Int. J. of Sustainable Water and Environmental Systems
Volume 3, No. 1 (2011) 1-4

Polysilicon Micro Pirani Vacuum Gauge

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Abstract

A new Polysilicon Micro pirani vacuum gauge that has a perforated grill structure with two parallel bridges has been designed and the fabrication method was established. A bridge with patterned square shape holes of poly-Si was formed on (100) silicon substrate. The bridge is suspended is suspended by its ends. This structure provides large active area and better heat distribution across the sensor, therefore improving full scale range of sensor. To optimize the shape, different sensor lengths and width were studied. Simulation with ANSYS software is used to study the deformation of the bridge due to its weight. Fabrication method of the sensor is fully explained. The sensor working pressure range is 10^{-4} mbar to 1000 mbar.

Keywords: *Pressure Vacuum Gauge, Heat Distribution, Polysilicon, Micro Scale*

1. Introduction

Micro Electro Mechanical System (MEMS) and Nano Electro Mechanical Systems (NEMS) are attractive for many scientists and engineers to reduce cost, increase sensitivity, fulfill severe conditions (high pressure and temperature) and very special environment in certain applications such as human body. Successes in down scaling of semiconductors and introducing high energy manufacturing techniques used in MEMS like lithography and plastic molding LIGA (Lithographic Galvanoformung Abformung) are the driving force for many researches in MEMS fields. For example with LIGA an element of 10 nm size could be easily molded. MEMS are found in many multidisciplinary applications such as car safety systems, micro thermal systems, micro pumps, medical micro pumps, optics and vacuum pressure gauges.

The pirani gauge is a thermal-conductive-type vacuum gauge. Its operational principle is that heat loss of a hot plate is proportional to the molecular gas density. The variation of pressure is measured by Wheatstone bridge [1]. The miniature pirani gauge is cheap, more accurate (±1.5 % for Micro pirani and ±15 % for the conventional one), easy for mass production, has low power consumption and has fast thermal response when compared with the conventional one.

Micro pirani gauges are used widely in many industrial and research environments. It is used in nuclear applications such as radioisotope nuclear energy converted to mechanical actuation, vacuum packaging of micro devices, inertial sensor, resonators and vacuum insulations. Kimura et.al proposed in a micro-air bridge (MAB) heater fabricated by using silicon planar and micromachining technologies, and suggested that this MAB heater with a temperature sensor will be widely used as a flow sensor, the thermal vacuum sensor, etc. to improve their sensitivities and responses due to a floating thin film [2].

Micro pirani gauges are classified into two categories: resistor type and micro bridge structure. Micromachined Pirani gauges consist of a suspended resistor where, for a given current, the resistor heats up by different amounts depending on the heat conducted through the gap between the pirani gauge and the substrate. Structures that allow for more heat conduction through the gas, allow for lower pressures to be measured. Heat is conducted through the gas to the substrate as atoms in the gas interact with the suspended bridge. At lower pressures where there are fewer atoms in the gas, the mean free path is much larger than the gap distance, which means that the atoms in the gas mostly collide with the bridge and transfer heat from it. Therefore, pressure is less sensitive to the gap dimension and more sensitive to the surface area of the bridge. At higher pressure, the mean free path of gas molecules is quite small, and therefore, to increase interaction between the gas and the bridge, the gap has to be reduced. Therefore, structures with smaller gaps between the pirani gauge and the substrate allow higher pressures to be measured, and structures with larger surface areas allow lower pressures to be measured.

Improvements to a single beam pirani gauge with ladder structure which allows for more exposed area, larger beam length and heat spreading cross support were performed in [3]

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DOI: 10.5383/swes.03.01.001