Research on Temperature Measurement Technology of Platinum Film Thermistor

Bingtao Zhang\textsuperscript{1,a}, Xi Chen\textsuperscript{1,b}, Jiafu Yuan\textsuperscript{1,c}, Haidong Zhu\textsuperscript{1,d}\textsuperscript{*}

\textsuperscript{1}School of Mechanical and Electrical Engineering, Guilin University of Electronic Technology, Guilin, 541004, China
\textsuperscript{a}email: guetzbt@163.com, \textsuperscript{b}email: chenxi2936@163.com, \textsuperscript{c}email: aricywh@163.com
\textsuperscript{*}corresponding author, \textsuperscript{d}email: zhuhaidong@guet.edu.cn

Abstract: Platinum film thermistor is developed by combining platinum film thermistor with thin film technology, which solves the cost and application problems of platinum film thermistor components. The principle, fabrication process and application of platinum film thermistor are introduced. A temperature acquisition device of platinum film thermistor is designed. It is verified that the platinum film thermistor has the characteristics of fast response and high accuracy. The temperature data of aluminum alloy plate heated at a single point is collected by using the temperature measurement system. The characteristics of the platinum film thermistor model are verified by comparing the collected data with the simulation data. The results show that the platinum film thermistor can accurately and efficiently complete the fine temperature change measurement, which has a broad development prospect.

1. Introduction
Metals, semiconductors and other materials have the characteristic that the resistance value changes with the temperature, so we can use it to measure the temperature \cite{1}. The sensor made of the physical properties of metal is called resistive transducer \cite{2}. In a certain range, the resistance of platinum film thermistor changes linearly with the temperature, which can be used to measure the tiny temperature change. Platinum film thermistor has the advantages of small heat capacity, small volume, fast response speed, small damage to the parts to be tested and small interference to the test environment \cite{3}, which is the most commonly used temperature detector in low and medium temperature zone.

The development of platinum film thermistor is from traditional platinum mica thermal resistance \cite{4}, ceramic platinum thermal resistance \cite{5}, glass platinum thermal resistance \cite{6} to thick film platinum thermal resistance element and thin film platinum thermal resistance element. In 1974, thin film technology was introduced to develop thin film platinum thermal resistance elements. With the development of lithographic printing technology, platinum film thermistor has developed rapidly in recent years \cite{7}. There are two main types of thin film thermistor: bonded-type and wired lead. As early as the 1980s, Heraeus company of Germany began the development of platinum thin film thermistor. The main processes used are platinum vapor deposition, photo-emission-etch, etching, etc. Its resistance accuracy is $\pm 0.06\%$.

In China, several typical electronic components have been formed in temperature measurement and control: filament winding platinum film thermistor, thermistor, platinum film thermistor. Filament winding platinum film thermistor is widely used in domestic industry to measure temperature, and has accumulated rich experience in the research of filament winding platinum film thermistor. However, the filament winding platinum film thermistor is expensive, low resistance, low sensitivity and poor
mechanical vibration resistance, and it is more difficult to adapt to the rigid requirements of high resistance and small volume in special parts such as spacecraft. It is very common to use thermistor as temperature sensor in China. However, thermistor has some inherent defects: the temperature range of thermistor measurement is narrow, which cannot adapt to the measurement in the range of -180°C to +650°C. In order to solve the problem of wide temperature range measurement, multiple thermistors are needed and occupy more measurement channels.

This paper introduces the processing technology of a new type of Pt1000 platinum film thermistor. Platinum ribbon thin films were prepared by sputtering method[8], and cylindrical heat-resistant glass was used as carrier. The platinum film thermistor is connected to the temperature acquisition system by three-wire system. The platinum film thermistor was calibrated by water triple-point cells[9]. Compared with the conventional DTM-280 thermocouple, the performance of Pt1000 platinum film thermistor is analyzed. The temperature data of the aluminum alloy plate heated at a single point are collected by the temperature measurement system, and the heat transfer characteristics of the aluminum alloy plate are analyzed.

2. The production process of platinum film thermistor

2.1. Fabrication of Platinum Film Thermistor Mask
In the study of mixed phase flow, the size of temperature measuring device will affect the flow field. In this study, the size of platinum film thermistor was controlled by Sputtering method. The mask for sputtering processing is divided into the mask for temperature measuring resistor and the mask for edge line. The mask is made of nickel with a thickness of 0.05mm. The first is the production of negative film, and the mask template five times of the actual size shown in Figure 1 is made by drawing software. Adjust the focal length of the film camera to shoot the negative film of the mask tissue reduced by five times. When photographing, the mask tissue is placed on the light-emitting board to ensure the exposure of the hollow part of the mask template. Use the camera to take pictures of the mask tissue. After the film is developed, the hollow part is transparent, and the other parts are black.

Use acetone and ethanol to clean the nickel sheet separately. Then use a spin coating apparatus to coat the two sides of the nickel sheet with resist. Afterwards, the above-mentioned mask film was covered on the nickel thin plate, and the ultraviolet exposure was carried out for 12 seconds. After exposure, it was immersed in NMD-3 developer solution, and the exposed part was developed about one minute later. The above process washes away the resist in the exposed part. After the exposed shape is formed, the nickel sheet is washed with distilled water, and then dried with nitrogen. The dried nickel sheet is immersed in a 60°C ferrous chloride solution, which can dissolve the exposed parts. One hour later, the exposed part was dissolved, and the nickel sheet was taken out and washed with ethanol. Use nitrogen to dry to complete the mask.

2.2. Preparation of Platinum Film Thermistor carrier
The ribbon-shaped platinum film is fixed on the surface of the cylindrical heat-resistant glass[10]. Both
sides are square platinum end caps. Use copper film wires on the side to lead out to connect to an external electric bridge. A conductive agent is covered between the lead copper wire and the end-capped platinum. Adopting this kind of packaging method can improve the anti-corrosion ability on the one hand, and can strengthen the mechanical strength and resistance to mechanical vibration on the other hand as shown in Figure 2.

2.3. Bridge construction and amplifier design

In order to make the fine temperature measurement experience the transition from the equilibrium state to the non-equilibrium state, the platinum film thermistor needs to be mounted in a balanced bridge. The resistance values of \( R_2 \) and \( R_3 \) are 620\( \Omega \), and the adjustable resistance range of \( R_1 \) is 0–2M\( \Omega \). The other bridge arm is a platinum film thermistor. Because the temperature changes are extremely subtle, an amplifier needs to be made to increase the signal output, as shown in Figure 3.

2.4. Detection and adjustment of initial value of platinum film thermistor

Due to the low temperature coefficient and non-linearity between resistance and temperature of platinum film thermistor, the error of high-precision temperature measurement using three-wire system mainly comes from lead resistance, self-heating effect, non-linear error and small error in some circuits. Therefore, it is necessary to test the main performance and pass the calibration after the fabrication of thin-film platinum film thermal resistance. Using a three-phase bottle of water, the resistance value \( R \) of the water three-phase point of the platinum film thermistor is measured. The platinum film thermal resistance was placed in a constant temperature bath\[^{[2]}\] and calibrated at -80, -40, -10, 100, 200 and 300 \( ^\circ \text{C} \) respectively. The platinum film thermal resistance value and the temperature value of the first-class standard thermocouple were measured. They are introduced into the Callendar-van Dusen equation,

\[
R_t = R_0[1 + AT + BT + CT^3(T - 100)]
\]  

(1)

In the temperature range of \(-200–0^\circ\text{C}\), the relationship between resistance and temperature is

\[
R_t = R_0[1 + AT + BT^2]
\]  

(2)

Where \( T \) represents the temperature of the platinum film thermistor, \( R_0 \) is the resistance value at 0\( ^\circ\text{C} \), and \( R_t \) is the resistance value of the platinum film thermistor at \( T \) \( ^\circ\text{C} \). Among them, \( A \), \( B \) and \( C \) are constant coefficients, which are determined by the structure of the sensor and the properties of the metal platinum.

![Figure. 3 Schematic diagram of balanced bridge and amplifier circuit equipped with platinum film thermistor](image-url)
3. Experimental design of platinum film thermistor temperature measurement

Use an alcohol blowtorch as a heat source to heat the oil in the metal tank container. Hang the platinum film thermistor and the conventional temperature measuring thermal resistance in the liquid. The temperature data collected by the temperature acquisition system verifies that the platinum film thermistor has the advantages of wide temperature measurement width, high sensitivity, and good interchangeability.

In order to verify the advantages of fast response and good accuracy of platinum film thermistor. The experimental setup is shown in Figure 4. Using alcohol blowtorch as the heat source, aluminum plate as the carrier, platinum film thermistor as the temperature sensor to measure the temperature at different positions of aluminum plate, and connecting the temperature acquisition device to collect the temperature data. At the same time, the Multi physical field simulation software COMSOL is used for simulation.

![Figure 4 Heat transfer experiment of flat plate](image1)

![Figure 5 The installation position of each channel](image2)

The aluminum alloy plate a is placed above the alcohol burner and heated by internal flame. The size of aluminum alloy plate B is the same as that of aluminum alloy plate a, and the locating holes on aluminum alloy plate B are evenly distributed at 20 mm, 40 mm and 60 mm from the center, with a total of 25 locating holes. The installation position of each channel is shown in Figure 5. In order to prevent the disturbance of the flame caused by human walking, a computer is used to collect the temperature data remotely.

4. Experimental results and analysis

The comparison test of platinum film thermistor and DTM-280 thermocouple adopts computer to collect temperature data remotely. Obtain the graph of temperature change with time as shown in figure (Figure 6). Throughout the test, the temperature change curves of multiple platinum film thermistor over time were almost the same. The maximum temperature fluctuation at different time points is 2.2 °C, and the standard deviation is 9.6 °C, which has good interchangeability. In the early stage of the test, the liquid to be tested heats up faster. Compared with the DTM-280 thermocouple, the platinum film thermistor has a more sensitive response speed. At 28.9 °C, the difference in response speed between platinum film thermistor and DTM-280 thermocouple is the largest, which is 21s. It can be seen that the platinum film thermistor has good interchangeability and sensitivity.

The temperature data of the platinum film thermistor of each channel changes with time as shown in Figure 7. It can be seen that the measured data at the symmetrical position are almost the same, and the temperature of each part rises with time. It can be reflected that when the central position of the plate is heated, the temperature gradient distribution of the plate is ring-mounted. According to the comparison between the simulation data and the experimental data, the temperature growth trend, temperature value, and temperature distribution all show consistency.
Figure 6 Comparison between platinum film thermistor and dtm-280 thermocouple

Figure 7 Temperature data of platinum film thermistor of each channel

Figure 8 shows the change trend of the platinum film thermistor temperature data of each channel over time. It can be seen that the center temperature of the aluminum alloy plate is higher than the surrounding temperature at any time during the heating phase. In the early stage of the experiment, the temperature of the aluminum plate is relatively low, and the heat dissipation performance is good. Continue to heat the overall temperature of the aluminum plate to increase, and the aluminum plate has poor heat dissipation performance and heat accumulation. As a result, the temperature difference between the center position and the edge position of the aluminum plate increases, and the temperature increase rate of each temperature collection point is inversely proportional to the center distance.

Figure 8 The temperature data of platinum film thermistor of each channel changes with time

5. Conclusion
This article introduces a new type of platinum film thermistor and its processing, production and calibration process. The experimental data verifies that the platinum film thermistor has the characteristics of fast response speed and good accuracy. Combined with the simulation software, the flat heat conduction model of the plate is verified. When the temperature of the aluminum plate is relatively low, the heat dissipation is uniform, so the temperature growth rate of the points with different distances from the heat source is basically the same. As the heating time increases, the overall temperature increases, the heat dissipation performance is poor, and heat accumulation occurs in the center. In addition, from the characteristics of platinum thin film thermal resistance, it can be known that platinum thin film thermal resistance can not only be used for laboratory measurement, but also can be widely used in the field of industrial production. Platinum thin film thermal resistance has high sensitivity and high accuracy, which has huge advantages and broad application prospects.
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