文章编号 1004-924X(2009)06-1350-05

应用 SU-8 粘合技术的微型压力、温度和湿度集成传感器

张建刚,庞 程,方 震,赵 湛
(中国科学院 电子学研究所 传感技术国家重点实验室,北京 100190)

摘要:压力、温度和湿度集成传感器具有体积小、成本低和可批量生产等优点,在环境监测和工业控制等领域应用广泛。基于微机电系统(MEMS)技术,本文设计和制作了一种尺寸为 5.5 mm×3.5 mm×0.8 mm 的高精度压力、温度和湿度集成传感器。该集成传感器由 SU-8 真空粘合技术制作的铂压阻压力传感器,铂电阻温度传感器和电容式湿度传感器组成。介绍了该集成传感器的设计思想、结构和制备过程,给出了实验和测试方法。结果表明,压力传感器的精度优于 0.05%;温度传感器的精度为 0.3%;湿度集成传感器的量程为 25%RH~95%RH,其性能曲线的线性相关系数为 0.998。集成传感器中的这 3 种传感器的高精度表明该集成传感器的制作工艺具有良好的工艺兼容性。

关 键 词:集成传感器;压力传感器;温度传感器;湿度传感器;聚酰亚胺;SU-8 粘合技术
中图分类号:TP212.6 **文献标识码**:A

Micro integrated pressure, temperature, and relative humidity sensor using adhesive bonding with SU-8

ZHANG Jian-gang, PANG Cheng, FANG Zhen, ZHAO Zhan

(*State Key Laboratory of Transducer, Institute of Electronics, Chinese Academy of Sciences, Beijing* 100190, *China*)

Abstract: The integrated pressure, temperature, and relative humidity sensors with high precision are highly needed in environmental monitoring and industrial control, for they have the superiorities on small sizes, low weights, low costs and easy to produce. Based on MEMS technology, a novel high precision integrated pressure, temperature, and relative humidity sensor is developed and its design principle and composition are introduced. Then, the fabrication process sequence and experiments for the integrated sensor are given. The 5.5 mm×3.5 mm×0.8 mm sensor chip consists of a piezoresistive Pt pressure sensor using adhesive bonding with SU-8, a Pt resistance temperature sensor and a capacitive humidity sensor. Experiments show that the pressure sensor has a linearity of 0.2% and a precision of 0.05% in square fitting; the temperature sensor has a precision of 0.3% and the humidity sensor shows the wide ranges of sensing ambient relative humidity from 25%RH to 95%RH and a linear correlation coefficient of 0.998 in 28.5 ℃. The high precisions of three sensors indicate the compatibility of the fabrication of this integrated sensor.

Key words: integrated sensor; pressure sensor; temperature sensor; humidity sensor; polyimide; adhesive bonding with SU-8

Received date: 2009-01-20; **Revised date**: 2009-04-30.

Foundation item: Supported by the National key Technology R&D Program of China (Grant No. 2006BAD08B01); the Innovation Project of Youth of IECAS (Grant No. 08Z1390237)

1 Introduction

The integrated pressure, temperature, and relative humidity sensor with high precision is highly needed in environmental monitoring and industrial control[1]. This kind of sensor fabricated by MEMS technology has the superiority on small size, low weight, low cost and easy mass production[2]. One of the challenges of this kind of sensor is that both the high precision of each sensor and the compatibility of the sensor fabrication should be ensured. However, in the past work[3-4] on this kind of sensor, the precision of each sensor has to give away to the fabrication process.

An integrated pressure, temperature, and relative humidity sensor with high precision, small size and low cost is developed. This paper reports the design, fabrication and test of this sensor chip which consists of a platinum piezoresistive pressure sensor using adhesive bonding with SU-8, a Pt resistance temperature sensor and a capacitive humidity sensor.

2 Device structure and Design

As shown in Fig. 1, the fabricated integrated sensor consists of a platinum piezoresistive pressure sensor using adhesive bonding with SU-8, a Pt resistance temperature sensor and a capacitive relative humidity sensor. Polyimide has been chosen as the relative humidity sensitive material of the capacitive relative humidity sensor. To ensure the vapour to diffuse freely into the polyimide and a uniform electrical field distribution in the polyimide, the upper electrode of humidity sensor has regular square meshes structure. The pressure sensor consists of a Si membrane on which a Pt electrodes is chosen as the sensitive material and a vacuum-sealed cavity formed by adhesive bonding with SU-8. According to the simulation, 15 μm and 2 000 μm as the thickness and the side length of the Si membrane are set. Pt electrodes have to cover more areas of the membrane to utilize strain as more as possible. The locations of the Pt electrodes used as Wheatstone bridge are determined according to the map of the stress distribution.

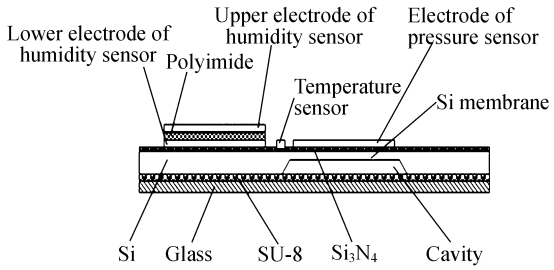


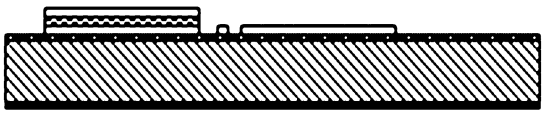
Fig. 1 Schematic diagram of the integrated pressure, temperature, and relative humidity sensor

3 Device fabrication

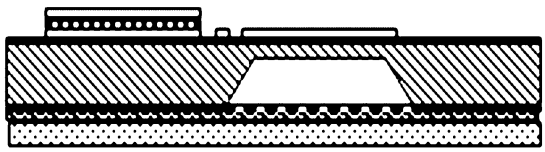
The fabrication sequence of this integrated sensor has three processes mainly and has been shown in Fig. 2. In the first process, a 0.5 μm thick dry thermal SiO_2 layer is grow on a double-sided, 7.62 cm n-type⟨100⟩ silicon wafer. Next, Si_3N_4 layer with a thickness of 0.2 μm is double-sided deposited by LPCVD (low-pressure chemical-vapor deposition). Then Pt layer as the lower electrode of humidity sensor, temperature sensor and electrode of pressure sensor is deposited on the front side of the silicon wafer by lift-off technology. And then, a Polyimide (PYRALIN PI2555, HD MicroSystems) thin film is coated and patterned on the lower Pt electrode of humidity sensor by the standard process of PYRALIN PI2555. Finally, the upper Pt electrode of humidity sensor with regular square meshes structure is deposited on the polyimide thin film by lift-off technology.

In the second process, the SiO_2 and Si_3N_4 layer of the back side which are used as masks for KOH etching are etched into a patterned shape. Then, the following KOH etching forms the Si membrane with a thickness of 15 μm. During

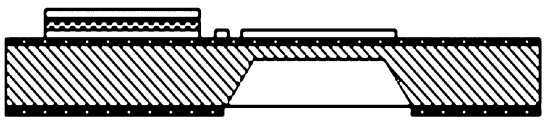
this KOH etching process, a special device is used to ensure the isolation between the KOH solution and the humidity sensor, temperature sensor and electrode of pressure sensor which are located on the front side of Si wafer.



(a) Deposition of humidity sensor, temperature sensor and pressure sensor with lower electrode



(b) KOH etching process



(c) Adhesive bonding with SU-8 of pressure sensor

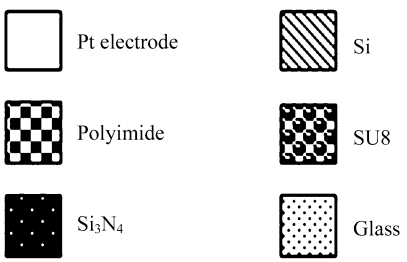


Fig. 2 Schematic fabrication process sequence of the integrated sensor

In the third process, a 10 μm thick SU-8 layer is spun on the glass wafer and is partially baked in 95 ℃ for 1 min. The silicon and glass wafer are aligned and brought into contact. Then, wafer to wafer bonding is performed with a pressure of 60 N on the wafers in a vacuum hot plate-by pumping 1 hour to a surrounding pressure of 10^{-4} Pa, then heating in ramp to 95 ℃ and maintaining it for 1 hour, finally cooling down to room temperature with the pump still running. Differing from the traditional adhesive bonding with SU-8 for packaging[5-7] and the work[8], we didn't use a bonding machine but adopted a different process to accomplish the bonding, and the process of adhesive bonding with SU-8 is performed in a more convenient and practical way. The front view of one of the fabricated sensors has been shown in Fig. 3.

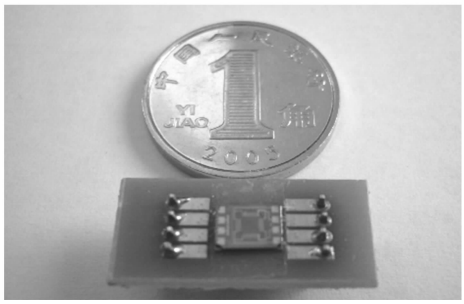


Fig. 3 Photograph of the fabricated sensor

4 Tests and results

The integrated sensor is wire bonded to a Printed Circuit Board (PCB) which is able to be connected with a test circuit which is also a PCB. As shown in Fig. 1, the size of the fabricated integrated sensor is 5.5 mm×3.5 mm×0.8 mm. Pressure controller (Paroscientific Inc. 745-23a) has been employed as the key instrument to characterize the pressure performance of the integrated sensor. Fig. 4 presents the pressure performance of the integrated sensor in 20.17 ℃. The precision of the pressure performance of the sensor is with a linearity of 0.2% and a square fit of 0.05%. RTS-60C temperature examination instrument has been used to characterize the temperature performance of

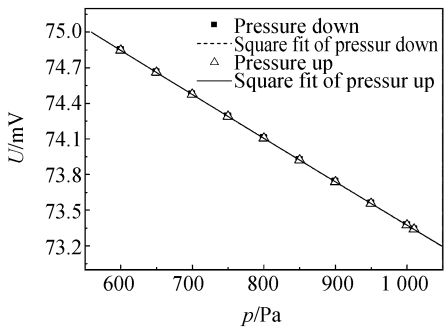


Fig. 4 Output of pressure sensor in 20.17℃

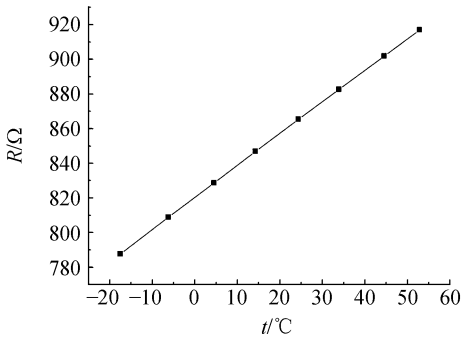


Fig. 5 Output of temperature sensor

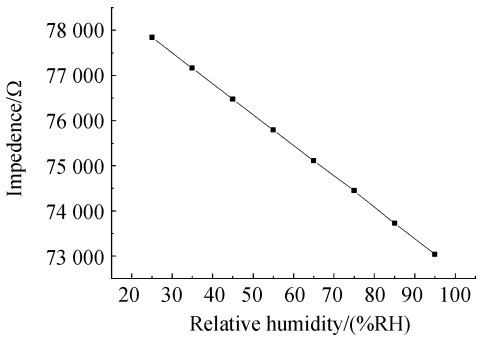


Fig. 6 Output of humidity sensor in 28.5 ℃

the integrated sensor which has been shown in Fig. 5. The temperature performance of the sen sor has a precision of 0.3%. Relative humidity examination instrument (Tianyi Inc. DJM10) has been used to characterize the humidity performance of the integrated sensor. Fig. 6 presents the humidity performance of the integrated sensor from 25%RH to 95%RH in 28.5 ℃. The humidity performance of the sensor has a linear correlation coefficient of 0.998.

5 Conclusions

An integrated pressure, temperature, and relative humidity sensor has been successfully fabricated by a new design and process. The precision of the pressure performance of the sensor is with a linearity of 0.2% and a square fit of 0.05%. The temperature performance of the sensor has a precision of 0.3%. The humidity sensor shows a wide range of sensing ambient relative humidity from 25%RH to 95%RH and has a linear correlation coefficient of 0.998 in 28.5 ℃. The size of the fabricated integrated sensor is 5.5 mm×3.5 mm×0.8 mm. The high precision of these three sensors indicates the compatibility of this integrated sensor.

References:

[1] MASON A, YAZDI N, CHAVAN A V, *et al*.. A generic multi-element microsystem for portable wireless applications [C]. *Proc. IEEE*, 1998, 86: 8.

[2] RITTERSMA Z M. Recent achievements in miniaturised humidity sensors-a review of transduction techniques[J]. *Sens. and Actuators A*, 2002, 96: 196-210.

[3] FUJITA T, MAENAKA K. Integrated multi-environmental sensing-system for the intelligent data carrier [J]. *Sensors and Actuators A. Physical*, 2002, 97-98(1): 527-534.

[4] DEHENNIS A, WISE K D. An all-capacitive sensing chip for temperature, absolute pressure, and relative humidity [C]. *Proc. of the 12th International Conference on Solid-State Sensors and Actuators (Transducer'03), Boston*, 2003: 1860-1863.

[5] PAN C T, CHENG P J, CHEN M F, *et al*.. Intermediate wafer level bonding and interface behavior[J]. *Microelectronics Reliability*, 2005, 45: 657-663.

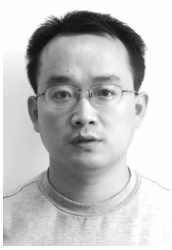
[6] WIEMER M, JIA C P, TOEPPER M, *et al*.. Wafer bonding with BCB and SU-8 for MEMS packaging, [C]. *Proc. of the Electronics System integration Technology Conference, Dresden, Germany*, 2006: 1401-1405.

[7] TIAN J, BARTEK M. Low temperature wafer level packaging of RF-MEMS using SU-8 contact Printing [C]. *2nd International Workshop on Wafer Bonding for MEMS Technologies, Halle, Germany*, 2006: 55-56.

[8] YU L M, TAY F E H, XU G L, *et al*.. Adhesive bonding with SU-8 at wafer level for microfluidic devices[J]. *Journal of Physics, Conference Series*, 2006, 34: 776-781.

Authors' biographies:

ZHANG Jiangang (1976 —), male, received his B. S. degree in applied physics and M. S. degree in condense matter physics from Beijing University of Aeronautics and Astronautics in 1998 and 2001, respectively. He is currently an assistant professor of the State Key Laboratory of Transducer Technology, Institute of Electronics, Chinese Academy of Sciences. His current research interests include heat transfer in MEMS, self assembly in MEMS, humidity sensors, integrated multi-sensors, and polymer MEMS. **E-mail**: jgzhanghli@yahoo.com.cn



FANG Zhen (1976 —), Ph. D. of the State Key Laboratory of Transducer Technology, Institute of Electronics, Chinese Academy of Sciences, his research interests are wireless sensor networks and the microsystem of integrate sensor. **E-mail**: zfang@mail.ie.ac.cn

PANG Cheng (1983—), received his B. S. in automotive engineering from Tsinghua University in 2005. He is currently working toward the M. S. degree in capacitive pressure sensors in micro systems of integrated weather sensors in the State Key Laboratory of Transducer Technology, Institute of Electronics, Chinese Academy of Sciences. **E-mail**: pangcheng05@mails.gucas.ac.cn

ZHAO zhan (1958 —), male, received his B. S. degree in physics in 1982 from Shanxi University and M. S. and Ph. D. degrees in physical electronics and devices in 1987 and 2003, respectively, from Institute of Electronics, Chinese Academy of Sciences (IECAS). Since 1994, he has been in the State Key Laboratory of Transducer Technology (SKLTT) at IECAS. Since 2000, he has been a professor for integrated sensor and microsystem at the SKLTT. **E-mail**: zhaozhan@mail.ie.ac.cn

---

●下期预告

超静定并联式六维力传感器动力学

侯雨雷[1],曾达幸[1],姚建涛[1],孙凤龙[2],赵永生[1]

(1.燕山大学 机械工程学院,河北 秦皇岛 066004;
2.宝山钢铁股份有限公司钢管厂,上海 201900)

提出了一种新型的基于 Stewart 平台的超静定并联式六维力传感器结构,并对其进行了动力学理论分析和有限元仿真研究。描述了该传感器相对于经典 Stewart 平台六维力传感器所具有的结构特点;利用有限元法,采用位移协调和力平衡条件建立了传感器弹性动力学理论模型,依此模型进行数值分析,绘制了固有频率与各结构参数间变化关系曲线;并利用 ANSYS 软件建立了传感器有限元模型,进行了振动模态分析,得到其固有频率和振型。