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Procedia Computer Science 93 (2016) 108 – 116

Procedia Computer Science

6th International Conference On Advances In Computing & Communications, ICACC 2016, 6-8 September 2016, Cochin, India

Analysing the effects of temperature and doping concentration in silicon based MEMS piezoresistive pressure sensor

Suja K J [a,*], Kumar G S[b], Rama Komaragiri[a], Nisanth A[a]

[a]Electronics and Communication Engineering Department, National Institute of Technology, Calicut- 673601, Kerala
[b]Sree Chithra Thirunal College of Engineering, Pappanamkode, Thiruvananthapuram-18, Kerala,

Abstract

Wide range of improvements in the silicon integrated circuits and micromachining technology enables the development of various sensing instruments. Micro Electro Mechanical System (MEMS) technology enables fabrication of micromachined components and batch fabrication through Very Large Scale Integrated (VLSI) processing. In MEMS piezoresistive pressure sensor, temperature can be considered as the main environmental condition which affects the system performance. In this work, a study on the effects of temperature and doping concentration in a boron implanted piezoresistor for a high sensitive silicon based MEMS piezoresistive pressure sensor is discussed. Using the fundamental semiconductor equations, the dependance of conductivity and hence the resistivity of a piezoresistor on operating temperature and impurity doping concentration is analysed. It is also being observed that in physical environment, the effect of stress on the performance of MEMS pressure sensor will be more compared with the temperature and for a given pressure output voltage varies in a linear manner. FEA simulation tool CoventorWare® has been used for the simulation.

Peer-review under responsibility of the Organizing Committee of ICACC 2016

Keywords: MEMS; Piezoresistivity; FEA; Temperature; Mobility model.

1. Introduction

Pressure measurement is an integral part of many systems and pressure sensors play a major role in industrial automation, biomedical applications[1] and very harsh industrial and oceanographical applications[2]. Silicon is a suitable material to build pressure sensors on microscale. The size of pressure sensor fabricated in initial days was comparatively large compared with the present day pressure sensor. A conventional pressure sensor is bulkier and suffers high pressure resistance, poor sensitivity, poor resolution along with large power consumption[3]. Silicon piezoresistive pressure sensor is one of the most widely used pressure sensors. Among various MEMS applications, MEMS pressure sensors have received great attention because they constitute 60% to 70% of the MEMS market[4]. MEMS piezoresis-

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* Corresponding author. Tel.: +91-9895127812 ; fax: +91-0495-2287250.
E-mail address: suja@nitc.ac.in

Peer-review under responsibility of the Organizing Committee of ICACC 2016
doi:10.1016/j.procs.2016.07.189

tive pressure sensor with resistors implanted on the diaphragm and the metallic contact is shown in Fig 1. The design

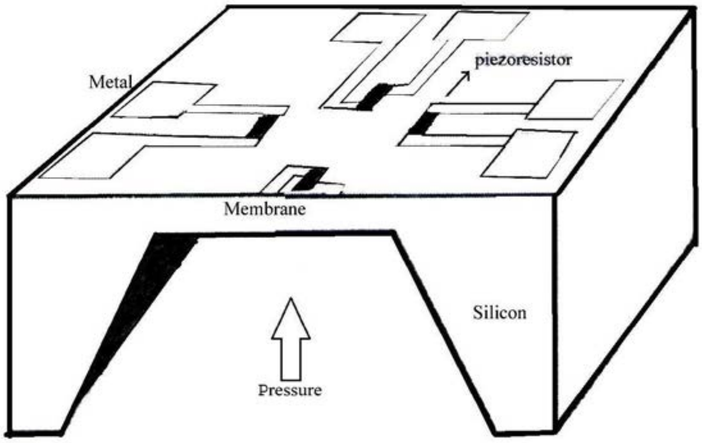

Fig. 1. MEMS Piezoresistive Pressure Sensor With Implanted Piezoresistors and Metallic Contacts

of the MEMS pressure sensor should be such that the variation in output according to temperature variation should be minimum. Further, the influence of temperature on the performance of pressure sensor is to be deeply analysed. The design of the MEMS pressure sensor should be such that the change in conductivity with temperature in the implanted piezoresistor on the diaphragm is minimum. For achieving this, the doping concentration is to be properly optimized. The work available in the literature for enhancing the sensitivity of pressure sensors, assume a fixed temperature. Hence a MEMS pressure sensor with enhanced sensitivity and linearity over a wide range of temperature is of great scientific significance and of practical importance. Further, the effect of temperature in the conductivity of boron implanted piezoresistors is also carried out. The information carried from the studies on different mobility models is utilised for optimizing the doping concentration.

2. Piezoresistive Sensing Mechanism

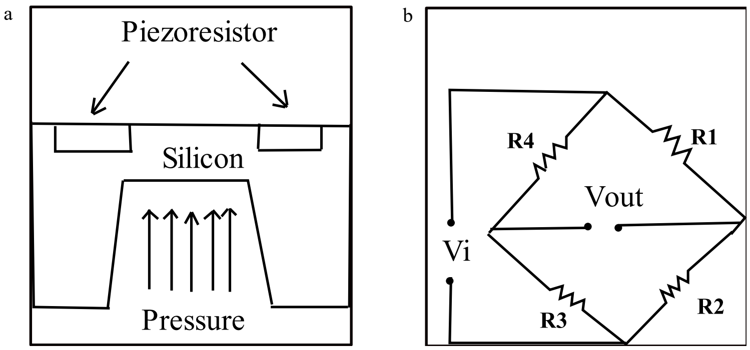

Fig. 2. MEMS Piezoresistive Pressure Sensor (a) Schematic cross section; (b) Wheatstone Bridge Configuration.

Schematic cross section of MEMS piezoresistive pressure sensor is shown in Fig 2 (a) and the resistors implanted on the diaphragm are arranged in a wheatstone bridge configuration as shown in Fig 2 (b). When a pressure is applied to the diaphragm, the diaphragm deflects and causes stress in the piezoresistors. The resistance change is linear with applied pressure for thin and small deflections and this change is measured by a Wheatstone bridge circuit[5]. Under zero applied stress, atoms occupy their actual position and are separated by lattice constant a in both directions. The