EMI) affects almost all electrical and electronic systems, from daily life and military activities to space exploration. With the popularization of electronic equipment, the miniaturization of electronic systems and their components, and the development of interconnection technology, how to ensure the normal operation of microchips, the safety of data, and the reduction of potential risks to human health are all problems that need to be solved urgently. For this reason, people are trying to develop materials with enhanced electromagnetic interference shielding effectiveness to prevent such adverse effects. In the 20th and 20th centuries, light materials of metals and metal coatings, such as plastics obtained by electroless plating, electroplating or vacuum deposition, were most commonly

used to realize electromagnetic shielding, in which shielding was mainly realized by reflecting electromagnetic waves. Metals with high magnetic permeability (nickel soft ferromagnetic alloy) can also effectively shield magnetic field to obtain good electromagnetic shielding effect^[22]. In fact, their good shielding effectiveness (SE) is mainly reflective, which is not the best solution due to potential secondary pollution. In recent years, electromagnetic materials mainly based on absorption mechanism can convert absorbed electromagnetic waves into heat energy, which has attracted more and more attention.

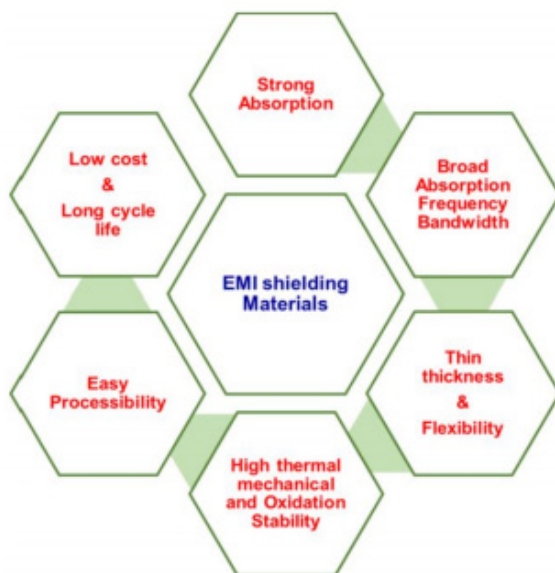


Figure 1. Ideal performance of EMI shielding materials^[23].

Li^[24] et al. studied and designed a fine structure of $\text{TiO}_2/\text{SiO}_2$ nanofibers through electrospinning technology, and prepared a light flexible hybrid film with multi-scale double continuous conductive network ($\text{TiO}_2/\text{SiO}_2 @ \text{PPy}$) and sandwich structure ($\text{TiO}_2/\text{SiO}_2 @ \text{PPy} @ \text{RGO}$). As an effective dissipation medium, the hybrid film has an electromagnetic interference shielding efficiency of about 30 dB in the X band (8-12 GHz). The tensile strength of the composite film was 2.71 MPa and the density was only 0.089 g/cm³. After reverse bending, the composite film still maintains good electrical shielding and electromagnetic interference shielding performance and shows good flexibility. The fine structure design strategy of electrospun nanofibers provides a feasible method for the preparation of lightweight, flexible and high performance electromagnetic interference (EMI) hybrid film shielding materials in flexible electronics, military and medical care applications.

Faisal Shahzad,^[25] and others' research have shown us the potential of several MXene and their polymer composites to shield electromagnetic interference. The electromagnetic interference shielding efficiency of 45 micron thick $\text{Ti}_3\text{C}_2\text{Tx}$ film is 92 dB (the electromagnetic interference shielding efficiency of 2.5 micron film is greater than 50 dB), which is the highest among synthetic materials with the same thickness so far. This kind of performance comes from the good conductivity of $\text{Ti}_3\text{C}_2\text{Tx}$, and the multiple internal reflections of thin films. MXenes and its composites provide the ability to easily coat to shield surfaces of any shape while providing high EMI and shielding effectiveness.

3. High thermal conductivity electromagnetic shielding composites

In order to meet today's technical requirements, various high thermal conductivity fillers are used to improve the thermal conductivity of microelectronic packaging materials, but there is little research to solve the problem of electromagnetic interference between electronic components. Therefore, it is urgent to develop an electromagnetic shielding material with high heat conductivity in microelectronic packaging field to solve the problems of heat dissipation and electromagnetic interference of electronic components.

Electronic packaging materials have the requirement of electrical insulation in some occasions. At present, carbon-based composite materials usually cause the improvement of electrical conductivity while improving thermal conductivity, thus affecting the practical application of packaging materials. Zhang^[26], et al. took polyvinylidene fluoride, PVDF and MWCNT and BN as their research objects and constructed an isolated double-network structure, which

meets the thermal conductivity and anti-interference performance of materials and also takes into account the electrical insulation performance of electronic packaging materials. Firstly, PVDF@MWCNT and composite microspheres were prepared in situ. Conductive networks were formed inside the microspheres and the thermal conductivity of PVDF and PVDF was improved. Then, outside the microspheres, insulation BN and thermal conductive fillers are used to construct a complete thermal conductive network path, and the electrical conductivity of the composite microspheres is reduced through integral coating, so that the composite material has good electrical insulation performance on the basis of synchronous improvement of thermal conductivity and electromagnetic shielding performance.

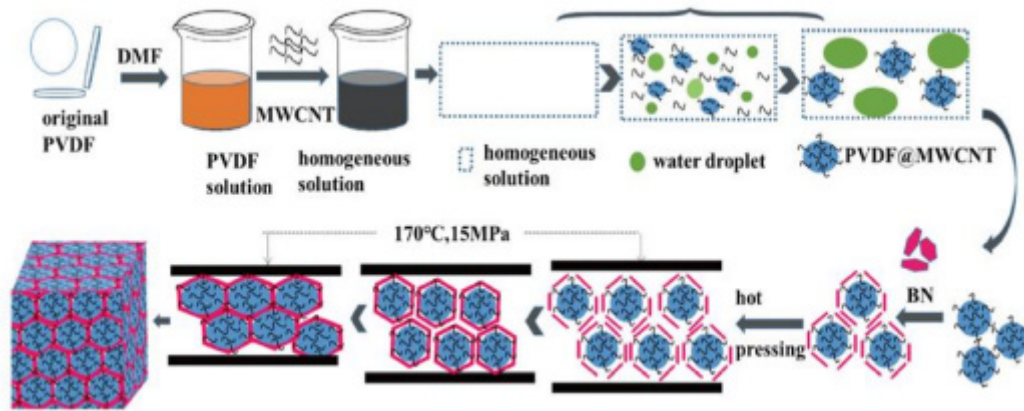


Figure 2. Preparation process of PVDF @MWCNT composites^[26].

The unique layered structure designed by Zhang^[27] and others has an excellent conductive network in the horizontal direction, while the conductive network is vertically blocked by the insulating layer. The multilayer film exhibits good electromagnetic shielding (11 layer is 37.92 dB) and excellent breakdown strength (up to 1.52 MV/m). When electromagnetic wave enters the layered composite material, it is repeatedly reflected due to the multi-layer interface effect, and finally gradually decays between the layered interfaces. As shown in Figure 3, the unique multilayer film has excellent conductive network in the horizontal direction. In the vertical direction, it has insulation and shows high potential as an efficient electromagnetic shielding material, which can solve the electromagnetic compatibility problem of modern electronic equipment.

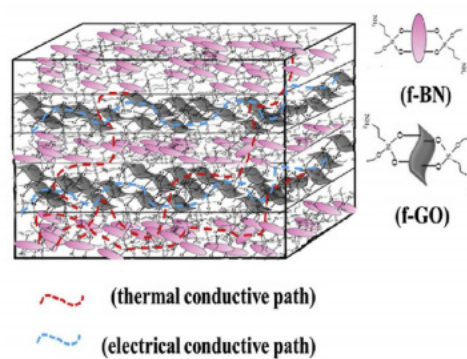


Figure 3. Thermal and electrical conductive schematic of the ordered multilayer film^[27].

4. Conclusion

This paper briefly introduces the research progress of polymer-based high thermal conductivity composites and electromagnetic shielding composites, and emphasizes the application of composites with high thermal conductivity and electromagnetic shielding properties in microelectronic packaging.

Although there has been extensive and in-depth research on microelectronic packaging materials, there is no effective method to solve the electromagnetic interference and heat dissipation problems of high frequency and high power electronic components. The bottleneck of high-frequency and high-power electronic products in the future is electromagnetic radiation and heating. In order to solve this problem, electronic packaging materials should have good electromagnetic shielding and thermal conductivity, which is the research focus of the next generation of micro-

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