An Extensive Fabrication of Eight Beam Configured Piezoresistive Micro Accelerometer

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Abstract

In this paper, the design and fabrication process of an eight beam configured single axis planar piezoresistive MEMS accelerometer is discussed in detail. Cantilever beam and calculated amount of proof mass was realized using bulk-micromachining in TMAH solution. Thickness of beam was controlled by back to front side etching technology. The resistors were place at appropriate location by analyzing the place using finite element method in ANSYS simulation. LPCVD polysilicon was used as a piezoresistors with thermal doping of boron at 1050°C for 40 minutes. The wafer level testing was performed and the measured value of resistors were analyzed and presented here.

Keywords: Polysilicon, MEMS, Accelerometer.

Introduction

Silicon micromachining technology creates the new windows for the development of new unique devices and structures. MEMS accelerometers are one of the simplest but also most applicable micro-electromechanical systems. In recent years, the various types of miniaturized silicon micromachined accelerometers are increasingly being implemented in different kinds of portable Microsystems, such as biomedical applications, space navigation systems, automobile applications, motion control systems and so on, because of size, weight, cost and power advantages [1]. Most of the accelerometers were based on three most famous sensing mechanisms i.e. piezoelectric, capacitive and piezoresistive. Each approach has its own inherent advantages and drawbacks. Piezoelectric accelerometers have a fast response but do not respond to a constant acceleration and it is difficult to operate below 1 Hz. Capacitive accelerometers have a dc response, a low drift and are very low-temperature insensitive, but the detected signal is difficult to measure because of the parasitic capacitance of connecting leads. Piezoresistive accelerometers suffer from dependence of temperature, but have a dc response, simple readout circuits, ability to meet the requirement of high sensitivity, high reliability, and low cost in addition to the potential for mass production [2]. In this work special attention is given to the polysilicon piezoresistive accelerometers, how do they work and their applications. Significant process steps for realization of exact proof mass with better corner compensation and controlled cantilever beam has been established. In order to improve the sensitivity of devices LPCVD polysilicon has been used as piezoresistive material. Finite element method has been used as theoretical tool to realize the piezoresistors at proper location.

Finite Element Simulation

In general, for the design of a MEMS technology based devices with moving parts, the analysis typically starts with a structural analysis as well as vibration analysis. This demonstrated work focuses on the modeling of the polysilicon piezoresistive silicon MEMS accelerometer only, which attempts to design a surface micro-machined accelerometer that satisfies our goal. In the design of the accelerometer, the selection of parameters like dimension of proof mass, the dimension of the silicon cantilever beams and the depth of the air gap between the proof mass and the bottom encapsulation were evolved. In the proposed structure the silicon proof mass is symmetrically suspended by eight beams. As shown in Fig.1 in which solid elements with 8 nodes (PLANE82) were used to mesh the structure. The values of silicon's Young's modulus, Poisson's ratio, and density used in the simulation are defined as 190 GPa, 0.29 and 2300 kg/m^3, respectively. An inertia load is applied in the z-axis direction. Without any external mechanical loading, the displacement of the proof mass will be zero. Silicon proof mass deforms in z-axis direction, when inertial load is applied to the centre. The developed maximum and minimum stress is represented in inset of Fig.1

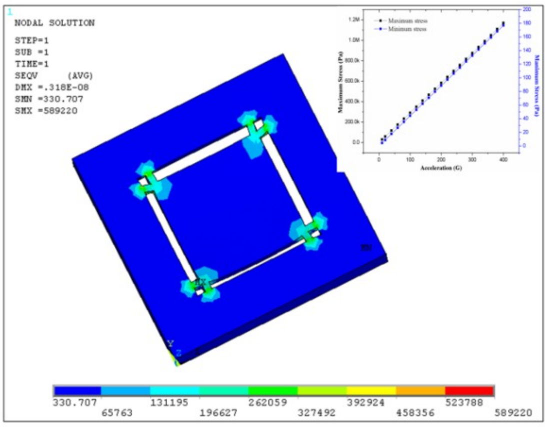

Fig.1: Stress distribution of designed MEMS accelerometer under the influence of high g.

Device Fabrication and Experimental Results

A batch of 2″ diameter Silicon wafers of (100) orientation with p-type impurities and both side polished, were given a through chemical cleaning treatment involving degreasing, RCA and Piranha. The native oxide, which appears during chemical process was removed from both the surface by dipping the wafers in dilute (2%), Hydro Fluoric (HF) solution. After chemical treatment, when the wafers were ensured with clean surfaces then baked at 250^{o}C for 4 to 6 hours in a 1000 class oven. The wafers were then applied under a grade one nitrogen jet and were loaded in horizontal quartz oxidation furnace for thermal oxidation. The samples were loaded in oxidation furnace at 800^{0}C in the flow of nitrogen gas. The ramp up temperature of the furnace was 10^{0}C/minutes. In this work dry-wet-dry oxidation processes were adopted. The final temperature of oxidation has been kept at 1100^{0}C. At this stage dry oxygen was passed in tube for 10 min. Furthermore, the wet oxidation was performed for 120 min at same temperature fallowed by 10 min dry oxidation again. After process oxidation, the temperature of the furnace was cooled down until 800^{o}C with ramp down to 5^{0}C/minutes and wafers were unloaded. During their respective process, the flow rate of wet oxygen was maintained with 0.5 liters/minutes while molecular nitrogen was flowed with160 cc/minutes. The thickness of SiO_2 (1 μm) on both polished side has been determined using Ellipsometer along with Surface profiler verification. First photolithography (PLG-1) was carried out for delineation of proof mass on one side of wafer. After PLG-1, bulk-micromachining was done in TMAH solution. The anisotropic etching was performed for 8 hours at 80-85^{o}C temperature. The wafers were examined after this process and found that the designed square corner has been shaped to octagonal as shown in inset (b) of Fig. 2. In order to delineate piezoresistors on the cantilever beam, LPCVD polysilicon layer is deposited on the opposite surface of etched proof mass. A thermal doping of boron at 950^{o}C for 40 min was carried out to adjust its sheet resistivity for required resistor's value. A blanket doping of boron is conducted by diffusion process with prior optimized diffusion parameters. At this stage back to front alignment process has been applied to align placement of polyresistors on the cantilever beam which is on the other side of the surface. The polyresistors were placed on the location where maximum stress was achieved in Fig. 1. A double-sided mask aligning system was used in this experiment. Furthermore, In order to realize Wheatstone bridge, the contact metal line was defined on same face. A composite layer of Ti (300A^{0}) and Au (2000A^{0}) were deposited using e-beam evaporation method followed by PLG process. PECVD SiO_2 of 1 μm was deposited in order to retain the Polyresistors during the final anisotropic etching. Last PLG process was performed to hang the moving proof mass with 50 μm thick cantilever beam. Fig. 2 shows the front side view of this hanging structure.

The wafer level testing was done using indigenously developed LabVIEW based computer aided measurement facility. The acquired value of resistance was captured using Agilent's 4284A LCR meter by placing the pointed probe on metal pads. The measurements were performed on five different locations on the wafer. The measured values were represented in Fig 3 which reveals almost equal value over entire wafer.

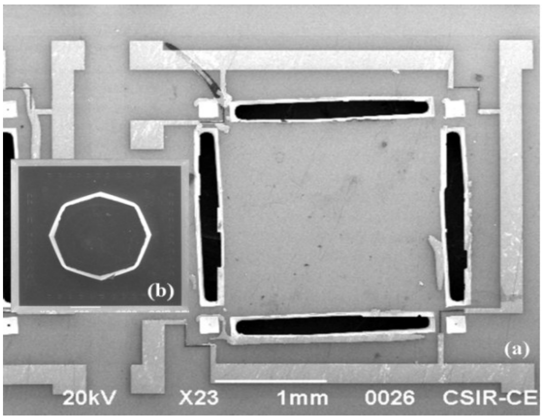

Fig. 2: Front side SEM image of fabricated accelerometer.

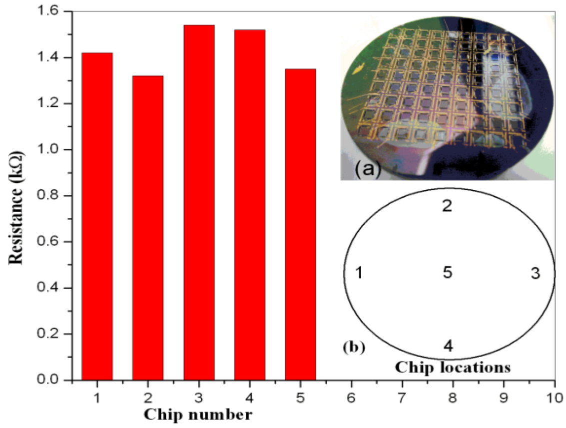

Fig.3: Measured values of piezoresistors on different locations.

Conclusions

An eight beam configured single axis piezoresistive MEMS accelerometer with an overall chip size of 4×4 mm^2 was developed. Basic structure of device consists of a seismic mass suspended by cantilever beams. The piezoresistive effect was employed as a sensing principle. The devices has designed and fabricated up to package level. The wafer level testing was done and the resistor values were found in the range of 1.5 kΩ.

References

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