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Mini Review

Development and Application of Ceramic Nanofiber Yarns

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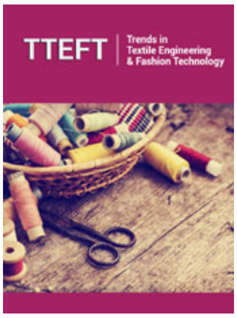

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Abstract

This paper briefly reviews the research progress of ceramic nanofiber yarns. The primary goal is to describe the advantages of ceramic nanofiber materials and the methods of fabricating ceramic nanofiber yarns, especially emphasizing the significance of ceramic nanofiber yarns in textile industry. Furthermore, the development prospect of ceramic nanofiber yarns is also outlined.

Keywords: Ceramic nanofiber yarns; Conjugated electrospinning; Sol-gel electrospinning; Flexibility; Mechanical properties

Introduction

Ceramic materials have many excellent properties such as low thermal conductivity, high temperature resistance, corrosion resistance and oxidation resistance [1], showing huge application potential in energy catalysis [2], filtration sterilization, high temperature insulation and other fields [3]. Traditional ceramic materials have high density and brittleness, so it is difficult to meet the requirements of high reliability structure application, which greatly limits its application in related fields. Compared with traditional ceramic structures, nano-structured ceramics have remarkable scale effect and surface/interface effect and have the advantage of being sintered at low temperature to achieve fineness. It is an effective method to improve the toughness and reliability of ceramics materials, showing unique mechanical properties and excellent physical chemical properties [4], making ceramic nanomaterials gradually become a research hotspot. Nano-scale ceramic fibers, in particular, have attracted much attention in recent years due to their high specific strength, high specific modulus, outstanding thermal stability and high specific surface area [5]. Ceramic nanofibers (NFs), due to its morphology, microstructure, composition and properties, enables them to be used in a variety of applications, such as the life sciences and healthcare sector, the energy and environmental sector, agriculture and food, electronics and magnetic devices, etc.

There are many ways to fabricate ceramic materials, among which polymer derived ceramics (PDCs) technology has become one of the mainstream preparation technologies for ceramics and their composites. Several methods have been developed to fabricate NFs, such as template method, self-assembly, phase separation, melt blowing, drawing and electrospinning method [1]. Among them, electrospinning is considered the most promising method for producing continuous NFs, which basically employs a simple, economical, and versatile setup to produce nanofibers of various shapes and sizes. The preparation of ceramic nanofiber materials by the combination of PDCs technology and electrospinning technology has been widely concerned by many researchers at home and abroad. Ceramic nanofibers with certain flexibility can be prepared by using the polymer as template, sol-gel electrospinning and calcination processing.

However, it has been found that due to the whipping and instability of electrospinning high-charge electric jet [6], most electrospinning ceramic nanofibers are collected in the form of non-woven fabrics. Under the action of electric field, the nanofibers are randomly stacked and arranged, further forming a chaotic aggregation structure, which results in poor mechanical properties, lack of sewability and other problems [7]. Referring to the traditional textile industry, it is known that the nanofibers need to form a continuous combination before they can carry out follow-up processing with traditional textile processing technology, such as knitting and weaving [8]. Therefore, the researchers developed tightly oriented electrospinning ceramic nanofibers, and twist them to construct ceramic nanofiber yarns, so as to enhance the tensile mechanical properties of ceramic fiber assemblages and broaden the scope of application.

Conjugated electrospinning is one of the most mature techniques used to produce nanofiber yarns. Conjugated electrostatic spinning technology is based on the principle of electrospinning. Positive pressure and negative pressure are applied to two opposite nozzles respectively, and the spinning liquid is drawn by the electric field force to form nanoscale precursor fibers. The fibers are collected on the trumpet collector and twisted into a bundle under the rotation of the horn, so as to realize continuous yarn formation of nanofibers [9]. The spinning process of conjugated electrospinning is stable, the preparation technics is also simple, and the fabricated yarns are continuous and uniform. This is suitable for the preparation of inorganic nanofiber yarns [10]. Zhang Dai et al. [11] used polyvinyl alcohol (PVA) as template to prepare flexible SiO2 electrospinning nanofibrous yarn by conjugating electrospinning process and calcining method. Due to the extremely small size of the crystal grains in the nanofiber, SiO2 yarn has perfect flexibility. In addition, there is no cracking phenomenon existing after bending at 180 degree. The SiO2 yarn showed a maximum stress of 3.8MPa and maximum elongation to 0.32%, which shows obvious weakness in tensile property. Therefore, its mechanical properties should be further improved before it can be used in functional textiles. Memarian, Farnaz et al. [12] successfully prepared TiO2 nanofiber yarns with high specific surface area and aspect ratio through sol-gel electrospinning technology. This yarn is from a solution containing titanium precursor and polyvinyl acetate (PVAc) as the polymer supporting material by using two opposite charged nozzles through spinning and followed by calcination process. Nanofiber yarns show high photocatalytic activity during dye degradation and are a splendid photocatalytic material. It can be removed from the solution without ultrasonic dispersion and centrifugal treatment and is easy to recover. At present, there are few reports on inorganic ceramic electrospinning nanofiber yarns, and the tensile strength and flexibility of these ceramic nanofiber yarns are very awful, which is difficult to meet the practical application requirements. The problem of poor mechanical properties of ceramic nanofiber yarns needs to be solved.

Conclusion

To sum up, it is of great significance to develop ceramic nanofiber materials with excellent mechanical properties, and the research of ceramic nanofiber yarn is a powerful way to solve this problem. At the same time, ceramic nanofiber yarns can combine the application scope of traditional micron fiber yarns and electrospinning nanofiber felt and have a wide range of applications in high-tech fields, such as high temperature insulation, reinforced composite materials and functional textiles. However, the tensile strength of ceramic nanofiber yarns is low, which is difficult to meet the needs of practical application. Further research is needed to enhance the tensile strength and flexibility of ceramic nanofiber yarns.

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