Development and Calibration of High Temperature Pressure Sensor

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Abstract. High temperature pressure sensors are widely used in petrochemical, aerospace, metallurgy, gas machine. According to the mechanism, the recent research on high temperature pressure sensors is reviewed. The comparison and analysis about working temperature and sensitivity among different pressure sensors are completed. High temperature pressure calibration system has less research, reasonable system design and calibration method is needed to further studies.

Introduction

High temperature pressure sensors are widely used in petrochemical, aerospace, metallurgy, gas machine, etc. For example, a large number of high temperature and high pressure gas flow produced by rocket engine will scour launcher. The temperature is usually about 3000K and the pressure is 3.5Mpa. The measurement of gas flow pressure is important for designing launcher. The measurement accuracy of ordinary pressure sensor cannot be guaranteed and even damaged under high temperature. So the research on high temperature pressure sensor has important practical significance.

With the development of new materials and new technology, many high temperature pressure sensors have been provided. According to the elastic element materials, the pressure sensors include silicon on insulator pressure sensor, polycrystalline silicon pressure sensor, SiC pressure sensor, SOS pressure sensor, alloy thin-film pressure sensor, the ceramic thick-film sensor, optical fiber pressure sensor, etc.

According to the pressure sensing mechanism of pressure sensors, the sensors include piezoresistive pressure sensor, capacitive pressure sensor and resonant sensor. After analyzing the recent high temperature pressure sensors at home and abroad, the design scheme of pressure sensor used in measuring rocket fuel gas flow pressure with ultra high temperature is proposed.

High Temperature Pressure Sensors

Piezoresistive Pressure Sensor

The mechanism of piezoresistive pressure sensor is piezoresistive of materials. The wheatstone bridge of sensitive membrane is built to convert the membrane deformation into voltage output [1]. The pressure producing deformation is obtained. Due to the semiconductor material has excellent piezoresistive effect and elasticity, in recent years, semiconductor pressure sensor developed by MEMS processing technology obtain great research. At present, piezoresistive film in widely used includes Si, SiC, metal, ceramic.

Silicon Piezoresistor

To poly-silicon pressure sensor, the doped poly-silicon piezoresistor was distributed on mono-crystalline silicon membrane. V. Mosser presented a poly-silicon pressure sensor using SiO2 membrane separation technology. The working temperature is about 200°C [2]. Using the same doping concentration, mono-crystalline silicon has bigger piezoresistive coefficient than poly-silicon. Insulating material is used as separator between piezoresistor and substrate for SOI mono-crystalline silicon pressure sensor. Kulite companies provided a SOI pressure sensor which can work at 480°C [3]. By etching epitaxial silicon film on the insulating substrate sapphire, SOS pressure sensor can be
obtained. Zhang Shirong presented a SOS sensor with big test range. The working temperature of SOS sensor can reach 350°C [4].

**SiC Thin-film**

Compared with Si material, SiC material has more superior piezoresistive effect, higher mechanical strength and higher resistance to thermoplastic deformation ability [5]. He Hongtao has presented a piezoresistive high temperature pressure sensor using the SiC material. The high temperature electric test indicates that the sensor can output the pressure sensitive signals in range of 700kPa at 550°C [6].

**Alloy Thin-film**

Alloy thin film sensor has lower sensitivity than semiconductor pressure sensor, but higher accuracy, better stability, better corrosion resistance, better temperature characteristic and wide temperature range [7]. Li Wei has compared the advantages and disadvantages of several alloy thin film pressure sensor. The result shows that nickel-chromium (NiCr) thin film pressure sensor be suitable for measurement in the range of -269°C—350°C, and platinum-tungsten (PtW) and palladium-chromium (PdCr) thin film pressure sensors be applied to pressure measurement at high temperature of 600-1000°C [8].

**Capacitance Pressure Sensor**

Capacitance pressure sensor has great higher sensitivity than that of piezoresistive sensor, and is much little sensitive to temperature change. But more complex interface circuit is required by the capacitance sensors with inherent nonlinear. The mechanism of capacitance sensor is thin film. The working principle of capacitance sensor is capacitance changing when capacitance plate gap decreasing under pressure.

SiC capacitance sensor is fabricated by bonding two pieces of SiC wafer after etching and thinning. Cao Zhengwei present a MEMS capacitance pressure sensitive element based on wafer thinning process of P type 4H-SiC [9]. The test results indicate that the prototype sensor can work under 873.15K and the sensitivity of sensor is 18.7fF/kPa. Li Sainan provided a SiC pressure sensor capacitance chip. Using finite element analysis, the sensitivity of the sensor is proved to have relatively high under 700°C [10]. Combined the technology of thin film and ceramic thick film technology, a new design of capacitive wireless passive high temperature pressure sensor is introduced by Yu Lanfang. The sensitivity of the capacitance chip is 2.65MHz/bar at 600°C [11].

**Resonant Pressure Sensor**

Resonant pressure sensor is composed of an inductor and a pressure sensitive capacitor, which constitute the LC resonance loop. When the sensitive capacitance changes with pressure, the frequency of the resonant circuit will change.

Based on this mechanism, Ji Xiaxia fabricated high-performance low temperature co-fired ceramic (LTCC) pressure sensor. Measurement results demonstrate that the sensor have the maximum average sensitivity of 1.96MHz/bar and linearity within 400 oC [12]. Guan Yang proposed and fabricated a wireless aand passive high temperature co-fired ceramic of Al2O3 (HTCC) pressure sensor [13].

**Calibration of Sensor**

Working at high temperature, high temperature pressure sensors commonly have larger temperature drift. In order to ensure the normal application of sensor, the high temperature pressure sensor need to be calibrated under the environment of high temperature. At present, the research on high temperature pressure calibration system is less.

Chen Zhijun builds a high temperature pressure calibration platform which consists of standard pressure source, high precision temperature control system and pressure transmission device. The platform has the ability of temperature drift measurement and calibration at 0-700°C [14]. The output pressure ranges from 0 to 1MPa. First, high temperature environment is set by temperature control system. The output of sensor at this time is the temperature drift. Then different pressure value is set,
the output of sensor are recorded. The correction shall be the high temperature measurement value minus the temperature drift.

Yu Yi developed a high temperature pressure test platform. The platform includes mainly nitrogen source, pressure control unit, temperature control unit, cooling system and data acquisition system. In test, the pressure was set at 70kPa, and the temperature of tanks was heated to four temperatures [15].

Conclusions
According to the working mechanism, the high temperature pressure sensor is divided into three categories, respectively resistance, capacitance and resonant. The working temperature was compared among different sensors. Alloy thin film pressure can work at highest temperature, while SiC thin film pressure sensor has higher sensitivity. Capacitance sensor has less sensitive to temperature, more complex interface circuit and nonlinear than resistance sensor. To semiconductor or alloy pressure sensor, the key influence fact is temperature drift under high temperature test.

Research on high temperature pressure calibration system is less. The reasonable and reliable calibration system of sensor is needed to be fabricated.

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References


