

Progress study of Micro Carbon Coils

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Abstract. As a kind of novel bio-mimetic carbon fibers, with diversities of high functions, carbon microcoils (CMC) have the outstanding properties of high specific strength, low-density, large specific surface area, heat resistance, corrosion resistance, chemical stability, conductive ability and thermal conductivity. Due to their special three-dimensional spiral structure, they have the chiral characteristics and a high flexibility. Carbon microcoils has become a research hotspot, especially the preparation of polymer-based carbon microcoils composite materials and they have wide more application such as flexible sensors, electromagnetic shielding materials, hydrogen storage materials, health care products and so on.

1. Introduction

Carbon elements can exist in a variety of interatomic structures, such as 0-dimensional fullerenes, 1-dimensional carbon nanotubes, 2-dimensional graphene and 3-dimensional diamonds, and they have many peculiar functions. With the continuous development of science and technology, carbon materials have been used in the military, industrial production and daily life more and more widely. Traditional carbon materials mainly include carbon black and graphite [1], mainly used in reinforcing agents, colourants, conductive functional materials, etc.. With the recent development of electronic information technology and intelligent technology, the traditional carbon material has been unable to meet the new application requirements. Therefore, high-performance carbon materials, such as spiral carbon fiber, carbon nanotubes, graphene, etc., have attracted much attention of a large number of scientific workers because of its low density, high strength, specific surface area, heat resistance, corrosion resistance, good conductivity and thermal conductivity, etc.

Carbon microcoil (CMC) is a high performance bionic new carbon fiber with a three-dimensional double helix structure similar to DNA. Spiral carbon fiber has a chiral characteristics, good flexibility, in addition to ordinary carbon fiber with high specific strength, low density, specific surface area, heat, conductive thermal conductivity and other excellent performance, and can be well combined with the polymer matrix. Spiral carbon fiber has become a hotspot in the field of materials, especially in the preparation of polymer-based helical carbon fiber composite materials and its application technology development, so that it has a wide range of applications in flexible sensors, absorbing materials, health care products and other fields The CMC was first discovered in the 1950s, Davis et al [2] found two intertwined carbon fiber in the CO catalytic cracking products, but the laboratory preparation of CMC yield is low, and reproducibility is poor. Until 1990, Japan's Motojima et al [3] synthesized helical carbon fiber using catalytic pyrolysis of acetylene method which Ni was used as a catalyst, and the method of repeatability and carbon fiber structure are better. CMC growth mechanism, Performance, application and small batch preparation. Since then, Spiral carbon fiber prepared by chemical vapor



deposition (CVD), has many advantages such as, easy to control, easy to operate, high yield, low cost [4]. Since Dr. Chen Xiuqin published the paper in "Carbon" in 1999 [5], Carbon Microcoil became a member of the new family of carbon materials and attracted worldwide attention. Many of the world's spiral carbon fiber research group can achieve small batch preparation, and can control its size, mainly including micron and nano-level two, controlling the preparation conditions to change the CMC diameter of the spiral, length and fiber Gap and so on. However, large-scale preparation of spiral carbon fiber still has more problems, such as the preparation of more stringent preparation conditions, large-scale preparation technology were still not mature, the utilization of gas raw materials was not high enough to improve CMC's purity and structural stability, uniformity.

As the polymer material has the characteristics of low quality, easy processing, good flexibility and deformation ability, corrosion resistance and low cost, the preparation of polymer-based helical carbon fiber composite material and its application have gradually become the focus of CMC research in electromagnetic wave absorbing material, flexible sensor, medical and health care products and other neighborhood applications [6]. Jiang Dibo et al [7] prepared and studied the CMC / HDPE composite electroosmotic behavior and mechanism. An et al. [8] prepared CMC/polyvinyl alcohol (PVA) composites and tested their mechanical properties. Kejiro Yoshimura, T. Katsuno et al. [9,10] developed a flexible tactile sensor with CMC and silicone rubber. S. Motojima et al. [11] prepared CMC/PMMA composite beads and tested their electromagnetic wave absorption properties. Gi-Hwan Kang et al. [12] prepared CMC/PU composites and studied their electromagnetic shielding properties. All in all, polymer materials as the most widely used human society, the most widely used materials, polymer-based CMC composite materials research and development of a large extent to expand the scope of application of CMC.

2. Helical carbon fiber structure

Spiral carbon fiber is a three-dimensional spiral structure of the carbon material, and the spiral structure is similar to the spring as a single spiral, and similar to the DNA as a double helix. The carbon fibers with regular double helix structure are usually obtained by pairing two fibers in the same direction, coaxial with the same speed, and the edge roll of the growth side. As the direction of rotation of CMC is different, it has a certain chiral characteristics, the ratio of its left and right is generally 1: 1 [13]. The spiral diameter is generally 2-30 μm , a single carbon fiber diameter is generally 0.1 ~ 1 μm , and the length is up to 0.1 ~ 10mm, and the fiber cross-section is round or flat. Conborn fibers can pile up and also have a certain gap bwtween them [14,15]. The specific morphology of the helical carbon fiber is shown in Figure 1.

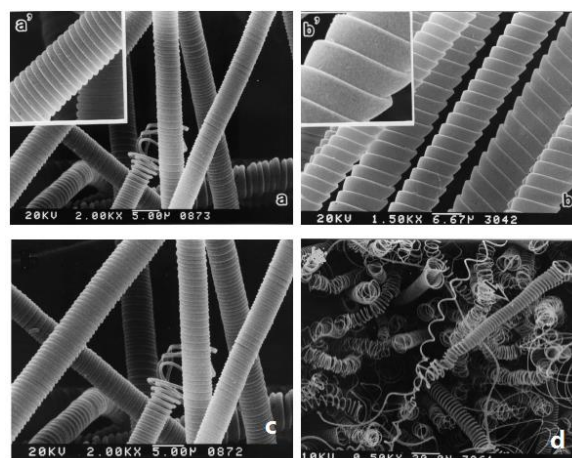


Figure 1. a) spiral carbon fiber with circular cross section; b) spiral carbon fiber with flat cross section; c) fiber spacing of 0 spiral carbon fiber; d) Fiber pitch is not 0 spiral carbon fiber.

3. Performance and Application of Spiral Carbon Fiber

3.1. Absorbing material

The absorbing material absorbs the electromagnetic wave energy projected onto its surface. In engineering applications, it is required that is light weight, high strength, heat, moisture, corrosion resistance and other properties, in addition to the requirements of absorbing materials in a wide range of high absorption rate. Absorbing materials used in radar stealth technology, aircraft, missiles, tanks, submarines, warships and other weapons and equipment, can effectively absorb the incident electromagnetic waves, significantly reducing the target reflection of electromagnetic waves, and achieve radar Stealth effect, which is an effective anti-radar detection means [16]. With the continuous development of science and technology, electromagnetic radiation has an increasing impact on people's lives. Electromagnetic radiation through the thermal effect, non-thermal effects and cumulative effects on the human body caused direct or indirect damage, so the application of absorbing materials has been extended to human safety, Microwave darkroom to improve the whole electromagnetic compatibility and other aspects.

High-performance absorbing materials require that the absorbing material matched with the impedance of the free space, it is to say that the electromagnetic wave can enter the absorbing material without any reflection, and the electromagnetic loss of the absorbing material is large [17]. At present, the absorbing materials are mainly ferrite, polycrystalline iron fiber, conductive polymer, nano-ceramic, magnetic metal nanoparticles, functional fibers, metal chiral micro-body, etc. [18]. Fiber-based absorbing materials have good prospects because of their unique shape anisotropy and excellent mechanical properties. At present, fiber-based absorbing materials are mainly carbon fiber, silicon carbide fiber and magnetic metal fiber [19], in which carbon fiber rather than other types of fiber has a small density, high specific strength, conductive heat and other excellent performance. Carbon fiber' morphology, can have a variety of forms in addition to a linear shape, and spiral is one of them. Spiral carbon fiber is a carbon fiber with similar DNA double helix structure or micro-spring structure. In addition to its excellent linear fiber density, high specific strength, chemical stability, heat resistance and other excellent performance, the special spiral structure also makes the material having good electrical properties, good mechanical properties and electromagnetic wave absorption characteristics. CMC products are mostly used to use its micro-spring characteristics, micro-coil characteristics and chiral symmetry characteristics. In particular, in the application of the absorbing material, the CMC, by virtue of its coil structure, generates a certain induced current when the electromagnetic wave is incident, so that the CMC converts most of the electromagnetic wave energy into heat energy, and the reflected electromagnetic waves will be greatly reduced. The absorption performance will be further enhanced by the orientation CMC in the matrix material, such as electric field orientation and tensile orientation, and the addition of ferromagnetic materials, such as ferrite. In addition, due to the structural characteristics of the spiral carbon fiber, the atoms on the surface are more likely to be excited, so the spiral carbon fiber absorption capacity is higher than the carbon nanotubes and linear carbon fiber, especially in the low frequency range. In summary, spiral carbon fiber is an ideal absorbing material.

In the absorbing material, the conductive polymer has the advantages of uniform texture, easy processing and low density, but its drawback is that the absorbing frequency band is narrow and the temperature range is small. The spiral carbon fiber has good heat resistance and high heat absorption capacity is precisely complement polymer's shortcomings. Spiral carbon fiber polymer composite material is expected to be a new generation of light, high absorption, broadband absorption, strong weathering of the new absorbing material.

3.2. Flexible sensors

With the continuous development of science and technology, the sensor has become a key part of the detection system. In the new era, the human proposed higher requirements to the sensors, including miniaturization, integration, intelligence and so on. Traditional sensors were characterized as relatively

hard or brittle because of the used materials are metal materials or ceramic materials, so the requirements cannot have a greater deformation, otherwise it will cause damage to electronic components. The flexible materials commonly used in semiconductor materials and organic materials, especially conductive polymer composite material, which is characterized as a good flexibility, can freely change their own shape, it can adapt to the uneven surface, to a certain extent, the expansion of the sensor application scope. Flexible sensor is a sensing device for sensing the distribution of surface force, and has wide application prospect in intelligent robot, medical measurement and biomechanics. Flexible sensors can be classified into flexible pressure sensors, flexible strain sensors, flexible temperature sensors, flexible humidity sensors, flexible gas sensors, flexible magnetic impedance sensors and flexible heat flow sensors [20] according to their use.

The volume of the spiral carbon fiber is 10 to 100 S / cm, and the conductivity of the helical carbon fiber is not good enough for graphene and carbon nanotubes [21]. But because of its micron-type spiral diameter coil structure, it can give the composite material special electrical properties. Spiral carbon fiber in general has a spiral diameter of 1 ~ 10 μ m [22]. It is known as the super-elastic carbon fiber (Super-elastic CMCs, referred to as SECMCs), when the spiral diameter is of 10 ~ 20 μ m. Because the helical carbon fiber has micro-similar spring-like spiral structure, even under very little pressure, the micro-spring will also occur telescopic deformation, accompanied by the inductance L, capacitance C, resistance R and other electrical performance parameters changes, so the CMC has a tactile Sensing performance. CMC tactile sensors can detect very small external load changes, only needed to add 10% CMC which make the tactile sensor more sensitive than that in the current market [23]. In general, the CMC tactile sensor has the following characteristics:

CMC tactile sensor can achieve a wide range of signal detection, which is flexible, easy to miniaturization, and has high sensitivity, the same as the human skin. The amount of CMC added to the smaller, is usually 1 to 10%. The sensors have excellent ability to distinguish, and you can identify electromagnetic waves, heat, sound and other different signals.

CMC is expected to become a new generation ideal material of lightweight, flexible, high sensitivity, intelligent sensor for the imitation of human skin to open up new roads.

3.3. Health care products

Carbon fiber is a kind of conductive thermal conductivity material, which was used as a source with far infrared heating element and had the role of health care therapy. Carbon fibers can be used as a new material in health care product. Spiral carbon fiber is a new type of carbon material with excellent Performance in addition to ordinary carbon fiber, due to its similar biological DNA or protein spiral structure, and it has excellent biomedical effect.

Spiral carbon fiber can increase the number of α waves in the brain, reduce the β wave to promote good sleep and reduce nervous tension and ease the effect of mental stress. Spiral carbon fiber also helps to enhance red blood cell oxygen carrying capacity, effective conditioning blood pressure. In addition, spiral carbon fiber can also eliminate the body of the backlog of free radicals, with anti-aging effect [24]. Yang Shaoming et al [25] prepared CMC composite ceramic beads using of CMC and ceramic as raw materials, which can change many chemicals, elemental chlorine, harmful bacteria and other substances harmful to the human body fluctuations into harmless or beneficial to the body, and the CMC microsprings vibrate the vibrations of the water molecules through the intermolecular vibrations, causing the water molecules to become smaller clusters of molecules. Drinking activated water can increase brain blood volume, suitable for long-term use of computers and mobile phones, lack of movement of the crowd.

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