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Piezoresistive Flexible Sensor Based on Microscopic Observation of Suspended Single-walled Carbon Nanotube Array

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Abstract: With the continuous progress of science and technology, piezoresistive flexible sensors have been widely used in aerospace, energy detection, military confrontation, medical and health services and life services. In this paper, the piezoresistive flexible sensor based on a single-walled carbon nanotube array suspended under a microscope is studied. This research is mainly to combine suspended single-walled carbon nanotubes, nucleic acid molecular hybridization technology and electrochemical analysis technology to develop a piezoresistive flexible sensor with high sensitivity and good selectivity based on microscope observation. Selective detection of nanotube array fragments. Using carbon nanotubes as the tip of STM/AFM effectively improves the resolution of piezoresistive flexible sensors. Experimental data shows that when the first device array structure is adopted, the sensitivity is 0.3412 in the interval of 0-15KPa; and the sensitivity is 0.4502 in the interval of 15-30KPa. Later, as the pressure continues to increase, its sensitivity tends to zero. The experimental results show that the piezoresistive flexible sensor based on the single-walled carbon nanotube array suspended under a microscope is within a certain range. As the pressure increases, the sensitivity also increases; beyond a certain range, as the pressure increases, the pressure the sensitivity of the resistive flexible sensor tends to zero.

1. Introduction

1.1. Background and Significance

Piezoresistive flexible sensors with suspended single-walled carbon nanotube arrays are improving our work, health and lifestyle in unprecedented ways. They can track our own situation and surrounding environment, and provide better choices for people's lives. Piezoresistive flexible sensors play an extremely important role in the medical field, successfully extending the senses of

medical staff, enabling medical staff to timely grasp the various health indicators of patients, and alleviating the human health caused by sudden diseases. Injury, and can more accurately grasp the patient's health.

Suspended single-walled carbon nanotubes, with their unique optical, electrochemical and catalytic properties, have shown their broad application value in many fields. As a new type of sensor, a piezoresistive flexible sensor can output electrical signals with a mapping relationship during the measurement process when the object to be measured expands and contracts, and changes in externally applied loads such as pressure and vibration. Compared with traditional rigid sensors, piezoresistive flexible sensors with suspended single-walled carbon nanotube arrays have the characteristics of elasticity, flexibility, arraying and multi-function, making them easier to use in complex environments. To some extent, make up for the working environment of traditional sensors that cannot be measured [1-2].

1.2. Related Work

At present, many domestic universities and scientific research institutions have conducted in-depth and extensive research on piezoresistive flexible sensors. Luo, N realized the idea of non-blocking and continuous BP monitoring through non-invasive and real-time cuffless blood pressure (BP) measurement, which is essential for the diagnosis and prevention of hypertension-related cardiovascular diseases. He proposed a wearable sensor patch system that integrates a flexible piezoresistive sensor (FPS) and an epidermal electrocardiogram (ECG) sensor for sleeveless blood pressure measurement. By developing a parameter model on the FPS sensing mechanism and optimizing the operating conditions, a highly stable epidermal pulse monitoring method was established, and it was proved that beat-to-beat BP measurement was performed from ECG and epidermal pulse signals. In particular, his research emphasizes the compromise between sensor sensitivity and signal stability. Compared with current optical-based sleeveless BP measurement equipment, the sensor patch requires much lower power consumption and can detect subtle physiological signal changes. However, his topic selection is not novel enough, and there is no professional data support, so he cannot give high-quality guidance to others' papers [3]. The research of Lin, X introduced a flexible pressure sensor based on PPy-cotton composite material, in which PPy is grown on cellulose fiber of cotton pad by in-situ vapor phase growth method, which is conducive to the uniformity of the composite material. The resulting device showed fast response and recovery speed, with response and recovery times of 220 ms and 240 ms, respectively. The best PPy-Cotton Pads (PCPs) sensors show a lower detection limit, about 50 Pa. At the same time, it has excellent durability when measuring the repeated loading and unloading pressure more than 1000 times. The final sensor he studied could be connected to different parts of the body and used to record physiological signals such as wrist pulses, vocal cord vibration, breathing and blinking. He believes that a 4*4 pressure sensor array indicates that PCPs sensors have a pressure distribution detection function and have great potential in the field of wearable electronic devices and biomedical devices [4]. Schwerter, M has developed an innovative piezoresistive pressure sensor design in order to allow for smaller sizes, smoothness and robustness of exposed surfaces, and integration into flexible sensor arrays. Contrary to known concepts, the sensing element and the conductive track are located in the pressure reference chamber and are therefore protected from environmental influences such as water or particles. The sensing element can be electrically accessed from the back through the through hole, so a completely flat surface can be achieved without any electrical components required for the flow experiment. The sensor includes a thin silicon sensing membrane and a body made of glass, which is used to fix the reference chamber and the via. The structure of the sensor body is completed by femtosecond laser ablation. A steep

ablation edge is achieved, thereby reducing the sensor size. The sensing film is made using potassium hydroxide (KOH) wet etching. The glass body and the silicon film can be connected by different technologies [5].

1.3. Innovation in this Article

The main innovative work of this paper includes the following aspects: (1) Combined with dielectric electrophoresis, regional selective electrodeposition of metal and microelectronics technology, a neatly suspended SWNT array is arranged on the curved PI film, and at the same time, a suspended SWNT array is realized. Measure negative strain, and increase the piezoresistive factor of the array to more than 400 through strain-based selective electrical burnout, and the linearity exceeds 95%, and a good static and dynamic curve is obtained. (2) Overcome the limitations of common flexible sensors used at low pressure, and develop and innovate the application. The sensor is installed on the side of the high-speed rail damping spring and subjected to periodic pressure of 10 to 60Kn at a frequency of 3Hz. During operation, the sensor outputs a stable and repeatable signal while maintaining shape integrity.

2. Piezoresistive Flexible Sensor with Suspended Single-Walled Carbon Nanotube Array

2.1. Performance of Suspended Single-Walled Carbon Nanotubes

Suspended single-walled carbon nanotubes have excellent mechanical, electrical, and thermal properties, and can be used in microelectronic components as radar wave absorbing materials. The surface of carbon nanotubes can also be modified by chemical methods such as addition, oxidation, reduction, etc., to achieve the purpose of improving the strength of carbon nanotubes, improving electrical conductivity and optical performance, making it a light guide material, a new type of luminescent material and an ideal molecule Carrier [6-7]. Implanting active substances into carbon nanotubes and using them as biosensors is expected to overcome various difficult diseases that have long plagued people. The small diameter, high strength and high aspect ratio of carbon nanotubes (the aspect ratio ranges from 10 to 105) make it an ideal material for STM/AFM tip. Compared with the traditional tip, the radius of curvature of the carbon nanotube tip is small, has good mechanical flexibility and elastic bending deformation, in the scanning process, can effectively reduce the force of the tip on the sample surface, can be more accurate Obtain the morphological features of the deep narrow gaps on the sample surface and the edge of the step, and will not damage the needle tip [8-9]. Using carbon nanotubes as the tip of STM/AFM can effectively improve its resolution. Suspended single-walled carbon nanotubes are resistant to strong acids and alkalis, and are basically not oxidized below 700 degrees in the air. They can be used as reinforcements for advanced composite materials, and can also be used in aviation, aerospace, environment and other fields. In addition, carbon nanotubes have strong anti-oxidation ability, have good microwave absorption performance, and can also be used as stealth materials [10-11].

There are two main models for the growth mechanism of suspended single-walled carbon nanotubes: open growth model and closed growth model. The opening growth model believes that during the growth of carbon nanotubes, the top is always open. When the growth conditions are not suitable, it tends to close quickly. As long as the carbon tube is open, it can continue to grow until it is closed. The closed-end growth model believes that the top of the carbon tube is always closed during the growth process. The radial growth of the tube occurs due to the continuous deposition of small clusters of carbon atoms. The five-membered ring defect at the end of the tube during the adsorption process of carbon clusters Completed with assistance, this model can be used to explain the low-temperature (about 1100 degrees) growth mechanism of carbon nanotubes, because the

dangling bonds required for opening growth are very unstable at such low temperatures. The carbon source cracks on the surface of the catalyst particles to form carbon nuclei. The carbon nuclei grow carbon nanotubes on the rear surface of the catalyst by diffusion, and push the catalyst particles forward until the catalyst particles are completely wrapped by the graphite layer, the catalyst is deactivated, and the carbon tube Stop growth [12].

2.2. Piezoresistive Effect and Application of Piezoresistive Flexible Sensors

The basic principle and resistance of piezoresistive mechanical sensors are similar to resistance strain, that is, under the action of force, the material is strained, and its resistance changes. The formula of the material resistance value can be expressed as:

$$R = \rho \frac{1}{s} \tag{1}$$

Where: R-resistance value, Ω; ρ-resistivity, Ω.m; 1-length, m; s-cross-sectional area, m^2. When the material is subjected to an axial force, the physical parameters of the material change, as shown in the following formula:

$$dR = \frac{1}{s} d\rho + \frac{p}{s} dl - \frac{pl}{S^2} ds \tag{2}$$

Simplified:

$$\frac{dR}{R} = \frac{d\rho}{\rho} + \frac{dl}{1} - \frac{ds}{s} \tag{3}$$

According to the material mechanics formula:

$$\frac{ds}{s} = -2\mu \frac{dl}{1} \tag{4}$$

μ-material Poisson's ratio:

$$\varepsilon = \frac{dl}{1} \tag{5}$$

$$\frac{dR}{R} = (1 + 2\mu)\varepsilon + d\rho / \rho \tag{6}$$

For ordinary metal resistance strain-type materials, the length and cross-sectional area are mainly changed, and the resistivity remains basically unchanged, that is, dp/p≈0. For materials with piezoresistive effect, in addition to changes in length and cross-sectional area, the change in pressure will cause a significant change in the resistivity of the material, and the value of dp/p is much greater than (1+2μ);. Therefore, in principle, the measurement accuracy of materials with piezoresistive effect is higher than that of ordinary resistance strain materials.

The piezoresistive effect refers to the phenomenon of stress-induced changes in the resistivity tensor component. The reason is that when the conductor strain is applied to the lattice of the semiconductor, the mobility of the carrier changes, thereby changing the resistivity. The piezoresistive effect was first observed by Bridgman in 1922 when tensile strain and static pressure were applied to the metal. The earliest experimental observations of the piezoresistive effects of

semiconductor materials silicon and germanium were Taylor, Bridgman, Smith, paul, and pearson. The varistor resistivity change with piezoresistive effect can be expressed as:

$$\frac{d\rho}{\rho} = \pi_1 \sigma_1 + \pi_2 \sigma_2 \tag{7}$$

P-varistor resistivity, Ω.m; π1-longitudinal piezoresistive coefficient, Pa^{-1}; π^2-transverse piezoresistive coefficient, Pa^{-1}; σ_1—longitudinal mechanical stress, Pa; σ_2-transverse mechanical stress, Pa. Of course, in addition to the change in strain, the resistivity p will also be affected by temperature. The piezoresistive pressure sensor utilizes the semiconductor (silicon) piezoresistive effect. Generally, the four piezoresistors that make up the bridge are arranged on the silicon diaphragm according to a certain rule to sense the pressure and tension. When the diaphragm is under pressure, the diaphragm bends, so that its upper and lower surfaces will stretch and compress, and at the same time cause the varistor to strain, causing its resistance to change. Piezoresistive sensors have many advantages, such as: simple structure, small size, high accuracy; good linearity and high sensitivity; easy to connect with secondary instruments; wide measurement range (1KPa-100MPa);

2.3. Basic Principles of Fuzzy Control

In physical systems, it is sometimes difficult to directly describe complex systems using linear identification technology. In general, a fuzzy control model for expressing complex systems can be constructed based on the physical characteristics of the system, input and output data, and corresponding empirical knowledge. The fuzzy controller is composed of signal input stage, rule processing stage and result output stage. The input part transfers the collected information to the corresponding fuzzy function, the processing part calls a rule base in the controller for each input to produce a result, and finally the output part converts the result into a specific control output value.

(1) Blurring means qualitatively representing the quantitative data acquired by the sensor. In the controller, usually each input value corresponds to two or more fuzzy physical quantities, the degree of blurring is defined by the membership function of the interface. If the input value of the temperature sensor is 28 degrees, the corresponding fuzzy physical quantity membership degree is: {moderate: 0.9, high: 0.3}.

(2) The knowledge base consists of two parts: database and rule base. The database stores the argument city of the input and output values in the entire control system, and contains the function rules and data operations defined in the rule base. The rule base is to design a set of rules according to the requirements of the control system functions. The rule library "IF-THEN" proposed by Takagi and Sugeno is generally used to define the rule base. Only the first part of the rule involves fuzzy sets. The first parts A and B of the rule represent fuzzy linguistic values characterized by appropriate membership functions. The latter part of the rule is expressed as a non-fuzzy equation, and the parameters are determined by the input variables. Through the "IF-THEN" rule, it is easy to imitate the reasoning ability of human experience and knowledge, and it is also the core part of the reasoning decision interface in the entire system.

(3) Inference decision-making the operation of inference decision-making based on empirical knowledge is similar to the reasoning ability of people in fuzzy concepts, and is at the core of the entire fuzzy system.

(4) When fuzzy and clear control the system, a quantitative value is needed as the manipulated variable in this system, and the previous part often obtains that the value with fuzzy properties cannot be directly used for manipulation, which requires the fuzzy amount to be processed to control it. Convert to explicit output. Usually this process selects different clearing methods

according to the membership functions and inference decision methods in the entire system, such as the center-of-gravity method and the large average method.

3. Piezoresistive Flexible Sensor under Microscope Observation

3.1. Experimental Equipment and Raw Materials

This experiment consists of the following materials: TE-200-E laser scanning confocal microscope, solid microscope OLYMPUSSZ61, polydimethylsiloxane (PDMS), SYLGARD 1 84 SILICONE ELASTOMER, curing temperature 25 ~ 150 degrees. Carbon fiber (SCF), brand T300, diameter 7μm, length 4mm, conductivity about $2.6*10^4$S/m. Carbon nanotube (CNT): CNTa, the diameter of the tube is 50~90nm, and the length is 5~10μm.

3.2. Experimental Procedure

This experiment focuses on the influence of the sensor element prepared by the binary filler system composed of carbon fiber and carbon nanotube under the microscope on the performance of the sensor. The carbon fiber/carbon nanotube sensor element with different contents is prepared by the SCFNA method. The experimental steps are as follows:

(1) Observe and make a uniform system containing PDMS/SCF/CNT materials with a microscope, that is, the filler is evenly distributed in the polydimethylsiloxane. Before mixing and stirring the conductive filler and PDMS, the two fillers were placed in a vacuum drying oven, dried and dehumidified at 100 degrees for 1 hour, and then mixed with PDMS according to 10wt% weight fraction, and then the carbon nanotubes were divided into filler weight fractions as 1%, 2%, 3%, 4% of the mixture is evenly mixed and then added to the HAAKE MiniLab internal mixer for internal mixing. The internal mixing parameters: speed 40 rpm, temperature 25 degrees, time 10 min. At room temperature, according to the ratio of PDMS:PDMS curing agent=10:1, add PDMS curing agent to the obtained material, put the stirred PDMS/SCF/CNT mixture into the drying oven again, and extract the vacuum at room temperature to remove bubble.

(2) Use the imprint mechanism sample for the homogeneous system obtained in step (1). Use the temperature control button to heat the mold to 175 degrees and place the homogeneous system on the mold. First, free compression, the upper mold moves down to a distance of 2mm, then the servo motor controls the precise movement of the upper mold to perform limited compression, and the system is compressed to the thickness of the experimental design according to the thickness of the gasket. Wait until the temperature drops to 120 degrees to remove the sample to obtain a sheet sample. In this experiment, 200μm, 300μm and 400μm thick sensor conductive elements were prepared.

(3) Press the pure PDMS layer as the upper and lower packaging surfaces of the sensor according to step (2). Cut the conductive element into an "L" shape for standby. The working area is the shorter side, which is used as the sensing part, and the other side is used as a flexible wire. Then, the prepared pure PDMS layer is cut into a square of 40mm*40mm, and glued to the surface of the composite. In order to make the conductive film adhere to the PDMS layer tightly, two slides were placed on the sample and pressed for 12 hours. The working area of the PDMS flexible sensor adopts the face-to-face encapsulation of microstructure to maximize the sensitivity of the device.

3.3. Data Collection

The sensitivity coefficient is a physical quantity that measures the sensitivity of the sensor to the measured physical parameter. When testing a certain amount of pressure change, the greater the

change in resistance value, the more sensitive the sensor. In this experiment, the sensitivity coefficient of the piezoresistive flexible sensor based on the force sensitive film (carbon black particle mass fraction 12%wt) was tested. The larger the measurement range of the sensor, the measurement error will also increase.

4. Performance Analysis of Piezoresistive Flexible Sensor with Suspended Single-Walled Carbon Nanotube Array

4.1. Sensitivity Research of Piezoresistive Flexible Sensor

This chapter divides the load interval of 100KPa into four parts, namely 0-15KPa, 15-30KPa, 30-60KPa and 60-120KPa. At the same time, the respective resistance change rates are fitted and the slopes of different intervals are calculated, namely Sensitivity. The sensitivities of three different structures of flexible pressure sensors are shown in Table 1. The histogram fitting diagrams of the sensitivities of the three design structures of flexible pressure sensors are shown in Figure 1.

Table 1. Sensitivity of flexible pressure sensors designed by three different structures

	Load (KPa)			
Structural design	0-15	15-30	30-60	60-120
The first	0.3412	0.4502	0.3623	0.2012
The second	0.3298	0.2981	0.2114	0.1982
The third	0.4365	0.3645	0.2803	0.3216

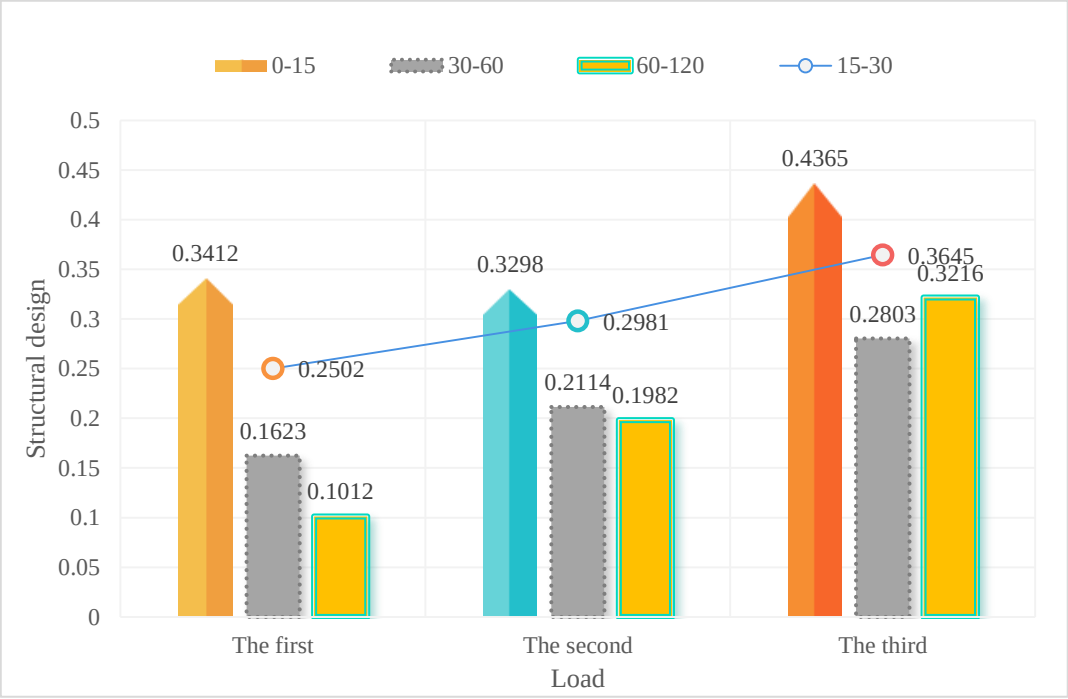

Figure 1. The histogram fitting diagrams of the sensitivity of the three design structures of flexible pressure sensors

Figure 1 shows that when the first device array structure is used, its sensitivity is 0.3412 in the interval of 0-15KPa; and its sensitivity is 0.4502 in the interval of 15-30KPa. Later, as the pressure continues to increase, its sensitivity tends to zero. The sensitivity of the flexible pressure sensor made by the first and second structures has a clear upward trend when the load is in the range of 0-15KPa. When it is in the range of 20-50KPa, the sensitivity remains at about 0.003. After that, as the load increases, the sensitivity tends to be stable, but it remains around 0.001. Therefore, in this experiment, when the sensor hysteresis and repeatability test, the load interval is set to 0-50KPa.

4.2. Performance Analysis of Piezoresistive Flexible Sensor with Suspended Single-Walled Carbon Nanotube Array

In this experiment, the self-prepared BOE solution was prepared by mixing HF (mass fraction 40%), NH4F (mass fraction 49%) and H2O in the ratio of 3:6:10. At normal temperature, the prepared BOE solution is diluted 5 times, 15 times, 20 times respectively. It was found in the experiment that even if the prepared BOE solution was diluted 5 times, the photoresist would still be greatly damaged during the etching process. When the BOE solution diluted 15 times or 20 times is used for wet etching, the photoresist will not be damaged. The specific data is shown in Table 2, and the specific image is shown in Figure 2. The left side of Table 2 shows the depth of corrosion of quartz by BOE solution diluted 15 times at room temperature after 6 minutes. It can be calculated that the corrosion rate is about 28.3 nm/min; the right side of Table 2 is 20 times diluted at room temperature the depth of the BOE solution corroding quartz after 6min, it can be calculated that the average rate of corrosion is 19.9nm/min.

Table 2. Two BOE solutions with different dilutions

Sample serial number	Dilute 15 times the depth	Dilute 20 times the depth
1	178.3	135.6
2	168.2	124.5
3	154.7	120.6
4	173.9	132.9
5	163.5	140.6

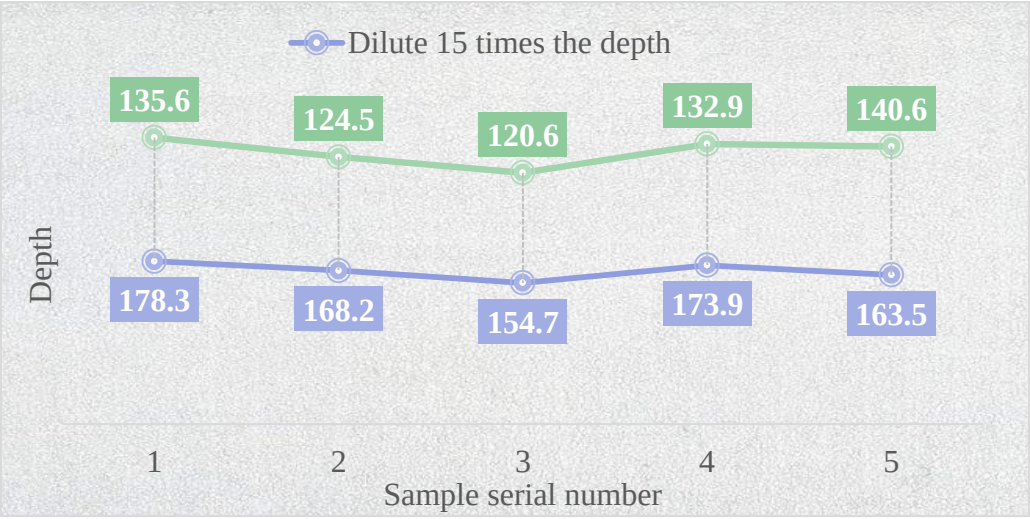

Figure 2. Data comparison of two BOE solutions with different dilutions

The BOE solution diluted 15 times in concentration was used to etch the trench with a depth of

6urn. After the corrosion, the solution on the surface of the sample was sucked off with a rubber-tip dropper and allowed to dry at room temperature. Scanning electron microscopy pictures, photoresist pressed against the ends of the carbon nanotubes, some carbon nanotubes adhered together, some did not adhere. In the process of preparing the suspended structure, the surface tension of the aqueous solution causes the adjacent carbon nanotubes to be pulled together. Due to the van der Waals force and electrostatic force between the carbon nanotubes, the carbon nanotubes adhere to each other. If the distance between two adjacent parallel carbon nanotubes is relatively large, the adhesion between them is insufficient to make them adhere, and they will separate during the natural drying process. It was found in the experiment that if the corrosion rate of the selected BOE solution is too small, during the corrosion process, due to the volatility of the corrosion liquid itself, it is easy to volatize naturally at room temperature, resulting in the suspension of the corrosion reaction. If the selected BOE solution has a high rate, it will damage the photoresist, so it is necessary to choose a suitable etching night concentration. The experiment found that the BOE solution diluted 15 times the concentration had better corrosion effect.

Due to the relationship between experimental conditions and time, the experimental results that are completely consistent with the theoretical calculation results cannot be obtained. In the experiment, only a small part of the carbon nanotubes adhered together. On the one hand, it was due to the uneven density of the horizontally grown parallel carbon nanotubes. Another possible reason was that the samples were not dried in a short time after being naturally dried. Observed under the scanning electron microscope. In addition, you can also consider the use of electron beam exposure to prepare trenches, using metal to fix the ends of carbon nanotubes, but it will greatly increase the cost of the experiment.

4.3. Effect of Ultrasonic Power on the Concentration of Multi-Walled Carbon Nanotube Dispersion

When deionized water is used as the dispersant solvent, and surfactants are added to the dispersion, the ultrasonic vibration method is one of the two methods used in the experiment. The dispersion performance of MWCNTs is improved by fluid cavitation under the action of ultrasound. Therefore, the ultrasonic power has an important influence on the concentration of MWCNTs in the dispersion.

The experiment uses ionized water and surfactant, and disperses MWCNTs in an ultrasonic cell disrupter with powers of 50W, 100W, and 150W, respectively. The ultrasonic time is 15min, and the corresponding MWCNTs dispersion 3, MWCNTs dispersion 5 and MWCNTs are obtained. Dispersion 7. After obtaining the centrifuged dispersion, the three equal amounts of the dispersion were equally diluted twice, and the ultraviolet-visible absorption spectrum was measured using an ultraviolet-visible spectrophotometer, and the MWCNTs dispersion obtained by using three kinds of ultrasonic power can be qualitatively analyzed. Liquid concentration. The UV-Vis absorption spectra of MWCNTs dispersion 3, MWCNTs dispersion 5 and MWCNTs dispersion 7 are shown in Figure 3. It can be seen from the experimental results that as the wavelength increases from the ultraviolet range to the near infrared range, the absorbance of the three groups of dispersions gradually decreases. The cause of this phenomenon is the scattering effect in the low wavelength range. In addition, the three groups of dispersions have two characteristic peaks in the range of 250nm-300nm, and similar conclusions were obtained in the experiment. The speculation is that the carbon nanotubes prepared by chemical vapor deposition are caused by different characteristics of polarizability and diameter Double-peak phenomenon. In the total spectral range, dispersion 7 has the highest absorbance, followed by dispersion 5, and dispersion 3 has the lowest absorbance. According to Lambert's law, the concentration of the dispersion liquid is proportional to the

absorbance, so it can be concluded that in the power range of 50-200W, the concentration of the dispersion liquid increases with the increase of the ultrasonic power.

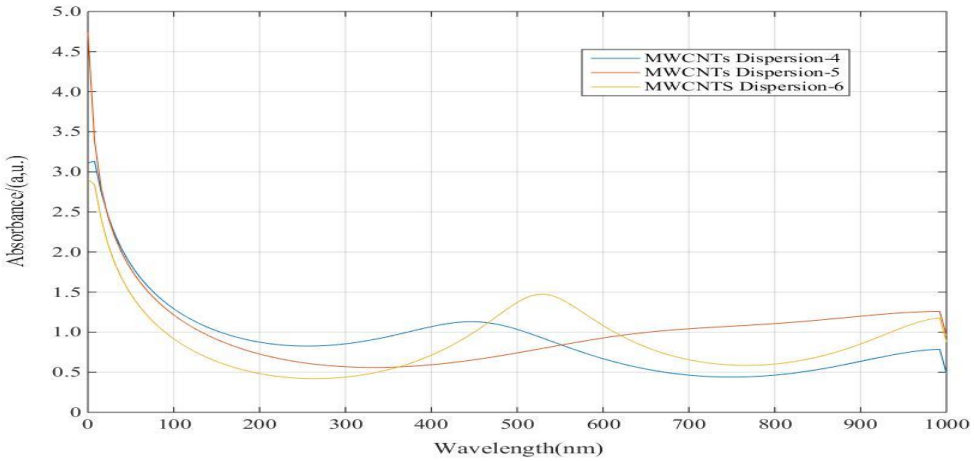

Figure 3. UV-Vis absorption spectra of MWCNTs dispersion 4, dispersion 5 and dispersion 6

4.4. Effect of Piezoresistive Flexible Sensors on Temperature Changes

The actual working condition of the sensor prepared in this study is in the environment of minus 30 to 50 degrees, periodically and intermittently working. The influence of temperature on the sensor is undoubtedly an important factor that cannot be ignored. Different from the traditional solid-state thermistor, combined with the constituent components, the change range of the sensor must be inferior to the thermistor, but the specific impact coefficient still needs to be obtained through repeated experiments. According to the characteristics and packaging characteristics of the polymer-based flexible sensor, the temperature and pressure of the sensor can be adjusted by a temperature-controlled press to explore the different coefficients of change of the sensor at different temperatures within the same pressure change range. The specific working principle is that the flexible sensor is vertically pressed by the upper and lower clamps, and the thermocouples are installed inside the two clamps, and the specific temperature can be set through the panel. After reaching the set temperature and stabilizing for 10 minutes, referring to the previous test method, observe the different change trend of the resistance of the thermocouple in the pressure range of 0~50N. According to the set parameters, taking into account only the limitations of heating equipment and room temperature 20 degrees. The experimental range is from 20 degrees every 10 degrees up to 50 degrees. Four sets of experiments are conducted to analyze the influence of temperature on the output resistance of the sensor. The data is shown in Table 3, and the specific image is shown in Figure 4.

Table 3. Piezoresistance characteristics of the sensor at different temperatures

F/N	20 ℃	30 ℃	40 ℃	50 ℃
2	392.31	691.33	608.88	289.38
4	491.49	565.12	330.36	411.44
6	325.90	371.94	497.18	247.11
8	345.22	492.03	211.26	499.26
10	508.55	253.88	412.63	435.46
12	332.64	653.15	356.36	547.97
14	612.19	639.83	280.74	549.94

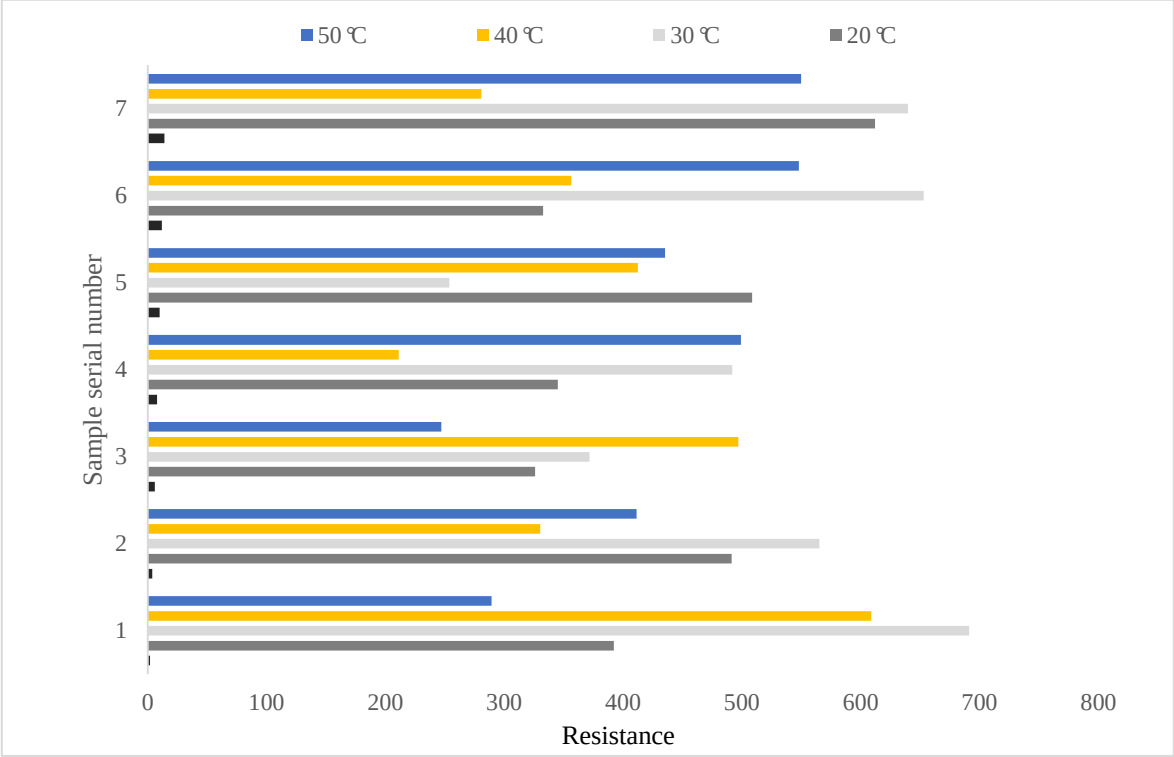

Figure 4. Piezoresistance characteristics of the sensor at different temperatures

From Figure 4 and Table 3, the average sensor output resistance at 20 (room temperature), 30, 40 and 50 degrees is 166.21, 170.45, 173.12 and 192.92, and the temperature compensation coefficient at 30 to 50 degrees is 1.12 and 1.21 respectively and 1.05.

5. Conclusion

In this study, based on the high-performance flexible piezoresistive sensor observed by the microscope, a series of applications have been made to the sensor. It is found that the flexible piezoresistive sensor has the advantages of lightness, thinness, and flexibility, and can not only be used to monitor large the joint movement can also monitor small muscle movements, and has great application prospects in medical health. In addition, the flexible piezoresistive sensor successfully measured the speed of the car driving through it, which shows that the flexible piezoresistive sensor is expected to be applied to intelligent transportation. The flexible piezoresistive sensor is made in the form of an array, which can successfully identify pieces in different positions, and has certain application prospects in intelligent interaction.

In this paper, the 5V voltage commonly used in the sensor circuit is used as the power supply voltage. In order to convert the nonlinear pressure-resistance change curve of the pressure sensor to a linear pressure voltage change curve, an inverting amplifier circuit is used to output and amplify the sensor output signal. After the charge pump circuit based on the ME7660C chip provides a voltage of -5V to the single-point pressure sensor, it is converted into a positive voltage by the inverting amplifier circuit and output to the A/D converter of the AVR microcontroller to achieve analog-to-digital conversion. The collected voltage data is sent to the host computer. The upper computer program is written by Labview and has the functions of sensor calibration, storage and display.

In this paper, we first investigated and summarized the preparation method of porous PDMS, and

then selected sugar/salt with simple process, few steps, low cost, non-toxic and environmentally friendly as the template to prepare porous PDMS as the research content of this article. On the basis of the original method, it was improved and optimized. By introducing the method of micro-domain fusion in the preparation process, the material properties of the prepared porous PDMS were improved. The porous PDMS prepared by the method in this article has a controllable internal pore size. The structured shape can be obtained at one time by using a mold. The residual amount of particles is extremely low, and the pore interconnection is good. At the same time, the overall preparation speed is also greater. Improvement. In addition, the porous PDMS treated with electrical conductivity was also characterized. The results prove that the pore wall of the porous PDMS after conductive treatment is covered with carbon black particles, which verifies the interconnectivity of the porous PDMS, and also provides a new method for preparing flexible piezoresistive materials, that is, using vacuum The porous material is filled with a conductive material by the suction method to prepare a flexible piezoresistive material.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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