Abstract

In this work, we report the fabrication and characterization of a SiC/SiO₂/Si piezoresistive pressure sensor. The sensor structure consists of six PECVD SiC thin-film piezoresistors configured in Wheatstone bridge on a thermally oxidized micromachined silicon diaphragm. In order to fabricate this sensor, three lithographic masks were designed: one to define the square diaphragm (1800 μm x 1800 μm), another for the piezoresistors and the third for the Ti/Au metal lines. The diaphragm was formed by anisotropic etching of Si in KOH solution and the piezoresistors by reactive ion etching (RIE) of SiC. The sensor chip size is 4.5 mm x 4.5 mm. It was bonded on an alumina substrate using silicone and an aluminum cup was used for protection. The output voltage of the sensor was measured for applied pressure ranging from 0 to 12 psi and voltage supply of 12V.

Keywords: Silicon Carbide, Amorphous Films, Piezoresistive Properties, Pressure Sensors

1. Introduction

Piezoresistive sensors exhibit a strong temperature dependence which affect their performance at elevated temperatures [1]. Silicon Carbide (SiC) has been recognized as an attractive material for high temperature applications because of its mechanical robustness, chemical inertness and electrical stability [2]. In this context, there is an interest by developing piezoresistive sensors based on thin films or substrates of this material.

Some studies have been reported on piezoresistive pressure sensors with diaphragms and piezoresistors of 6H-SiC, while others studies show sensors having 3C-SiC piezoresistors on Si or SiO₂/Si diaphragms [3-4]. However, few works have investigated the development of piezoresistive pressure sensors based on amorphous SiC films. Motivated by this, in this work we present the fabrication process of a piezoresistive pressure sensor based on SiC films deposited on thermally oxidized (100) Si substrates by plasma enhanced chemical vapor deposition (PECVD) from SiH₄ + CH₄ + N₂ + Ar gas mixtures at room temperature.

The layout of the sensor, with six piezoresistors configured in Wheatstone bridge on a square diaphragm, was defined following the model proposed by L. F. Fuller and S. Surdigo [5] in order to place the piezoresistors where the stress on the diaphragm is the highest when pressure is applied. This optimized design allows to maximize the sensitivity of the sensor.
2. Experimental

2.1. Deposition and characterization of the SiC thin films

Silicon carbide (SiC) thin films have been deposited on thermally oxidized (100) silicon substrates using a PECVD system equipped with a radio frequency (RF) source operated at a frequency of 13.56 MHz under the following deposition conditions: substrate temperature (room temperature), pressure (200 mTorr), Ar flow rate (20 sccm), CH4 flow rate (20 sccm), SiH4 flow rate (4 sccm), N2 flow rate (2 sccm) and deposition time (20 min).

Composition, thickness, structure, resistivity and elastic modulus of the SiC films were investigated by Rutherford backscattering spectroscopy (RBS), profilometry, x-ray diffraction (XRD), four points probe and nanoindentation respectively. In Table 1 are summarized the characteristics of the SiC film. As can be observed, the film is non-stoichiometric and amorphous. Besides, it exhibits low resistivity and low elastic modulus.

<table>
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<th>Table 1. Characteristics of the SiC film used</th>
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<td>Si</td>
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<td>C</td>
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<td>Composition (at.%)</td>
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<td>Structure</td>
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<td>Resistivity (Ω cm)</td>
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<td>Elastic Modulus (GPa)</td>
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2.2. Fabrication and characterization of the sensor

The fabrication sequence of the sensor is shown in Figure 1 and consisted of the following steps: (a) 2 inch (100) p-type Si double side polished wafers were RCA cleaned and thermally oxidized, (b) The backside of the wafer was coated with
photoresist and the first photolithographic step was performed to define the diaphragm. (c) The diaphragm was formed by anisotropic etching of Si in KOH solution at 85°C for 90 min. (d) The next step was to deposit SiC film on the frontside of the wafer by PECVD. (e) SiC film was coated with photoresist and the second photolithographic step was performed to define the piezoresistors. (f) In order to form SiC piezoresistors, the SiC film on the regions not protected with photoresist was etched by reactive ion etching using SF6+O2 gas mixtures. (g) A layer of 25 nm of Ti was sputtered onto the sample and subsequently a layer of 250 nm of Au. (h) The last photolithographic step was performed to define metal lines and unwanted Ti and Au were etched using an etchant solution. (i) The final structure of the piezoresponse pressure sensor is achieved.

Figure 2. Photographs of the sensors: (a) SiC piezoresistors configured in Wheatstone bridge, (b) sensor chip bonded to alumina substrate with Al metallization, (c) two sensors and (d) packaged sensor.

In Figure 2 are shown photographs of the sensor. The dimensions of the diaphragm are 1800 μm x 1800 μm x 30 μm. Two SiC piezoresistors have L = 700 μm and W = 100 μm and the others piezoresistors each one consists of two resistors in series with L = 350 μm and W = 100 μm. The sensor chip size is 4.5 mm x 4.5 mm. It was bonded on an alumina substrate using silicone (Dow Corning 3140) and an aluminum cup was used for protection. Figure 3 shows SEM images of the sensor.

Figure 3. SEM images of the sensor: (a) cross section of the SiO2/Si diaphragm, (b) six SiC piezoresistors (50X), (c) two SiC piezoresistors with Ti/Au metal lines (200X) and (d) Ti/Au contact (500X)
Initial testing of the sensor was performed for pressures up to 12 psi. Figure 4 shows the output voltage as a function applied pressure on the sensor at room temperature. It was obtained an offset of 62 mV and a sensitivity of 3.90 mV/psi.

3. Conclusions

We have fabricated a SiC/SiO2/Si piezoresistive pressure sensor. The sensor consists of six SiC piezoresistors into the surface of a SiO2/Si diaphragm close to the edges. The sensor was packaged and tested. It was observed a good sensitivity and linearity.

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References