Original Research Article

Application of high temperature semiconductor material silicon carbide in MEMS

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Abstract: Silicon carbide high thermal conductivity, high breakdown voltage and other characteristics are significant, not only can promote the device power density and reliability improvement, but also to ensure that the production of power electronic devices to strengthen the voltage resistance, enhance the stability of the system. Because of this material property, we have found in practice that silicon carbide is not only used to manufacture power devices, but also can play a significant role in the field of micro-electromechanical. In order to solve the problems of thermal expansion and corrosion of traditional silicon-based sensors, researchers are strengthening the use of silicon carbide. This paper focuses on the high temperature semiconductor material silicon carbide, combined with the characteristics of silicon carbide, and focuses on the analysis of its application in MEMS.

Keywords: High temperature semiconductor materials; Silicon carbide; Mems; Apply

1. Introduction

Micro-electro-mechanical system (MEMS) can integrate micro-electronic technology and precision machining technology with a high technical level. Mems usually uses silicon as the main material and is fabricated by silicon microelectronics and micromachining. However, because silicon is suitable for working at temperatures below 250 ° C, and its corrosion resistance is not strong, silicon based MEMS is difficult to work in high temperature, corrosion and other environments. As a high temperature semiconductor material, silicon carbide has the characteristics of high thermal conductivity, high breakdown voltage, high saturated electron drift rate, etc., and has been widely used in various fields. Therefore, in harsh environments, the use of silicon carbide can be strengthened.

2. Characteristics of high temperature semiconductor material silicon carbide

Silicon carbide is a high temperature semiconductor material, which can be widely used in many fields such as power electronics and microwave radio frequency. In the application process of silicon carbide technology, it covers quite a lot of links, such as the growth of silicon carbide single crystal, preparation during the period, epitaxy, etc., and strictly controls the precision, focusing on the use of advanced technological means. Silicon carbide has a higher hardness, second only to diamond. Moreover, it has a high thermal conductivity, compared with traditional semiconductor materials, high temperature semiconductor material silicon carbide can work in high temperature and high pressure environment, showing more advantages. At the same time, silicon carbide band gap is large, can meet the needs of high temperature, high pressure and other harsh environment. Through the analysis of silicon carbide, it can be seen that it can also show good chemical stability under high temperature and extreme environment, and the probability of chemical reaction is low. It also has strong adaptability in high temperature and corrosive environment[1]. Silicon carbide has good oxidation resistance and can always remain stable in high temperature and oxidizing environment. In addition, silicon carbide has a high corrosion resistance, can resist most acid erosion, so in the chemical industry, silicon carbide can play a greater role and value.

3. Application of high temperature semiconductor material silicon carbide in MEMS

In view of the advantages and characteristics of high temperature semiconductor material silicon carbide, it can be applied in MEMS to ensure that corrosion, high temperature and other problems during the application of silicon-based MEMS can be effectively avoided.

3.1. Application of high temperature semiconductor material silicon carbide in MEMS sensors

The application of high temperature semiconductor material silicon carbide in MEMS can be deeply integrated with sensors and provide support for the innovation of sensor technology. Silicon carbide has a high melting point and high thermal stability, and can always remain stable in extreme high temperature environments, so it is an ideal material for sensor manufacturing.

3.1.1. High temperature gas sensor.

Because the crystal has good quality, silicon carbide can be used as one of the important materials in the high-temperature gas sensor, and the sensor can be made from it. This kind of sensor uses catalytic metals such as platinum and palladium as a gate. When hydrogen atoms or hydrogen groups are diffused continuously and finally reach the gate, they gather at the metal oxide interface, thus forming a double electric layer to ensure that the flat-band voltage of the MOS capacitor can be effectively reduced. In practice, we can find that hydrogen and silicon carbide sensors containing hydrogen gas can work in a high temperature environment, the specific temperature is between 350 and 500°C. For example, the porous silicon carbide hydrocarbon gas sensor made of silicon carbide as the main material, the front is to obtain porous silicon carbide under the corrosion of PEC, the chromium grid is evaporated in the upper position, and the back without holes is deposited nickel. The main function of the chromium grid is to establish the electric potential on silicon carbide. All kinds of hydrocarbon gases can decompose the electric potential, so by changing the grid potential, different hydrocarbons can decompose quickly at different times, the current flowing through the device under the electric potential can be timely read, and finally the concentration of various gases can be accurately measured[2].

3.1.2. High temperature temperature sensor.

In a high temperature environment, the performance of traditional silicon sensors will be affected because of thermal expansion, oxidation, corrosion and other problems, and in practice, it can be found that the sensor made of high temperature semiconductor material silicon carbide can effectively solve this problem, and can maintain stable physical and chemical characteristics at hundreds or even thousands of degrees Celsius. It can be used in many fields such as aerospace, oil and gas exploitation. For example, in the aerospace field, silicon carbide high temperature sensors can be used to monitor the temperature, pressure, flow and other parameters inside the aircraft engine, so that the aircraft can be in a safe and stable operating state; During oil and gas exploitation, the use of silicon carbide high temperature sensor can withstand high temperature and high pressure oil and gas environment, real-time monitoring of the pressure and temperature inside the oil well, to ensure that the mining efficiency is improved while the safety performance is guaranteed. In the field of nuclear power generation, sensors based on silicon carbide materials can be used to monitor the temperature distribution inside the reactor, so that the reactor can operate stably and reduce the probability of accidents. In addition, high temperature

temperature sensors have high sensitivity and accuracy. Through the application of advanced processing technology and integration technology, silicon carbide sensors with small size, low power consumption and high performance can be manufactured and integrated into microelectronic systems, which can realize the accurate measurement of small physical quantities and ensure the real-time and high efficiency of monitoring[3].

3.2. Application of high temperature semiconductor material silicon carbide in MEMS actuators

Silicon carbide is not only used as a power device, but also in the application of MEMS actuators, which can show unique advantages and broad application prospects. Silicon carbide is characterized by high hardness, high mechanical strength and high stability, which can provide support for the manufacture of high-performance actuators. In MEMS, silicon carbide can be used to manufacture micro-valves, micro-pumps, micro-switches and other devices. In high temperature, high pressure and corrosive environment, silicon carbide material can always remain stable. For example, in the aerospace field, silicon carbide microvalves can be used to control the liquid and liquid flow inside the aircraft to ensure that the aircraft can be in a stable state of operation without abnormal conditions; In the medical field, silicon carbide microvalves can be applied in many aspects such as drug delivery and body fluid circulation, ensuring that the treatment effect is improved at the same time, the quality of life of patients can be improved as a whole. The silicon carbide actuator also has the advantages of fast response and high precision, because the high thermal conductivity and low loss of silicon carbide materials are significant, so the silicon carbide actuator can respond to external stimuli in a short time, while achieving effective control and enhancing its accuracy. At the same time, silicon carbide actuators can also be effectively integrated with other actuator technologies to form a composite actuator system. For example, the silicon carbide micro-valve and micro-motor, micro-cylinder, etc. can be combined to achieve the purpose of precise control of complex fluid systems, and can also be flexibly adjusted according to the actual situation. At present, the composite actuator system can be applied in many fields such as industrial automation and intelligent manufacturing, and can achieve good results.

4. Concluding remarks

In summary, in view of the advantages of high temperature semiconductor material silicon carbide, its reasonable application to MEMS can not only improve the working state of machine equipment, but also promote the improvement of machine performance. Therefore, with the continuous improvement of the technical level, relevant personnel should strengthen the research on silicon carbide, and adopt a suitable way to integrate with MEMS to ensure that the advantages of silicon carbide can be maximized.

References

[1] Tian Wenchao, Qian Yingying, Zhao Jingrong, et al. Research progress of microsystem packaging based on silicon Carbide devices [J]. Microelectronics & Computers, 2023, 40 (01) : 50-63.

[2] Yang Chenguang, Wang Xiufeng. Research progress on preparation and application of silicon-based SiC thin films [J]. Materials Review, 2019, 38(7) : 26-39. (in Chinese)

[3] Liang Ting, Jia Chuanling, Li Qiang, et al. Research on Capacitive High temperature Pressure Sensor based on Silicon Carbide Material [J]. Instrument Technique and Sensor, 2021, (03) : 1-3+8.