

Research Article

Auxiliary Fiber Art Creation Design Based on Conductive Fiber Textile Wireless Structure Sensor

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The integration of fiber materials into modern pottery creation is an attempt to explore its boundaries as a specific material and art form. Fiber materials, such as fabric and paper, are not resistant to high temperatures, and the clay attached to them can retain the surface texture, texture, and original three-dimensional form of the fiber materials intact during the kiln firing process, making up for the defects of single material molding and maintaining the visual effect of ultrathin and highly translucent works. The light source inside the work is more conducive to creating a specific artistic atmosphere. The purpose of this paper is to explore how fiber materials become the basis of ceramic works and the source of decorative expression, so that this expression and process can be systematically analyzed and interpreted in the application of ceramic art creation. Along with the rapid development of nanotechnology, electronics, and optical technology, people's clothing fabrics have been increasing in demand in terms of function and appearance. This paper focuses on the research and development of fiber textiles from the field of science and technology and discusses the current status of fiber textiles and the possibility of combining fiber art with science and technology. In this paper, wood cellulose-multiwalled carbon nanotube/wood cellulose composite films were prepared, as well as wood cellulose films and wood cellulose/multiwalled carbon nanotube composite films. The optimal reaction time for the preparation of the films was 2 h, and the optimal reaction temperature was 70°C. Experimental results show that the dispersibility of multilayer carbon nanotubes in wood cellulose multilayer carbon nanotubes/wood cellulose composite films in wood cellulose multilayer carbon nanotubes composite films is superior. If the amount of multilayered carbon nanotubes was 3 wt%, the fracture point extension and accessibility of the wood cellulose multilayer carbon nanotubes/wood cellulose composite film are 12.2% and 106.7 MPa, respectively. It is 93.7%, respectively. 10.7% is higher than wood cellulose/multilayered carbon nanotube composite films.

1. Introduction

With the increasing demand for textile garments in terms of appearance, function, and fashion, many nanostructures and nanomaterials, including nanoparticles, carbon nanotubes, and nanoelectronic components, have been gradually used in fiber textile processing in the past two decades. In terms of water repellency, the addition of nanomaterials to fibers can increase the surface tension of the fiber material, thus achieving a water repellency effect [1]. These effects can be achieved by nanowhisker technology or coating nanoparticles, and commonly used nanomaterials include silica, titanium dioxide, and nanowhiskers. Nanowhisker technology creates a

fleece effect, where the individual whiskers are spaced smaller than water droplets but larger than water molecules, resulting in high surface tension and causing water to remain on the surface. In addition, the coating of nanoparticles on the fabric surface will build up a nanoscale 3D structure, which can also produce high surface tension [2]. For example, the surface of polyester is treated with nanotechnology to produce a nano-scale roughness and thus a high tension, which allows water droplets to stay on the surface of polyester. In terms of anti-static, synthetic fibers, such as polyester and nylon, have high static charges because the materials are not hydrophilic [3]. Conductive nanomaterials such as titanium dioxide nanoparticles, zinc oxide whiskers, and tin oxide antimony nanoparticles

can eliminate the electrostatic charge that accumulates on textiles and provide antistatic properties [4]. In terms of antiwrinkle, conventional textile fibers can be impregnated with resin to achieve antiwrinkle properties [5].

This method reduces the tensile strength, abrasion resistance, and dyeability of the fibers, while leading to hydrophobicity [6]. Incorporation of nanoparticles into cotton and silk can achieve antiwrinkle effects without reducing fiber strength. For example, titanium dioxide nanoparticles with carboxylic acid as catalyst can be used to form cross-linking and acidic groups between cellulose molecules to achieve antiwrinkle effects [7]. In terms of enhancing the physical properties of fabrics, carbon nanotubes incorporated into fibers can improve the strength and toughness of fabrics while reducing the weight. Carbon nanotubes can be impregnated, dried, cured, and finally covered onto the fibers. In terms of UV blocking, nanoscale semiconductor oxides such as titanium dioxide and zinc oxide can effectively absorb and scatter UV light, and these inorganic nano-UV blockers are nontoxic and chemically stable. Among them, zinc oxide nanorods can be grown directly on cotton fibers to achieve UV-blocking effect [8]. In terms of antimicrobial activity, silver nanoparticles can provide bacterial antibacterial and bactericidal properties to fibers. The large surface area of silver nanoparticles can increase the contact of bacteria and fungi. When silver nanoparticles come into contact with bacteria, they adhere to the cell wall membrane, react with the proteins in the bacteria, and adversely affect their cellular function to inhibit cell growth. With the rapid development of consumer electronics in recent years, especially new wearable consumer electronics such as smart watches, smart glasses, and smart clothing, fibers have continued to gain attention for applications and R&D in related fields. Fibers need to be conductive in order to meet the conductive requirements of various microsensors, actuators, and energy storage devices [9]. Nanomaterials such as multiwalled carbon nanotubes, graphene, or gold nanoparticles can provide electrical conductivity to fibers. Conductive fibers can be incorporated into garments, such as cotton yarns that become electrically conductive when gold nanoparticles are used in them [10]. The prepared cotton yarns can conduct electricity and light up LED lights. These conductive nanofibers can also be combined with solar cells and applied to clothing. Solar cells can be implanted into textile fabrics or attached to the surface of clothing with flexible solar cells, which can be powered by conductive fibers. In fiber capacitors, flexible lightweight fiber capacitor electrodes have been designed for energy storage, and zinc oxide nanowires and discharge membranes can be combined into textiles to provide mixed electrostatic and piezoelectric effects [11]. With the development of high performance computing microprocessors and microcomputer integration, smart electronics are increasingly used in the field of clothing and wearable devices. Both physiological and postural data of the human body can be collected and analyzed through the use of different types of sensing devices in garments, such as ion sensors, pressure sensors, and temperature sensors, and finally used to correct or alert unhealthy postures or physiological conditions. Miniature actuation devices, such as microvibrating motors, can also be integrated into textiles to promote blood circulation and weight loss [12]. These miniature electronics

can be powered by a variety of means from internal or external sources, such as electricity generated by friction, energy from body oscillations, power absorbed by solar cells, or high-density fabric batteries. LEDs and fiber optics are increasingly being used in the fashion and entertainment industries as programmable vision components are used in clothing [13]. These garments can also be used in conjunction with a variety of sensors to change the color of the garment through data collected by the sensors, such as touch, movement, temperature, light, electric fields, or other external stimuli.

The optical effect of traditional textiles is usually achieved using LEDs, mainly due to the perfect processing of LEDs, their low cost, small size, and the availability of different colors. However, because LED materials are rigid, they are not really compatible with flexible textiles when used as screens. LED screens used in cell phones, tablets, and laptops, for example, are also nonflexible and often encounter many limitations when used in textiles. Therefore, flexible OLED screens composed of organic film will be the first choice for textiles or clothing. Compared to OLED flexible screens, flexible touch screens have an additional layer of touch, usually prepared using nanosilver wire or graphene. In addition to OLEDs, QLED (Quantum Dot Light Emitting Diode) technology has great potential for apparel applications. A comparison of Samsung's OLED and QLED TVs shows that QLED offers a wider color gamut and consumes less energy. In addition, in the field of touch sensing, fibers can also be combined with micromotors for touch fiber screens, offering more possibilities for interaction. This work produced wood cellulose multilayer carbon nanotubes/wood cellulose composite film as well as wood cellulose/multilayer carbon nanotube composite film. The optimum reaction time for the film was two hours, and the optimum reaction temperature was 70°C.

2. Related Work

Fiber Bragg gratings have high strain and temperature sensitivity and are often prepared for use in biosensors and temperature and pressure sensors. Fiber Bragg gratings can also be used in textile fibers, allowing textiles to exhibit a specific color when external light is directed at them. Fiber Bragg gratings are spatially phase-distributed gratings formed within a fiber core, where light is guided by a bandgap effect. The key to Bragg grating bandgap guidance is wavelength filtering [14]. When light is injected into a Bragg grating, only the colors defined in the reflector bandgap spectrum are guided. When white light is shot into the fiber, after the first few centimeters, the colors defined in the reflector bandgap spectrum are revealed. The spectrum of the reflector bandgap can be changed by the thickness of the reflector layer, producing different color effects. Fiber fabrics based on fiber Bragg gratings are colored in external natural light, and when white light is directed into this fabric, it reveals bands of vivid color [15]. This fiber fabric sample offers the possibility to control the color exhibited by the fiber fabric by modulating the intensity of the incoming white light and the external natural light [16]. Bragg fiber can be easily woven into garments, and in contrast to yarns or fabrics decorated with optical coatings or pigments, textiles made of Bragg fiber are resistant to

mechanical abrasion and will not fade even after repeated washing. The effect of Harry Potter cloak of invisibility can be achieved by applying metamaterials to the fiber fabric [17].

Metamaterials can achieve stealth by changing the path of wave propagation, making the wave bend when passing through the object to achieve the purpose of bypassing. When applied to textile garments, to achieve 360-degree optical stealth effect, two problems need to be solved: one is to reduce the speed of light to make it better control; the second is to change the refractive index and change the light path to achieve the effect of bypassing. At present, there are through the use of gold and propylene plastic to achieve the stealth effect [18]. The thin and uniform thickness of the gold film can slow down the speed of light, and on top of this gold film is a thin and transparent but not uniform thickness of the propylene plastic layer; the purpose is to change the light path. When these two materials are combined together, when the light arrives, it will encounter propylene plastic or gold in different areas, and the path of the light will keep changing, so that it will eventually go around and achieve the effect of stealth [19]. At present, the stealth research and development is still in the nanoscale range and is only applicable to two-dimensional space for the time being and has not been able to achieve the same effect as the Harry Potter stealth cloak. Vantablack is composed of carbon nanotube blackbody, one of the blackest substances known, which consists of vertically aligned carbon nanotubes that do not emit visible light at room temperature and absorb up to 99.965% of the visible wavelength.

This is due to the fact that when light is shot into a carbon nanotube blackbody it is hardly reflected out but is continuously refracted in the walls of the tube until it is finally converted into heat energy. Materials similar to this black hole effect are currently being tried out in watches, automobiles, and architecture, and similar attempts are expected in the fiber textile field in the near future. 2000 years later, a large number of nanotechnologies and nanomaterials are being used in textiles, including various nanoparticles, nanostructures, and nanomicroelectronic devices that provide different and new functions to traditional textile materials. These nanomaterial developments have also advanced new manufacturing methods in textiles, including particle impregnation, spraying, and multi-functional composite fiber stretching, which have matured into applications such as water repellency, antistatic, UV protection, antibacterial, wrinkle resistance, and enhanced mechanical and electrical properties [20]. Nanotechnology is currently not widely used in the creation of fiber art, mainly because current nanotechnology research and development focuses on functionality and is relatively scarce in the direction of visual effects as well as appearance. For example, conductive fibers, micro-sensors, and solar cells are all nanotechnologies that provide functional effects. The visual aspect can often be achieved through traditional, mature industrial technologies. For example, the optical effects of traditional textiles are achieved through LEDs, mainly because the technology is more mature and leads to higher controllability and lower costs, making it more accessible to artists in the field of fiber art.

Due to the existence of mature processes such as LEDs, there is little demand for OLEDs in textiles, and the high

cost of OLED screens makes it difficult to apply them widely. So when artists in the fiber arts want to use new nanotechnology, they are more or less skeptical about these cutting-edge technologies. In the field of scientific research, nanotechnology research and development is always forward-looking, the technology is constantly updated, and the general direction of research and development is basically fixed [21]. When nanotechnology is combined with fiber art, there are many practical considerations, and it is necessary to look backward when creating art with nanotechnology, using nanotechnology that is already relatively mature. More often than not, the artist needs to come up with relevant technical and artistic needs and then incorporate nanotechnology into his or her own creations, rather than chasing after the direction of new nanotechnology development. This will lead to difficulties in landing the final creation, and its operability and controllability are relatively low. From the future direction of development, the continuous cross-border of textile field is the method of continuous extension of each knowledge field, and with the continuous expansion of nanomaterials in electronic and optical fields, the deep interaction of fiber art and nanomaterials, each moving forward to achieve a new partner of mutual human social knowledge meaning.

3. Artistic Presentation Based on Conductive Fiber Sensors

3.1. Conductive Fiber Preparation Method. Spinning method is the conductive ions and fibers combined together; there is a method to mix the conductive fibers into the spinning solution, through the wet spinning directly form yarn, although the process is complex, but the formation of yarn durability and conductive ions distributed evenly. Wet spinning and gel spinning methods are mainly conductive polymers, conductive metal ions, or conductive carbon materials, and matrix polymer composite spinning made of conductive fibers and conductive polymers (such as polyacetylene, polyaniline, polypyrrole, and polythiophene) is directly spun. Wet spinning includes the process of preparing the spinning liquid, then pressing the spinning liquid out of the spout hole to form a fine stream, and when the fine stream of spinning liquid is solidified into the initial fiber, the initial fiber is posttreated to obtain the fiber. Many people have prepared conductive filaments with sensing properties by compounding the spinning fluid with conductive materials. Nanosilver was blended with a polyester polymer and a filament with 220% strain, and a conductivity of 2450 S/cm was obtained by a wet spinning process as in Figure 1, which can be used as a strain sensor to detect human movements. The conductive filaments based on spandex and PEDOT were prepared by wet spinning, and the strain-sensing yarn with knitted structure was used to test up to 160% strain by weaving the filaments into a loop yarn with a knitted structure, which is elastic enough to produce a change in resistance with strain during deformation. The conductive fibers can be woven directly into the wrist brace, and the resulting wrist brace can be used as a strain-sensing fabric to measure the movement of the elbow joint in real time when worn on the elbow.

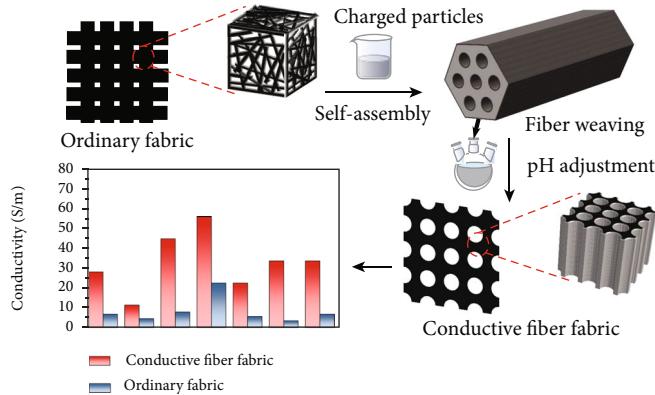


FIGURE 1: Preparation process of conductive fibers.

Covering the surface of fibers with conductive substances, such as by chemical methods, can impart conductive properties to fibers. People take advantage of the greatly reduced resistivity of doped conductive polymers to make them conductive by covering the surface of a polymer fiber as a conductive layer. For example, electrochemical methods have been used to improve the electrical conductivity of fibers by forming a coating of a conductive organic polymer, polyaniline, on the surface of certain polymer fibers. The conductive polymer polypyrrole was synthesized on the surface of polyacrylonitrile (PAN) nanofiber yarn by in situ liquid deposition to obtain composite nanofiber yarn with excellent electrical conductivity. Metal ions can be covered on the surface of various fibers by coating, grafting, or chemical deposition. For example, Zhu Yannan used polyvinyl alcohol and silver powder to prepare conductive silver paste and then sized nylon fibers by coating method, and the silver paste formed a silver coating on the fiber surface to obtain metallic silver conductive fibers. This method is simple and easy to use, but unfortunately, this surface coating only covers the surface of the matrix fiber and is not uniformly distributed over the entire fiber cross-section. Conductive spandex filaments were obtained by depositing nanosilver on the surface of a polyurethane fiber with a multi-filament structure. During the stretching process, as the polyurethane fiber stretched and changed, the surface nanosilver layer continuously fractured and combined, and a change in resistance occurred, and this conductive polyurethane fiber exhibited an ultrahigh sensing coefficient of 9.5×10^5 and a maximum strain of 450% as a strain sensor. Carbon-based conductive materials can also be coated, grafted, or chemically deposited on the surface of various fibers; for example, they coated graphene oxide uniformly on a polyester/spandex knitted fabric and obtained a graphene-based flexible strain fabric sensor by redox reaction with an operating range of 0%-30% strain and a sensing coefficient of up to 18.5. The graphene knitted fabric with graphene surface was obtained by the redox reaction, and the sensing principle of the graphene knitted fabric was established by the change of different stretching directions of the knitted coils, and most of the human physiological activities such as wrist bending, knee bending, and arm bending were tested by this knitted fabric sensor.

3.2. Visual Presentation of Conductive Fiber Wireless Sensing Assistance. Color interacts with the rhythm, rhythm, and order in the visual formal beauty of the pattern, as shown in Figure 2. The beauty of color depends on the mutual matching of various colors. The oriental color perception symbolized by the five colors of red, white, black, yellow, and cyan is in line with the aesthetic characteristics of oriental people who emphasize expression and intuition. In the Kao-Kung-Ji, drawing and painting are a way of drawing patterns with dyes on ancient clothing and fabrics. Embroidery is closely related to drawing and painting. During the Zhou Dynasty, when clothing was divided according to the hierarchy of costumes, clothes were painted in a way that the upper garments were painted and the lower garments were embroidered. The five colors are the red, green, yellow, black, and white, and the five colors represent the connection between the five colors and the universe. The ancient silk fabrics excavated from the Chu tomb in Jiangling, Hubei, contain embroidery, knitting, brocade, and other categories, and the clever and harmonious color matching on the jacquard fabric opens the high visual aesthetics on the five-color embroidery of the painting and drawing. Chu art pattern color with red and black as the main color mainly expressed in lacquer ware. The idea of red material source is related to fire, sun, and blood. During the Warring States period, Chu patterns in lacquerware decoration mostly painted techniques. Chu lacquerware color is generally black lacquer Zhu painting that is the main. Chu art is in red and black colors, reflecting the Chu people's desire for life and the escape from death; the Chu people hope to enter the sky after death, rather than the concept of the underworld. Black belongs to the color without light, between the warm red and the lacquer black; under the visual contrast, red is more concentrated feedback to people's visual perception, between the two applications make the vessels have elegant and beautiful characteristics. In the primitive period, there is a commonality between red and black color use and Chu pattern color. The primitive human ability to perceive color comes from the visual visible sensory function. The same life and color is the essential feature of the spontaneous color activity of prehistoric man, in order to adapt to the basic needs of life. People chose natural pigments as an instinct of life and unconsciously formed such a

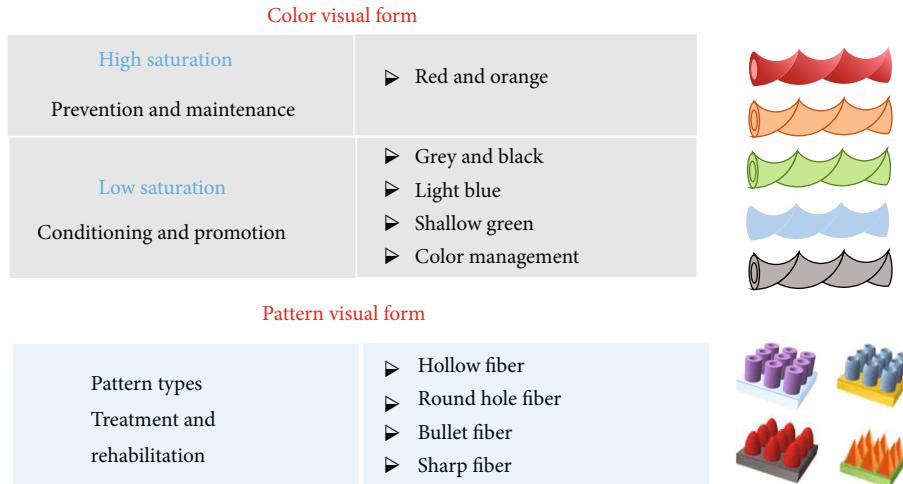


FIGURE 2: Color and pattern visual form.

consciousness. The primitive period red and black represent the red flame in the darkness. The color pottery culture in the primitive period was painted in red and black. The color on the pottery is produced by high temperature firing and preserved for a long time. Black represents the primitive man after hunting beasts, burning charcoal black and inspired.

Pattern in the basic picture of the pattern warm color uses more color; the picture is harmonious and unified. In the lacquerware, warm colors are commonly brown, brown, yellow, and other colors; cooler colors are a small amount of blue, green, white, etc. Among them, green, white, blue, gold, and yellow are usually used as auxiliary colors to increase the color contrast of the pattern and enrich the picture effect. In the pattern color, between the color plays a transitional role, commonly used earth yellow, light yellow, emerald green, gray green, etc. In the silk color, generally warm colors, red, yellow system is frequently used; similar colors make the picture color transition natural, mainly in the brightness and hue levels of contrast. In the pattern, embroidery threads are also often used in similar colors. The use of red and yellow as the main colors originates from the people's worship of fire. Clothing is mainly colored with vermillion red, gold firefly, plain green, vivid red, and greenish blue. The embroidery threads are in red-brown, crimson, orange-red, vermillion, light yellow, earthy yellow, golden yellow, yellow-green, and cobalt blue. From the costumes excavated from Masan No. 1 tomb, it is obvious that the aristocracy loved red and yellow color system with high purity and vivid color. Pattern modeling is a harmonious form that consists of several identical elements or different elements to form the overall picture. The layout is scattered in a left-right and front-back staggered manner, and new forms of graphic composition are created through the repetition and panning of the picture. Chu's control of the modeling as a whole, from the local to the whole, and then from the whole to the local, has an accurate concept of spatial structure and imagination. The multidirectional turning and connecting ups and downs between each other enrich the visual texture of the object. The patterns in the two-dimensional space are dominated by plane shapes such as fabrics, bronze mirrors, and jade. The overall visual theme of the bronze ware on the three-dimen-

sional composite lacquer pattern is clear, the relationship between primary and secondary is clear, and the composition is full. According to specific pattern types, patterns include simulation-based realistic shapes, geometric patterns, and abstract shapes of animals and characters. In this paper, two objects are combined and reconstructed into a composite shape, as shown in Figure 3. The composite conductive fiber containing carbon black is usually gray-black, limiting its application, and then began the study of white conductive fibers, with a particle size of about $1\text{ }\mu\text{m}$ of copper, silver, nickel, cadmium, and other metal sulfides, iodide, or oxide as a conductive material; through the composite spinning process can be widely used for dyeing white conductive fibers.

Composite conductive fibers are mainly organic conductive fibers made by composite spinning method, in which the conductive material is continuous along the fiber axially and easy to escape the charge. Composite structure is common in the skin core structure, island structure, sandwich sandwich structure, and comingled structure. Carbon black composite conductive fibers have excellent conductivity and durability, and longevity is better. Metal compound composite conductive fibers have relatively poor electrical conductivity and are suitable for the production of light-colored civilian textiles. Composite organic conductive fibers have good wear resistance, flex resistance, oxidation resistance, and corrosion resistance, and other fibers are easy to hold together, easy to blend or interweave, with excellent and durable conductivity. Therefore, this fiber is widely used in industrial production and clothing and accessories. 1974 dupont, the U.S. company took the lead in the development of polyester containing carbon black as the core, nylon for the sheath of the skin core composite conductive fiber Antron, after a number of well-known chemical fiber companies have begun to study the composite conductive fiber containing carbon black. For example, the conductive masterbatch prepared by melt granulation of white conductive titanium dioxide prepared by the melt spinning technology of blended conductive fiber and trilobe composite conductive fiber has better conductivity and mechanical properties than the blended conductive fiber. It has a smooth surface and is suitable for weaving and drenching. In addition to better

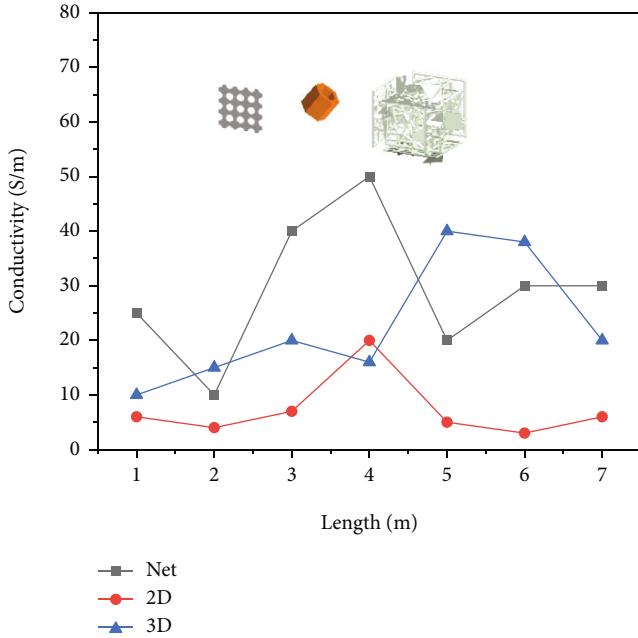


FIGURE 3: Conductive fiber pattern type.

sensing, the spinning of thermoplastic polyurethane and carbon nanotubes can also be used as flexible strain sensors to be spun into the skin-core structure of filaments. In addition to better sensing coefficients and elasticity (>350%), extremely small deformations (0.35% N-1 in the range of 0.025-50 N) can be detected.

3.3. Combination Method with Fiber Art. The creation of art works is based on newness and change. Fiber art works are created with a variety of techniques, materials are different and unique, and the visual senses presented by different material carriers are different. Fiber art is different from the cold and hard visual image of patterns on lacquerware, jade, and bronze and is relatively close to silk weaving but more subjective and varied than patterns on silk weaving. Fiber artist Wan Man once said woof is the source of everything. Woof is a unique Chinese silk handicraft; from the tomb unearthed in the text also recorded in the silk weaving process “woof” has been produced, woof combined painting and fabric. The woof combines the painting with the fabric. Using the method of breaking the weft through the warp, the painting is placed under the warp, and the weaver marks the position of the corresponding warp with a pen, then weaves the weft with a shuttle of the corresponding color. The weaving process in fiber art is the same as the traditional Chinese handicraft technique of “weaving through the warp and breaking the weft.” The traditional silk weaving process gives fiber art an important creative root. As a carrier for conductive active materials and a receptor for conductive fiber sensors, the selection of a wearable flexible base material is of utmost importance. The textile substrate has good mechanical properties, flexibility, resilience, and skin-friendly characteristics, and the cost is simple, and the material is easy to obtain. Compared with other smart electronic devices such as membranes and foams, textile-based flexible sensors can

realize seamless connection with fabric products such as garments and home textiles to achieve an integrated design. Since textile substrates possess a variety of structures with different dimensions, flexible sensors can be classified into one-dimensional (fiber or yarn), two-dimensional (fabric, PDMS membrane, etc.), and three-dimensional sensors (gel, 3D printing with sponge, etc.) depending on their dimensions. However, the current way of combining textile-based flexible mechanical sensors with smart garments is limited to assembly and does not meet the needs of some complete integration with textiles. Moreover, most of the flexible sensors are structured with a single substrate and cannot combine the characteristics of substrates that utilize many different structures. Therefore, the study of flexible substrates with three-dimensional frame structure that can be composed of one-dimensional conductive fibers is the focus of current research. In this study, we use a one-dimensional core yarn as a flexible substrate to prepare a multidimensional textile-based flexible sensor.

From Figure 4, it can be seen that GCSY is spring-like when it is not stretched, and the surface of polyester is smooth. It can be observed in the figure that the polyester surface in GCSY is covered with a uniform layer of graphene sheets. The figure shows that although the yarn structure has changed after stretching, the graphene on the surface of the polyester remains unchanged. The graph shows that GCSY can be stretched up to 300% deformation under normal environment with two-hand tension. GCSY also breaks slowly after stretching more than 300% in the instrument measuring tensile strength, and finally, the whole yarn breaks after stretching 500% change. In the stretching process, GCSY resistance first becomes larger with the increase of stretching, then with the increase of stretching resistance change gradually flattened, and finally with the increase of stretching resistance gradually becomes smaller.

4. Wireless Structural Sensor-Assisted Creation of Conductive Fibers

The resistance of GCSY changes from 0% to 100% as the stretching increases and then gradually becomes smaller with stretching. In this paper, we can clearly see the change of the state of the polyester filament on the surface of the yarn by taking SEM images of GCSY at different stretching times and establish a physical model to analyze the reason for the change of resistance of GCSY during stretching by observing the change of the state of the yarn. It is observed in Figure 5 that the polyester filaments in GCSY are loosely coiled on the surface of spandex filaments at the beginning, and after stretching, the polyester filaments are gradually stretched, and the contact area between them gradually increases, and after being stretched to a certain extent, the polyester filaments are gradually pulled tightly and then tightly wound on the surface of spandex filaments, resulting in a gradual decrease of the contact area on the surface of polyester filaments. Therefore, this paper establishes the cross-sectional model of GCSY to analyze the reason for the change of GCSY resistance; in the 0%-100% stretching process, as the contact area of the polyester filament increases, the contact resistance between the polyester filament produces a part of the contact

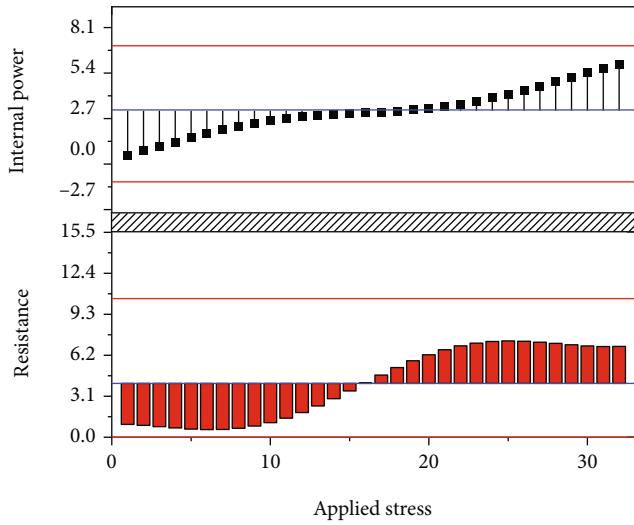


FIGURE 4: Physical properties of conductive fibers with stress.

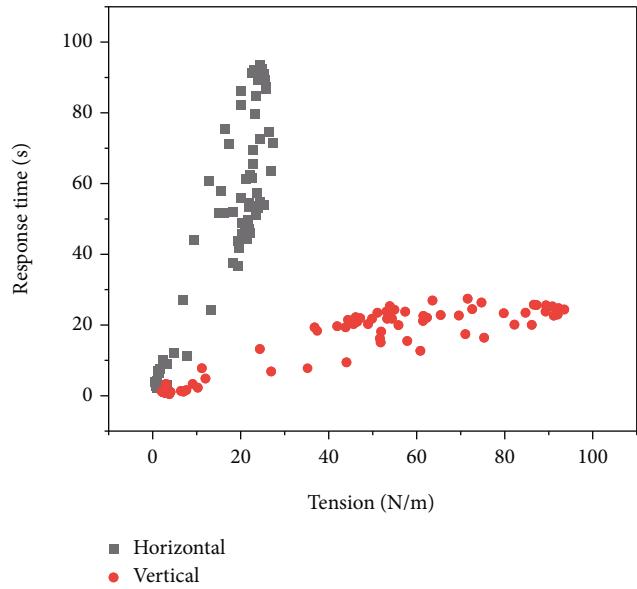


FIGURE 6: Response time curve when releasing tension.

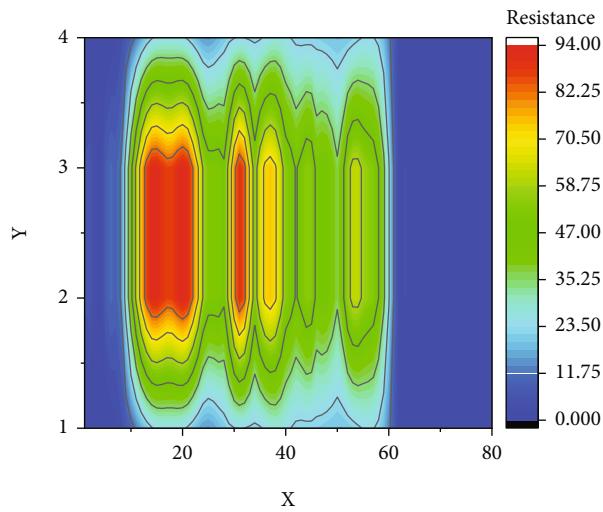


FIGURE 5: Resistance change during stretching.

resistance; with the increase of the contact area, the contact resistance also gradually increases, and then after the 100% stretching between the polyester filament contact area and gradually becomes smaller contact resistance that slowly becomes smaller, so resulting in GCSY in the 0%-100% stretching process resistance gradually becomes larger, and after 100% stretching resistance gradually becomes smaller.

Some of the properties of GCSY are accomplished by an automatic stretching device with controlled speed and adjustable distance, which is shown in Figure 6. After removing the core yarn spandex filament of GCSY as core yarn, the yarn was obtained as the outer layer of several loose polyester filaments (GSY). The loose CSY was tested together with the GCSY as the original state for the change of resistance during the stretching process at a rate of 0.4%/s. From the figure, it can be observed that the resistance of the GCSY gradually increases during the stretching process to 100% and gradually decreases during the 100%-120% strain, while the resistance

of the GSY without spandex filaments gradually decreases during the stretching process with a range of less than 50%. Accordingly, it can be shown that spandex and polyester play a mutually supportive role in core-spun yarn, and the interaction between polyester filaments is an important factor in the change of resistance while spandex filaments are an important factor in the large strain range. The sensing factor (GF) of GCSY is up to 1.46 (stretch < 5%), which allows GCSY to detect extremely small deformations such as pulse and heartbeat. The sensing factor of GCSY decreases with increasing stretch. The response time of GCSY is obtained by testing the time when a leaf is dropped on GCSY from above, and the strain time of GCSY is 0.12 s. The response time of GCSY is 0.12 s when the yarn is contracted by slightly stretching GCSY to a taut state and then suddenly releasing the curve. Due to the looseness of the initial structure of GCSY, there is a buffer time called creep time when the yarn is suddenly stopped after high speed stretching, and the relative resistance change curve of GCSY stretched at a rate of 0.4%/s for 20%, the creep time of GCSY is 1.32 s, and the resistance change is 0.54%. In order to test the durability of the yarn, the GCSY was placed on an automatic stretching device set to return after each stretch of 100% and is the resistance change curve of GCSY stretched for 10,000 cycles; it can be seen that although after 10,000 stretches, the relative resistance of GCSY does not change much.

The relative resistance curve was obtained by bending the wrist and straightening the wrist. The TSS was then placed on the knee, which requires a larger deformation range. In order to further understand the principle of resistance change of knitted fabric, photos of knitted fabric in original state, transversely stretched state and longitudinally stretched state, were taken under super depth of field lens, and it can be observed that the top and bottom coils of TSS in normal state are closely connected and after transversely stretched coils are separated from left to right, while after longitudinally stretched top and

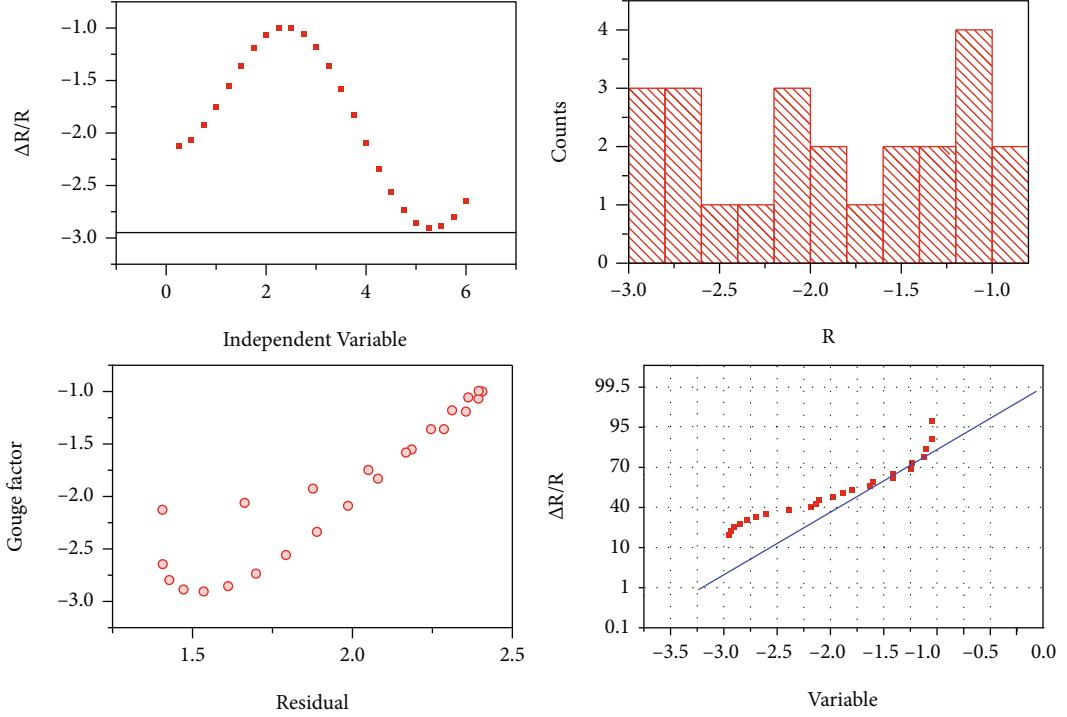


FIGURE 7: Variation curve of sensing coefficient for different stripes.

bottom coils are no longer closely linked but gradually separated and connected only at the junction. Based on the above pictures, the model of TSS and the resistance model are established to analyze the principle of resistance change of the strain sensor after being stretched. During the transverse stretching process, the longitudinal coils are considered as a whole, and the dispersion of the left and right coils, Ra1, Ra2, and Ra3 from parallel to series, is the main reason for the increase of the overall resistance. In the longitudinal stretching process, there is an obvious phenomenon that the contact area of the upper and lower coils becomes smaller, and the contact resistance Rbc1 and Rbc2 become larger due to the contact area becoming smaller is the main reason for the overall resistance becoming larger. The knitted strain sensors (TSS) with different patterns were knitted by seamlessly connecting CSY and GCSY with knitted loops on a knitting circular sock machine, as shown in Figure 7, and the elasticity of the knitted fabric was obtained not only from the elasticity of the yarn but also from the elasticity of the knitted structure. The graph “Qingda” and three longitudinal stripes of 0.3 cm, 1 cm, and 3 cm width were written in GCSY. From the graph, we can see that the relative resistance change and test range of the three different stripes are different; the wider the stripes the larger the test range and the greater the relative resistance change. The width inductance of stripes in 0.3 cm, 1 cm, and 3 cm horizontal width stripes is 15, which is 14 times that of GCSY. Knitted fabrics are much less elastic when stretched in the transverse direction than in the longitudinal direction, so the test range of 0.3 cm, 1 cm, and 3 cm transverse width stripes is much lower than that of the same width longitudinal stripes, but the GF value is higher than that of the longitudinal stripes with the same parameters.

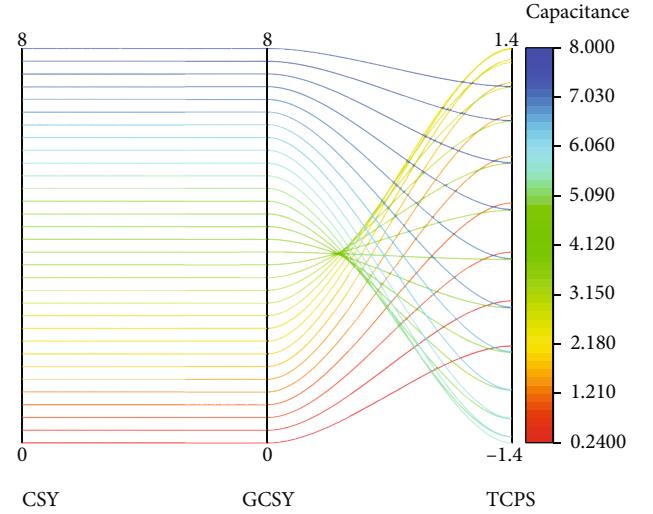


FIGURE 8: Capacitance change histogram of TCPS.

The knitted fabric knitted by CSY and GCSY through a sock machine is called a fabric-based strain sensor (TSS). The black part of the fabric is composed of GCSY, which is the part with sensing effect, so the black part is placed on the surface of the measured part during the test, and the knitted fabric can be worn directly on the body for the test as can be observed from all the pictures. First, the TSS is placed on the wrist at the pulse, and two wires are led at both ends of the pulse for testing, and the relative resistance change curve when the pulse beats is obtained as shown in Figure 8, and it is observed that the pulse of the subject beats about three times

every two seconds. A wrist guard-like TSS is placed on the wrist, unlike when the pulse is measured. As can be seen from the picture, the black sensing area is located above the wrist during this test, and the relative resistance change curve is obtained by bending the wrist and straightening it. In addition to bending and other human physiological activities, the TSS can be worn on the small arm to test the relative resistance change curve during muscle contraction, arm joint rotation, and knee joint rotation. On the basis of TSS, after setting the knitting apparatus, CSY and GCSY are used to weave a fabric with ten small GCSY squares, and the two identical fabrics are connected by a thin and uniform thickness of silica gel in the middle, so that the upper and lower two identical fabrics correspond to the upper and lower GCSY squares, thus obtaining a flexible capacitive sensor (TCPS) with silica gel in the middle medium, shaped like a keyboard, and soft as shown in the figure can be both. It can be turned and tied into a buckle shape. The upper and lower electrodes were connected to test the capacitance, and the capacitance was changed by pressing one finger, two fingers, and six fingers on the keyboard-like TCPS. The reason for the change in capacitance is the change in the dielectric silicone in the conductive layer on both sides.

The optical effect of traditional textiles is usually achieved using LEDs, mainly due to the perfect processing of LEDs, their low cost, small size, and the availability of different colors. However, because LED materials are rigid, they are not really compatible with flexible textiles when used as screens. LED screens used in cell phones, tablets, and laptops, for example, are also nonflexible and often encounter many limitations when used in textiles. Therefore, flexible OLED screens composed of organic film will be the first choice for textiles or clothing. At present, the flexible OLED screen has been successfully developed by Softtek to be combined with clothing and brought to the market. After that, it is expected that the flexible touch screen will also be used in the field of clothing to achieve more interactive effects. Compared to OLED flexible screens, flexible touch screens have an additional layer of touch, usually prepared using nanosilver wire or graphene. In addition to OLEDs, QLED (Quantum Dot Light Emitting Diode) technology has great potential for use in apparel. A comparison of Samsung's OLED and QLED TVs shows that QLED offers a wider color gamut and consumes less energy. In addition, in the field of touch sensing, fibers can also be combined with micromotors for touch fiber screens, offering more possibilities for interaction.

5. Conclusion

From the direction of future development, the continuous cross-border of textile field is the method of continuous extension of each knowledge field. With the continuous expansion of nanomaterials in electronic and optical fields, the deep interaction of fiber art and nanomaterials, each moving forward, accomplishes the new companion of mutual human society in the sense of knowledge. In this paper, we first analyze the excellent structure of spandex filament and polyester filament complementing each other in core-spun yarn. The GCSY can be used as a strain resistive sensor to measure both small deformation signals such as pulse and macroscopic large

deformation signals such as large leg bending and can also transmit signals of human physiological activities to cell phones based on wireless Bluetooth signal transmission. On the mobile phone based on wireless Bluetooth signal transmission, GCSY-based BSS and TSS can be worn directly on the body for testing in addition to having all their advantages. The TSS-based TCPS is a simple pressure capacitive sensor that can also transmit signals well. After testing the performance of GCSY as a strain sensor, the experimental data proved that GCSY has good sensing effect, high sensitivity, and repeatability, and TSS has all the advantages of GCSY in addition to being directly wearable and having adjustable sensing coefficient. More often than not, artists are required to come up with relevant technical and artistic needs and then integrate nanotechnology into their own creations, rather than chasing after the direction of new nanotechnology development. This can lead to difficulties in landing the final creation, and its operability and controllability are relatively low. In the future, the study of flexible substrates with three-dimensional frame structure that can be composed of one-dimensional conductive fibers is the focus of current research.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work.

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