초고온용 다결정 3C-SiC 마이크로 압력센서의 특성

덩 샤오 티엔, 정귀상*
울산대학교 전기전자정보시스템공학부

Characteristics of polycrystalline 3C-SiC micro pressure sensors for high temperature applications

Duong Xuan Thien, Gwiy-Sang Chung*
School of Electrical Eng., University of Ulsan

Abstract : High temperature micro pressure sensors were fabricated by polycrystalline (poly) 3C-SiC piezoresistors formed by oxidized SOI substrates with APCVD. These have been designed by bulk micromachining below 1×1 mm^2 diaphragm and Si membrane 20 ㎛ thick. The pressure sensitivity of fabricated pressure sensor was 0.1 mV/Vbar. The non-linearity of sensor was ±0.44% FS and the hysteresis was 0.61% FS.TCS of pressure sensor was -1867 ppm/℃, its TCR was -792 ppm/℃, and TCGF to 5 bar was -1042 ppm/℃ from 25 to 400℃.

Key Words : Polycrystalline 3C-SiC, High temperature pressure sensor,

1. Introduction

Recently, with their operation at over 300℃, sensors are necessary for applications with harsh environment such as automotive, aerospace, shipbuilding, industrial automatic control, and nuclear power plant. It is impossible for the piezoresistive type pressure sensor based on silicon (Si) to be used in a temperature over 120℃ due to the p-n junction leakage current and difficult to fabricate a membrane for a pressure sensor using the anisotropic etching technique to control its thickness accurately. Although Si on insulator (SOI) and poly-Si on insulator (PSOI) the membrane of pressure sensors can control the thickness by Si on insulator (SOI) and poly-Si on insulator (PSOI), but there is the linearity problem at 200~250℃.

The material, which can be substituted for the existing Si characteristic, operating in the harsh environment with an optimization is essential. Silicon carbide (SiC) is excellent material because of its advantages in the larger band gap (2.41~3.26 eV), the higher break down voltage (2.2~2.4×10^6 cm/s), the higher thermal conductivity (3.0~3.8 W/cm·K), the higher electron mobility (2.0×10^7 cm / sec).

In this paper, the micro pressure sensor based on polycrystalline (poly) 3C-SiC thin films grown on the oxidized SOI substrate was made and characteristics of the fabricated sensor have evaluated for high temperature of 400℃. Moreover, when forming a membrane using the SOI substrate, its thickness control is easy through the etch delay in the SiO_2 layer.

2. Fabrication

Fabrication process sequences of the poly 3C-SiC micro pressure sensor are shown in Fig. 1. (a) the SOI (Si/SiO_2/Si : 20 ㎛/0.5 ㎛/230 ㎛) that substrate was cleaned and then the oxide film with about 0.8 ㎛ was deposited on it by the wet oxidation furnace for the mask formation.

The SiO_2 on the back side was removed by buffer oxide etchant (BOE) solution to form a diaphragm, at 82℃within Tetramethylammonium (TMAH), which is an 8 hour anisotropic etching solution. The membrane is possible to control the exact membrane thickness as the etch delay in the SiO_2 layer. (b) The poly 3C-SiC thin film with 0.5 ㎛ grows on the oxidized SOI substrate using APCVD, the PR/Al mask that was formed by the photo lithographic process for piezoresistors. (c) The poly 3C-SiC thin film was etched to the rest except the mask part using the magnetron reactive ion etching (RIE). (d) The thermally stable TiW (titanium tungsten) for the metallizating process and Au metal for the wire bonding which were deposited by using the sputtering system in sequence. The Au/TiW/PR can be selectively removed by the lift-off method.

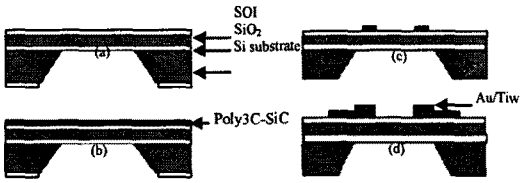

Fig 1. Fabrication process sequency of a poly-silicon 3C-SiC micro pressure sensor.

3. Results

The pressure sensor is placed within the temperature chamber can temperature control, which applied power supply +5V, used

the N_2 gas for pressure regulator from 0~8 bar. Fig. 2 shows relative between output voltage and the applied pressure(0~8 bar) while change temperature(25~400℃) of pressure sensor. The sensitivity decreases when temperature increases. However, the output voltage depends on the temperature.

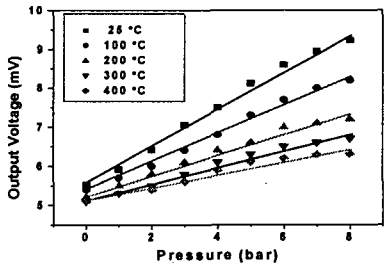

Fig 2. Output characteristics of fabricated pressure sensor according to temperature.

With Fig. 3, the pressure sensor showed the excellent characteristic of the non-linearity result, ±0.44 %FS, in the pressure range of 0~8 bar.

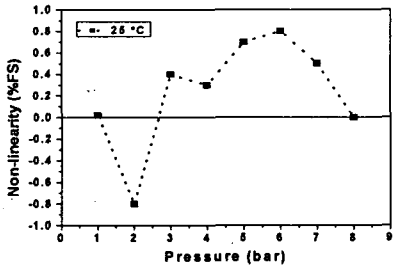

Fig 3. Non-linearity of pressure sensitivity in the in the range of applied pressure

Fig. 4 shows that the hysteresis characteristic of thefabricated pressure sensor was measured by 0.61 % FS with the applied pressure.

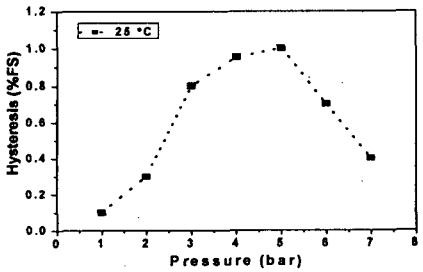

Fig 4. Hysteresis of fabricated pressure sensor in the range of applied pressure.

The TCS of poly 3C-SiC was measured as -1,867 ppm/℃ and showed the excellent temperature characteristic as its single 3C-SiC. And one resistance of designed piezoresistors was 7.5 k Ω. while the fabricated pressure sensor was measured about 6 kΩ and the total resistance was 24 kΩ. The TCR (25~400℃) of poly 3C-SiC was low measured as -792 ppm/℃. And it has the constant characteristic at the high temperature. The TCGF (25~400℃) increased as -1,042 ppm/℃ to the pressure of 5 bars (see figure 5)

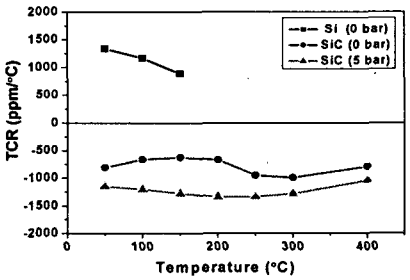

Fig 5. Variations of TCR and TCGF according to temperature.

4. Conclusions

In this research, the poly 3C-SiC micro pressure sensor was made when using the oxidized SOI substrate. The sensitivity was 0.1 mV/V·bar according to the applied pressure. Even though the sensitivity was low, a non-linearity was very superior as ±0.44%FS. Moreover, the hysteresis characteristic was measured as 0.61 %FS.

The sensitivity and linearity showed characteristics that decrease when the temperature increases from 25 to 400℃. Therefore, it is expected that the fabricated poly 3C-SiC micro pressure sensor can be applied to the harsh environment at 400℃.

Acknowledgements

This research was financially supporting by the Ministry of Education, Science Technology (MEST) and Korea Industrial Technology Foundation (KOTEF) through the Human Resource Training Project for Regional Innovation, and the Korea Research Foundation Grant funded by the Korean Government (MOEHRD)(KRF-2006-D00177).

References

[1] Y. T. Lee, H. Takao, and M. Ishida, Sensors and Materials, Vol. 17, No 5, p. 269, 2005.
[2] C. Malhaire and D. Barbier, Thin Solid Films, Vol. 427, p. 362, 2003.
[3] G. S. Chung, C. M. Ohn, and C. W. Nam, J. Korean Sensors Soc., Vol. 16, p. 197, 2007.