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# Application of chemical bio-sensor based on nano-conductive rubber in sports rehabilitation

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**Abstract.** With the development of robot technology, it is more and more important for the research of flexible multi-dimensional tactile chemical sensors for intelligent robots, especially bionic robots and service robots. Because flexible multidimensional tactile chemical sensor has the function of measuring the pressure distribution of any material and free surface, it has wide application prospect in many fields such as sports training, rehabilitation medicine, sports biomechanics and so on. In this paper, the new liquid-formable pressure-sensitive conductive rubber material was studied, which not only has good mechanical and electrical properties, but also the production cost is low and the preparation process is simple and easy. Flexible multidimensional array tactile chemical sensor not only has the flexibility of human skin, but also has the function of obtaining 3D direction force information. The research work and achievements of this thesis have laid a good foundation for further research on the application of robot sensitive skin and flexible tactile chemical sensor.

**Key words.** Missing.

## 1. Introduction

Based on high molecular material silicone rubber, conductive rubber is added with various conductive fillers to form a composite system with conductive function [1]. It not only has a conductive function, but also has many excellent properties of polymer materials [2]. Depending on the requirements, we can adjust the electrical and mechanical properties of the material. Conductive rubber is a good function of anti-static products and anti-electromagnetic shielding device composite materials [3]. Therefore, it is widely used. In addition, people use the conductive rubber force sensitive or temperature-sensitive effect developed a variety of electronic key materials, touch components, temperature sensitivity and force sensitive chemical sensor materials, which makes the application of conductive rubber continues to expand. The current multi-dimensional array of tactile chemical sensors cannot

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have both flexibility and measurement of multi-dimensional force characteristics of information. We propose a new flexible multidimensional array tactile chemical sensor based on pressure sensitive conductive rubber. The research work and the results can provide a new idea for the interdisciplinary research of materials science, instrument science, chemical sensor technology and artificial intelligence, so as to lay a good foundation for the further study of the application of robot sensitive skin and flexible tactile chemical sensor. It is expected to promote the development of bionic robots and service robots. In many fields, such as sports training, rehabilitation medicine, human body modeling and simulation, sports biomechanics, it has wide application prospect.

## 2. Materials and experiments

### 2.1. Matrix material

The flexible pressure sensitive conductive rubber matrix belongs to the polymer material. The mechanical properties of flexible pressure sensitive conductive rubber are largely dependent on the properties of the matrix material, since the matrix material has a significant effect on the properties of the composites after the addition of the conductive filler [4]. For example, adding a large number of conductive filler in the rigid matrix, although the conductivity is good, it will make the composite material brittle. However, for the flexible tactile chemical sensor used in the field of robotics, we need to choose the material with smaller and more flexible molecular force. As a continuous phase and composite of composite materials, the polymer matrix plays two roles, one is the matrix material, and the other is the fixed packing [5, 6]. The choice of polymer matrix material has a great influence on the comprehensive performance of conductive composites [7]. In general, the greater the crystallinity of the polymer, the higher the conductivity. It is generally believed that the conductive particles are distributed in the amorphous phase of the crystalline polymer matrix, and the increase of the crystallinity of the matrix is helpful to improve the concentration of the conducting particles in the amorphous phase, which is favorable for the formation of conductive path and the resistivity of the material [8].

### 2.2. Conductive material

Conductive filler is an important part of pressure sensitive conductive rubber. For a polymer material having an insulating property, a conductive polymer composite material can be usually made by adding conductive particles. Depending on the nature of the conductive filler itself and its content in the rubber matrix material, it determines the conductive properties and pressure sensitive properties of the pressure sensitive conductive rubber [9]. Therefore, according to actual needs, we choose the appropriate type, shape and dosage of conductive material. Commonly used conductive fillers include metal-based fillers, carbon-based fillers, metal oxide-based fillers, and composite fillers.

Conductive carbon black is a kind of carbon material with special microstructure, particle morphology and surface properties. Its main ingredient is carbon, containing a small amount of hydrogen, oxygen and sulfur and other elements, which determines the chemical properties of carbon black. Compared with other conductive particles such as metal, carbon black particles are the largest amount of conductive filler. A conductive polymer with carbon black as filler, its conductivity depends on the structure, particle size, specific area and porosity of carbon black to a large extent. The results show that the smaller the particle size of carbon black, the more complex the structure. The carbon black properties have a significant effect on the conductivity of the composites. Thus, the conductivity of the carbon black filled polymer composite depends on the type and amount of carbon black.

## *2.3. Nano - modified materials*

Nanomaterial and nanotechnology will be the core material and core technology in new material and new technology. In the fields of microelectronics, metallurgy, chemical industry, electronics, national defense, nuclear technology, aerospace, medical and biological engineering, nano-materials research has been widely used. At the same time, it will also improve people's living environment and protect people's health. Nanomaterials generally refer to particles in a particle size. It is neither a typical microscopic system nor a typical macro system, but a typical mediated system. As the particle size into the nano-scale, the structure compared with conventional materials have undergone great changes. It has many unique physical and chemical properties in catalysis, photoelectricity, magnetism, heat, mechanics and so on. In recent years, nanomaterials have been used in polymers to improve the performance of polymer materials, and have achieved considerable results.

As shown in Table 1, we conducted experiments on the conductivity, material softness and piezoresistive properties of the samples. Among them, the proportion of nano-modified materials and silicone rubber is the percentage of mass. The piezoresistive characteristics of the samples of different nano-modified materials are shown in Fig. 1. On the basis of ensuring the softness of pressure sensitive rubber, nano-silica and aluminum oxide material can be better modified pressure-sensitive conductive rubber mechanical properties, piezoresistive properties, conductivity and other comprehensive performance.

Table 1. Comparison of different nano-modified materials

| Sample | T1 | T2 | T3 | T4 |
|---|---|---|---|---|
| nanomaterials | zinc oxide ZnO | calcium carbonate CaCO | silica $SiO_2$ | aluminum oxide $Al_2O_3$ |
| carbon black CB3100/silicone rubber | 8 % | | | |
| nano - materials/silicone rubber | 3 % | | | |

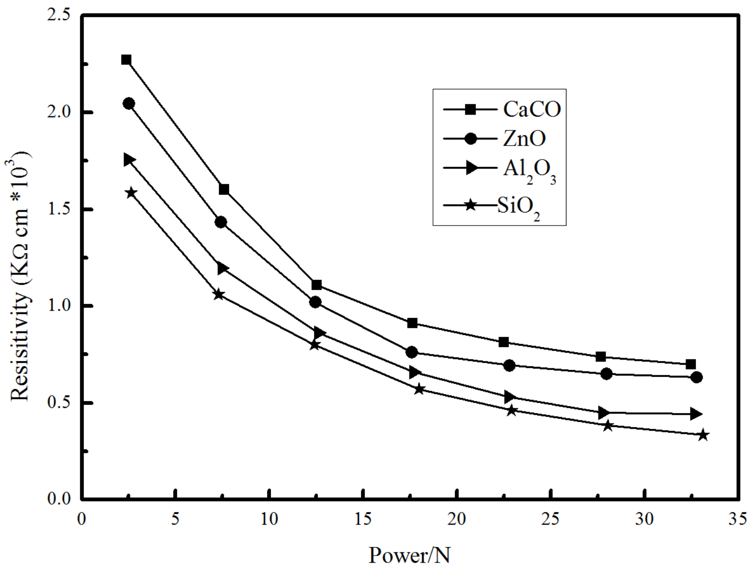


Fig. 1. Piezoresistive properties of different nano-modification materials

## 3. Research results and discussion

### *3.1. Experimental phenomena and results of dispersion treatment*

Under normal circumstances, nano-conductive filler and nano-modified materials have a high surface energy, so it is very easy to reunite.In order to make the prepared conductive composite material has good uniformity and good conductivity, nano-conductive filler and nano-modified materials need to be dispersed. For nano-conductive filler, if the dispersion is not good, conductivity is not good. In the polymer matrix, the nanoparticles can be orderly distributed or disordered. In general, the aggregation of nanoparticles is aggregated particles, and the size of aggregates is always greater than the primary particle size of nanoparticles. Even if the coupling agent has been added to the silicone rubber to make the particles dispersed evenly, and the compatibility of the particles with the matrix is improved, it is difficult to disperse the particles to the primary particles. As the nano-modified materials have more surface-active light base and a large surface energy, thus limiting the nano-modified materials to enhance the effect.

The dispersion of nanoparticles refers to the process of uniform distribution in the liquid phase of the powder particles. It usually consists of three phases: liquid wetting the solid particles; through the external force to make the larger aggregates dispersed into smaller particles; to ensure that the powder particles in the liquid medium long-term uniform dispersion, and to prevent the scattered particles to re-aggregation. According to the different methods of dispersion, it can be divided into physical and chemical treatment methods.

From the above experiments, we can see that nano-carbon black in the form of aggregation dispersed in the rubber matrix. At the same time, the results also explain the importance of the dispersion of nanoparticles on the structure and properties of the material forming. With the combination of mechanical agitation and ultrasonic agitation, we can make nanoparticles better dispersed in the polymer. Through the combination of mechanical stirring and ultrasonic dispersion method, the conductivity and stability of the material can get a relatively good effect. Therefore, combined with the effect of various factors, the first step is to use the mechanical stirring method to obtain the small aggregates from micron to hundreds of nanometers. Then, through the ultrasonic dispersion method, we get hundreds of nanometers to tens of nanometers nanometer particles. In the decentralized treatment, through the experiment, we can be preferred for nano-conductive filler and nano-modified materials with better dispersion effect of the dispersant and dosage.

### *3.2. The effect of the loading of conductive particles*

The content of the conductive filler filled with pressure sensitive conductive rubber plays a key role in the electrical properties, mechanical properties and softness of the prepared sample. After the material is molded, it not only has a certain flexibility, but also has a suitable conductivity and pressure sensitive characteristics. Table 2 is the use of different proportions of conductive filler samples of each sample mass percentage. Figure 2 is the hardness of the sample at different addition ratios. Figure 3 shows the conductivity of the sample at different fill ratios.

Table 2. Experimental samples of conductive fillers at different addition ratios*

| Samples | | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 |
|---|---|---|---|---|---|---|---|---|---|
| Component proportion | CB3100/RTV | 4 % | 6 % | 7 % | 8 % | 9 % | 10 % | 12 % | 15 % |
| | naphtha/RTV | 50 % | | 60 % | | 70 % | | 80 % | 100 % |
| | $SiO_2$/RTV | 2 % | | | | | | | |
| | Si-69/RTV | 3 % | | | | | | | |

*CB3100 is carbon black, RTV is silicone rubber, and Si-69 is a silane coupling agent.

As can be seen from these two figures, under the premise of ensuring the flexibility of the composite material after molding, the filling ratio of the conductive filler is more suitable for the content of the pressure-sensitive conductive rubber. In this proportion, we can adjust the different conductivity requirements and pressure sensitive range.

### *3.3. Experiment and discussion*

The mass ratio of conductive rubber should be within the percolation zone, so we test the temperature of the diafiltration sample. The temperature range of the experiment is 30 °C–90 °C. The temperature of the sample is recorded at a tempera-

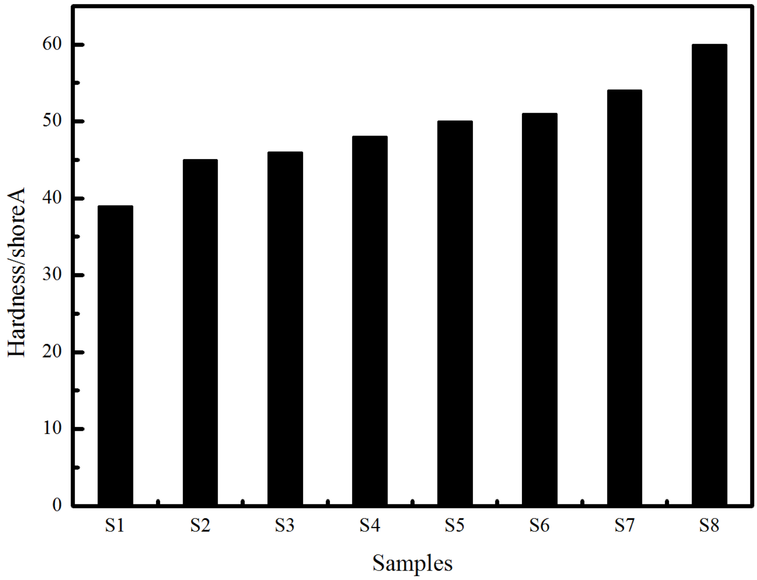


Fig. 2. The hardness values for different addition ratios

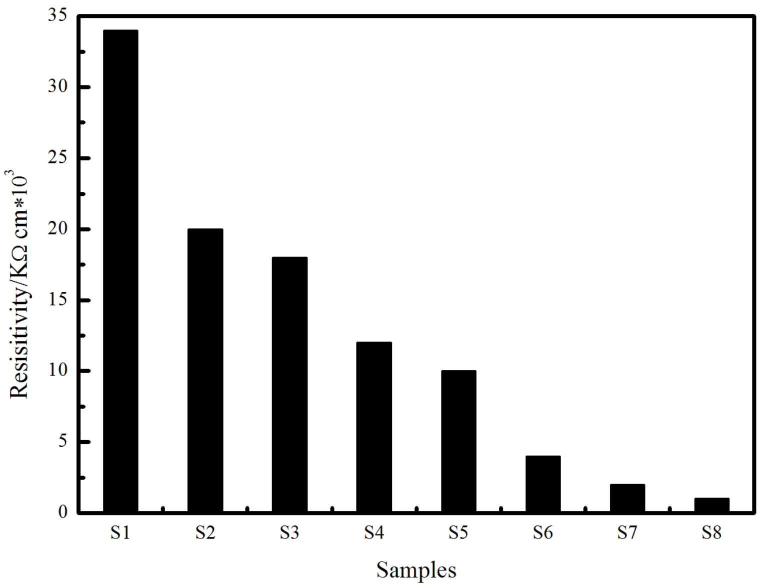


Fig. 3. Different proportionality of the conductive properties

ture of 10 °C for 20 minutes. The resistance temperature characteristics of pressure sensitive conductive rubber samples are shown in Figure 4. From the figure, we can see that the resistivity of samples N3, N4, N5 with the temperature rise are fluctuated, especially the low filling of the sample is more significant. This shows that the effect of temperature on the tunnel effect is more obvious, that is, the thermal disturbance plays a leading role. As a result, the resistivity of the sample is decreasing, and it exhibits a negative temperature coefficient characteristic.

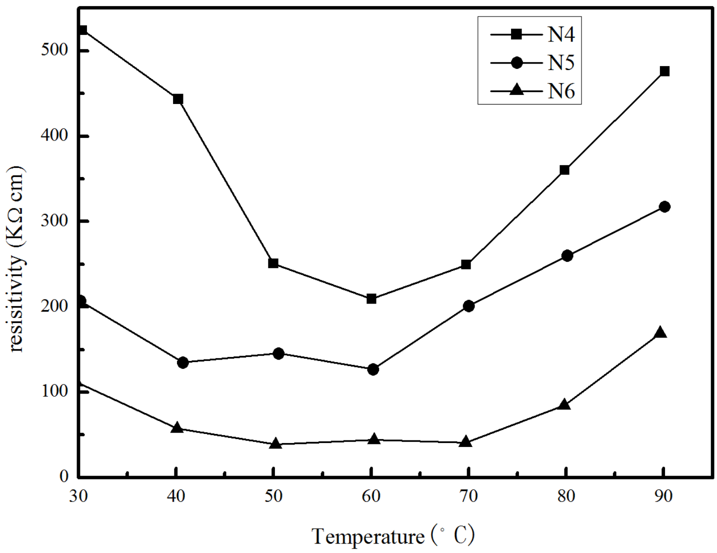


Fig. 4. Resistance temperature characteristics of pressure sensitive conductive rubber

After the temperature reaches a certain value, due to the different thermal expansion rate of the conductive carbon black particles and silicone rubber, resulting in a larger gap between the carbon black particles and the destruction of some conductive networks. As a result, the resistivity of the sample increases, and the thermal expansion at this time plays a dominant role, which exhibits positive temperature coefficient characteristics. In addition, it can be seen from Figure 5, with the increase in the content of carbon black, pressure-sensitive conductive rubber resistivity gradually reduced, and the temperature stability is getting better and better. This reduces the effect of thermal disturbances and also counteracts the thermal expansion of colloids. Therefore, under the high filling ratio, the interaction of thermal and thermal expansion can improve the resistance temperature characteristics of the sample. At the same time, by the temperature effect experiment, it further validates the effect of the conductive mechanism of the tunneling effect under the low packing concentration in the percolation zone.

## 4. Conclusion

In this paper, we studied the pressure-sensitive conductive rubber materials, the performance of each component and preparation technology. Firstly, analyzing the mechanical properties of the base material of flexible pressure sensitive conductive rubber and the conductivity, surface structure, physical and chemical properties of various conductive fillers, we obtained pressure sensitive conductive rubber matrix material and conductive filler with good mechanical and electrical properties. Then, we studied the properties and composition of various nano-modified materials suitable for improving the performance of pressure-sensitive conductive rubber. Finally, we studied the effects of material dispersion treatment, material forming process and various auxiliary materials, which provided economically feasible material formulation and process for the preparation of pressure sensitive conductive rubber. However, the current study is just preliminary. The design of the structure, the calculation model, and the self-characteristics of the pressure-sensitive conductive rubber material need to be improved and perfected. With further model correction, we can improve the detection accuracy of flexible multidimensional array tactile chemical sensors. The research results can not only meet the urgent needs of the robot field, but also can be used in sports training, rehabilitation medicine, sports biomechanics and many other areas.

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