Practical application and understanding of the function and manufacture of a Micro Pressure Sensor

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Resume- In this paper, the practical application and understanding of the function and manufacture of a micro pressure sensor was investigated. It was included learning general micro technology processes such as photolithography, chemical vapor deposition and silicon etching. The pressure sensor fabricated fall under a category of sensors that are know as *Micro-Electro-Mechanical Sensors* (MEMS) , these sensors are applied in the mechatronics field, whereby the characteristic dimensions are in the micrometer range. All the procedure steps were followed to fabricate successfully the micro pressure sensor and tests to analyze the functioning of the pressure sensor are being accomplished.

Key-Words: Microtechnology , Sensor, Silicon , Mechatronic
Knowledge Area: III - Engenharias

Introduction

A pressure sensor measures an amount of force applied over a specific area and in the case of a MEMS device, this is accomplished by measuring the deflection of a silicon plate called the "membrane" (Figure 1). The amount of the deflection can be measured in various ways, and in the case of this lab, is accomplished through use of piezoresistors. In a technique similar to strain gauges, resistor increase their impedance as they are stretched or lower their impedance as they are compressed.

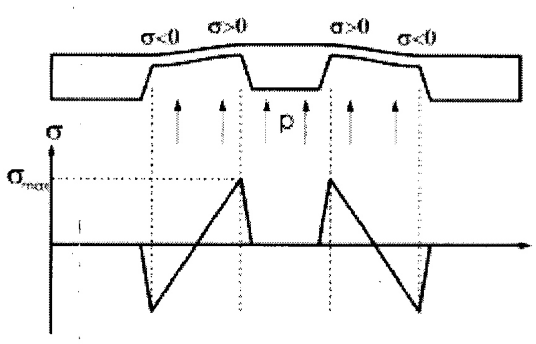

Figure 1 – Deflection of a membrane under pressure

Piezoresistance in silicon acts slightly differently than that of metal piezoresistors. Depending on the type of doping, as well as direction of strain compared to the crystal orientation different values are created. This is attributed to the movement of impurities doped into the silicon crystal structure and their respective alignment change under stress loading, resulting in higher or lower electrical resistance.

The Wheatstone bridge (Figure 2) is an important aspect of impedance measurement in that it measures the difference in resistance over the bridge while compensating for temperature changes and other effects. This allows for very precise measurement in varying conditions. The piezoresistors are therefore specially oriented in positions of maximum strain.

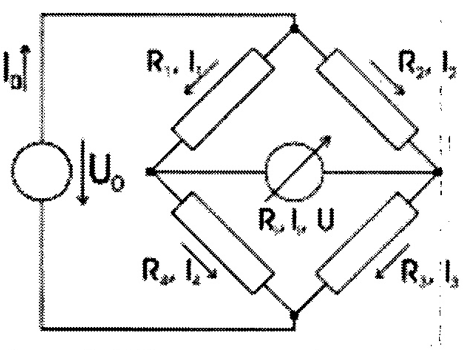

Figure 2 – Wheatstone bridge layout

Using Equation 1 , it is possible to calculate the resulting potential from a change in resistance of any of the resistors in the equation above.

$$U = U_0 * \frac{R_2R_4 - R_1R_3}{(R_1 + R_4)(R_2 + R_3)}$$

Equation 1

When pressure is applied to the surface of the silicon membrane the resulting force produces a deflection which is converted through use of piezoresistors into a resulting voltage change, which in turn is analyzed and calibrated.

In order to develop the required form for proper measurement of deflection of a silicon membrane, several microtechnology processes must be applied. The steps that are of importance to the creation of the membrane and piezoresistors are those of diffusion and wet etching.

Diffusion is a process of doping a very pure element with impurities in order to form semiconductors. This can be done with n-type doping , which is done by adding valence-five elements into valence-four substrates, such as Phosphorus doping in Silicon. This increases the amount of free electrons, creating a “donor material”. The opposite is p-type doping, which adds valence-three elements to valence-four elements in order to develop an acceptor material. In other words, the electrons are pulled into the p-type material, such as with Boron diffused into Silicon.

The second important process is the wet-etching. Wet-etching is a way of etching silicon chemically in order to obtain physical shapes required for MEMS devices. Using photolithography, sections of a Silicon wafer are protected from contact with the etching solution, thereby allowing control of etching designs. As can be seen in Figure 3, if the silicon were to be etched in an isotropic fashion, even protected sections of the wafer would be etched. Using a well characterized method of plane crystalline silicon anisotropic etching with potassium hydroxide (KOH), silicon will etch at a 54.7º, thereby hindering any under etching.

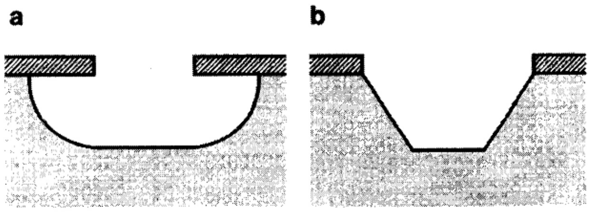

Figure 3 - Protected Sections of the Wafer

Methodology

The process and development of the sensor was placed at the Institute for Microtechnology, Technische Universität Braunschweig, in the Clean room.

It was used 4 Silicon wafers N-Prime, 350 μm +/- 25 μm, polished on both sides.

First process was the application of oxide by PEVCD (Plasma Enhanced Chemical Vapor Deposition) diffusion, at the top surface during 8 minutes at 300ºC (produces roughly 600 nm). After first process, the structuring of photoresist for diffusion will be placed with a vapor-coat HDMS (hexamethyldisilazane) for 5 minutes at 115ºC, then an spin-coat 1 ml maP 1215 at 3000 rpm, during 30s. Dry for 1 minute at 110ºC.

The next step is to expose for 12s for the first mask *„Widerstand“*, and develop for roughly 30s in maD 532 MIF (metal ion free) , rinse and spin dry and a hardbake for 5 minutes at 110ºC.

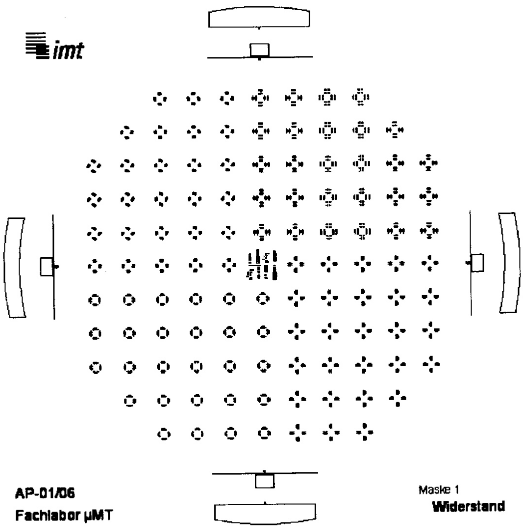

Figure 4 – Mask “Widerstand”

Using an O_2-plasma activation with Potency of 50W during 5 min. Etch in 1:2 diluted buffered HF (Hydrofluoric) for 6:45 min MIF. Then rinse away remaining acid, conductance rinser and again spin-dry. To finish this step an O_2-plasma ashing is done to remove all the photoresist from the etched wafer.

To start an Boron diffusion over the top surface a spin-coat with 500 μl Borofilm at 3000 rpm for 30s, then heat Borofilm to room temperature for at least 30 min and shake the Borofilm bottle well before filling the syringe, following to heat and diffuse at 1100ºC for 60 min. To remove the oxide the wafer was etched in a 40% HF solution for 4 min. MIF and then washed off remaining acid, conductance rinser and spin-dry. An application of themal oxide for insulation is necessary, during one hour at 1100ºC.

The structure photoresist is placed for contact holes, again using a vapor-coat HMDS in the same conditions as before. After this step, the wafer is exposed for 12 seconds, mask “*Viakontakt*”, developed for 30 sec. in maD 331, rinse and spin-dry, to finish this step is used an hardbake for 5 min at 110ºC. All the steps to form a structure oxide is repeated as before.

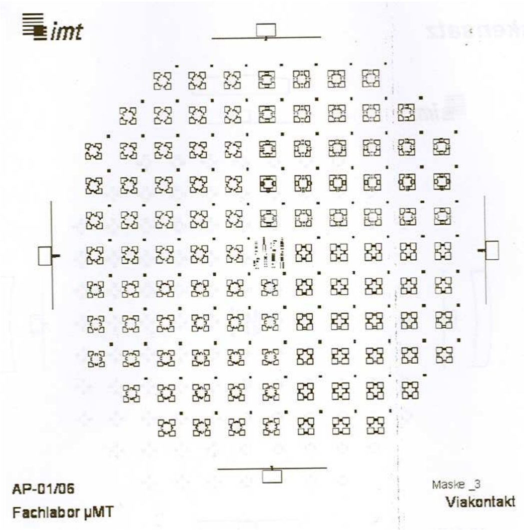

Figure 5 – Mask "Viakontakt**"**

An aluminum structure is placed also over the top surface using sputtering, with a potency of 400W and 300 seconds. One more photoresist structure is placed for conducting paths using the same steps and is exposed for 12 sec, mask "*Leiterbahn*". An O_2-plasma activation is done before etch the wafer in aluminum etching solution at 35ºC for 45-75 sec. (obs.: formation of bubbles is noted and not desirable, watching with water solve this problem).To analyze the veracity the resistance values must be measured and then an aluminum temper heat at 400ºC in damp H_2O-atmosphere (with bubbler) for 30 minutes.

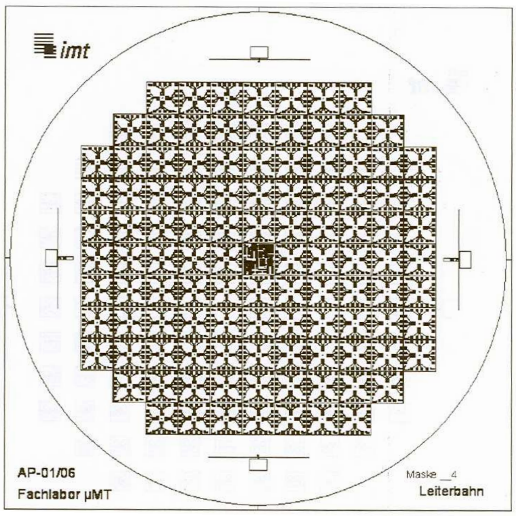

Figure 6 – Mask "Leiterbahn"

Now the procedures will be placed at the bottom surface, starting with application of PECVD-oxide first and PECVD-nitride for KOH-etching for 30 min at 300ºC. Next step is structure photoresist for etching grooves and pads, following the same steps using vapor-coat HMDS at both surfaces and spin coat 1 ml maP 1215 at 3000 rpm for 30 seconds and dry.

At the bottom side, expose for 12 seconds, mask "Aetzgrube", develop for roughly 35 seconds in maD 331, rinse , spin-dry and hardbake for 5 minutes at 110ºC. At the same surface, structure nitride and oxide (Barrel etcher), then etch in 1:2 diluted buffered HF for 6:30 minutes, conductance rinser and strip resist.

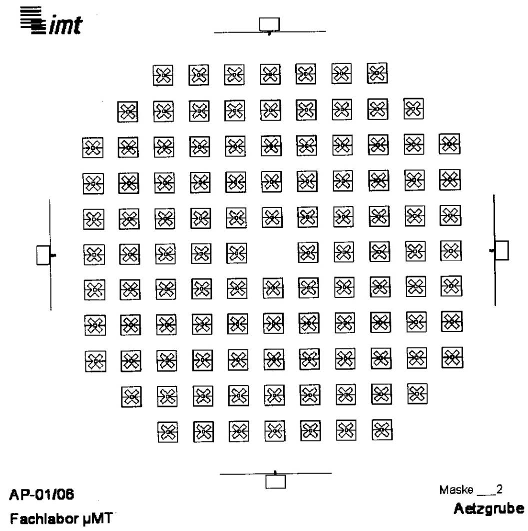

Figure 7 – Mask "Aetzgrube"

Measure wafer thickness is very important in this step to continue the process, this measure is done with stylus. After the measure, glue wafer to a glass wafer with wax. Lay aluminum foil on the hotplate and heat to 160℃, spread the wax on the glass wafer, press the wafer into the wax in a warm environment wrap the Teflon tape around the edge. Etch the wafer in 40% KOH at 70℃ for 2 hours. Again conductance rinser , spin-dry , determine etch rate measuring the thickness again. Further etch to a 150 μm membrane thickness.

The last step is conductance rinser, spin-dry , determine etch depth, saw and separate.

Results

The Micro Electro-Mechanical Sensor was successfully fabricated in the Clean Room.

Tests to analyze the functioning of the pressure sensor are being accomplished.

Discussion

The steps to fabricate the micro pressure sensor were totally followed and the result in the end was successful if you compare with others pressure sensors developed at the Force Sensor

Lab. To achieve a perfect resolution and precision of the functioning of the sensor, the final results will have to be read to compare with others pressure sensors.

Conclusion

During the development of this process, it was possible to acquire an ample knowledge about microtechnology process and mechatronics. The instruction of a tutor during all the process was also very important to the total comprehension.

The experience to operate and to leave inside an advanced laboratory of microtechnology was unique for my academic development.

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