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2007-Novel structures of a MEMS-based pressure sensor

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Since some years ago, when the first prototypes were developed, the number of silicon based microsensor applications has been progressively increasing. Piezoresistive pressure sensors represent the most mature microsystems technology and are used in a wide range of applications, even entering the home appliances field. As a consequence, the optimization of the fabrication technology has become an important issue because of the need to have more reliable processes with greater yield and lower costs.

The basic and distinct properties of silicon pressure sensors are batch processing, small size, high sensitivity and mechanical stability. They normally consist of a thin silicon diaphragm with four diffused piezoresistors in a closed Wheatstone bridge configuration. The performance of the sensor strongly depends on the geometry of the diaphragm, i.e. its area and thickness, and the position of the piezoresistors. However, it needs to be improved from a point of view of low stress strength, offset drift with temperature, complicated electric circuits to amplify a feeble signal and so on.

This paper describes two different designs of the MEMS-based pressure sensor. In the first design, a pitch-based carbon fiber is employed as a piezoresistor instead of a doped silicon. In the second design, an array of micro-switches concept is firstly introduced for MEMS pressure sensors. Those sensors proposed in this research provide several advantages in comparing with conventional MEMS pressure sensors. For the fabrication of the pressure sensors, conventional micromachining technologies such as photolithography, anisotropic wet etching, sputtering and anodic bonding are used. Optimization is conducted using a finite element method. Basic characteristics of the fabricated pressure sensors are successfully evaluated and the validity of the proposed pressure sensors are also verified. Details for the novel structures of a MEMS-based pressure sensor with pitch-based carbon fiber and micro-switch array will be presented at the conference.

Key words : **MEMS, Pressure sensor, piezoresistor, diaphragm, carbon fiber, micro-switched array**

Novel structures of a MEMS-based pressure sensor

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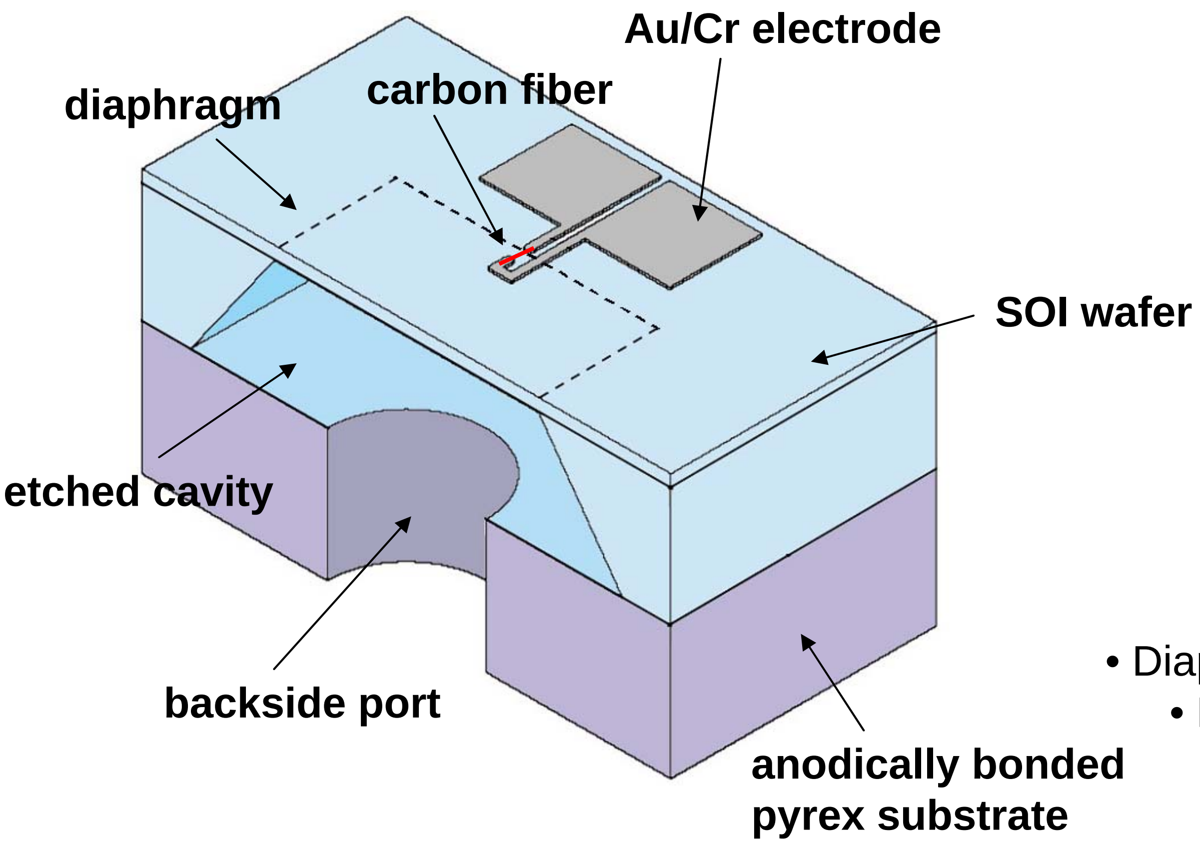
Micromachined Pressure sensors

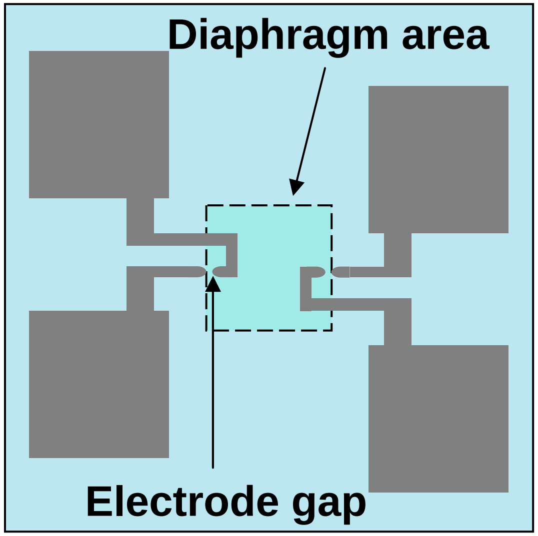
	Disadvantages	Advantages
Piezoresistive & Capacitive pressure sensor	• Temperature sensitivity • High thermal noise • Complicated electric circuits	• Low production costs • High sensitivity • Low hysteresis • Miniaturization

We propose novel structures of a MEMS-based pressure sensor

Design 1	**Pressure sensor using a pitch-based carbon fiber**	• Simple fabrication • Simple circuit interface • Low temperature effect
Design 2	**Pressure sensor using an array of micro-switch**	

Design of a pressure sensor using a pitch-based carbon fiber

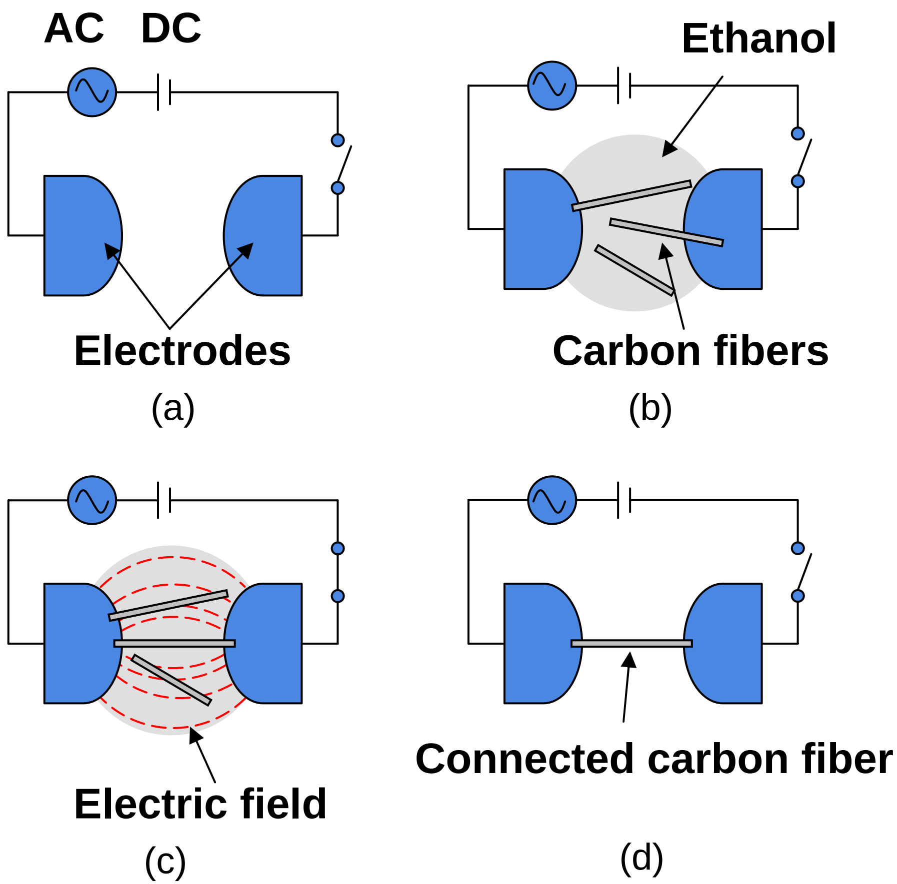


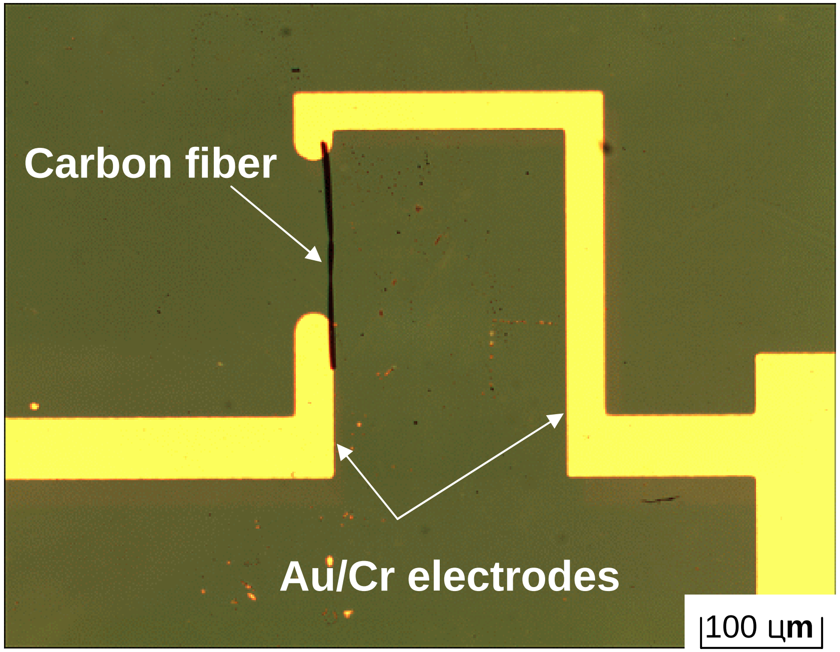


Specifications

- Sensor size : 4.0 × 4.0 mm^2
- Diaphragm thickness : 21 μm, 3 μm
- Diaphragm size : 1.5 × 1.5 mm^2
- Electrode gap : 150 μm
- Electrode thickness : 0.1 μm

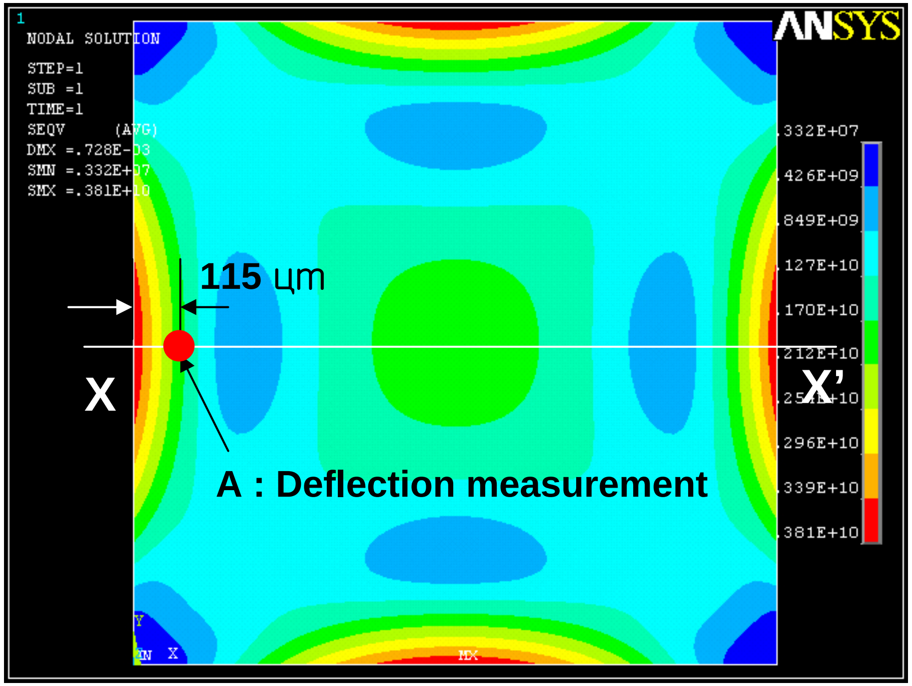
Dielectrophoretic forces : polarizability of a carbon fibers surrounded by non-uniform electric field

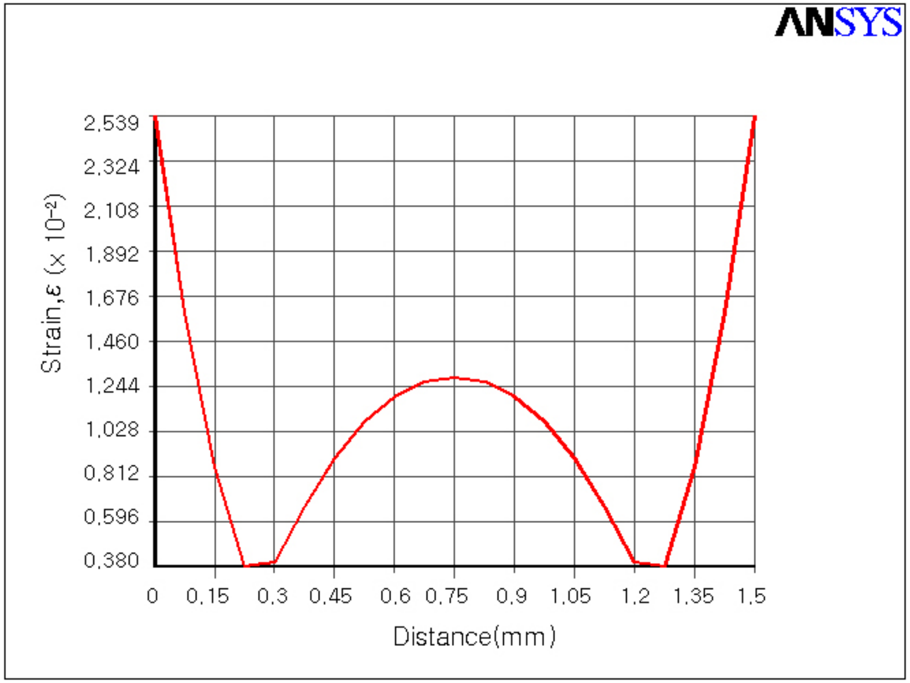




A carbon fiber assembled on between two electrodes using dielectrophoresis
D = 7.22 цm, L = 203 цm

A simulation result of diaphragm stress with 3μm thickness (1atm)

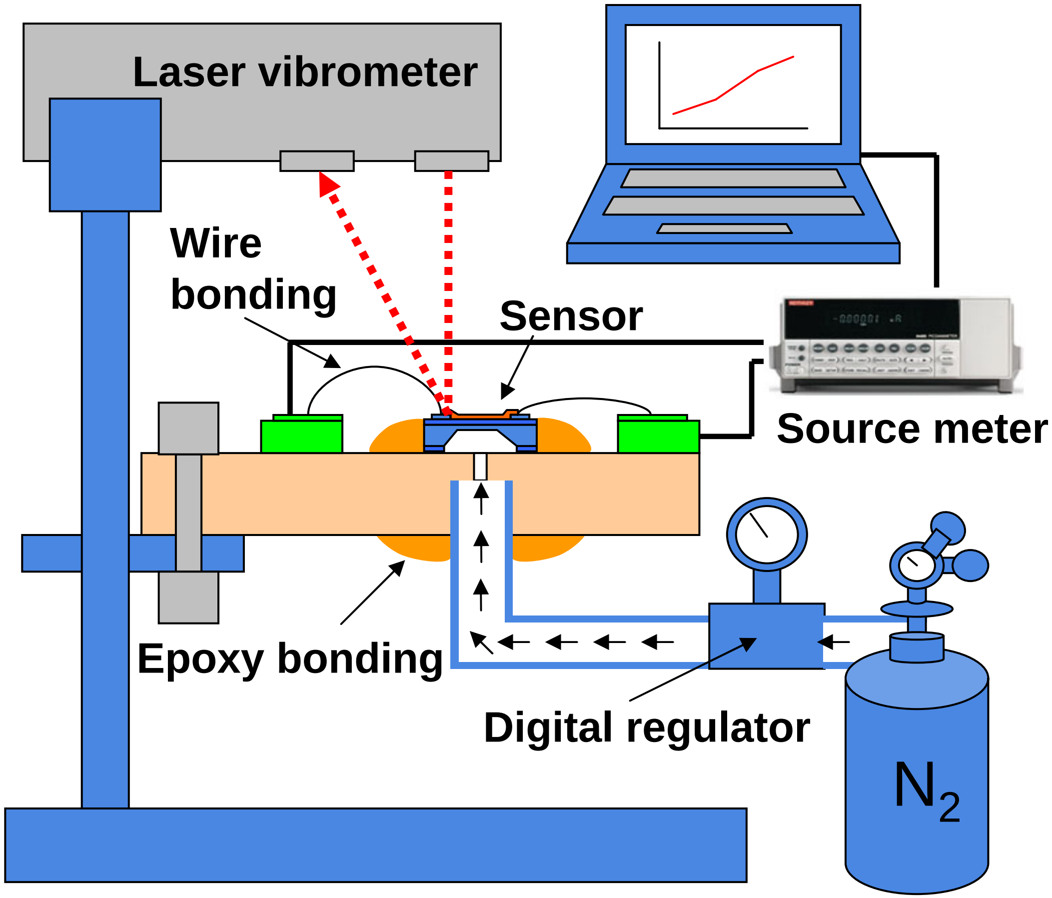


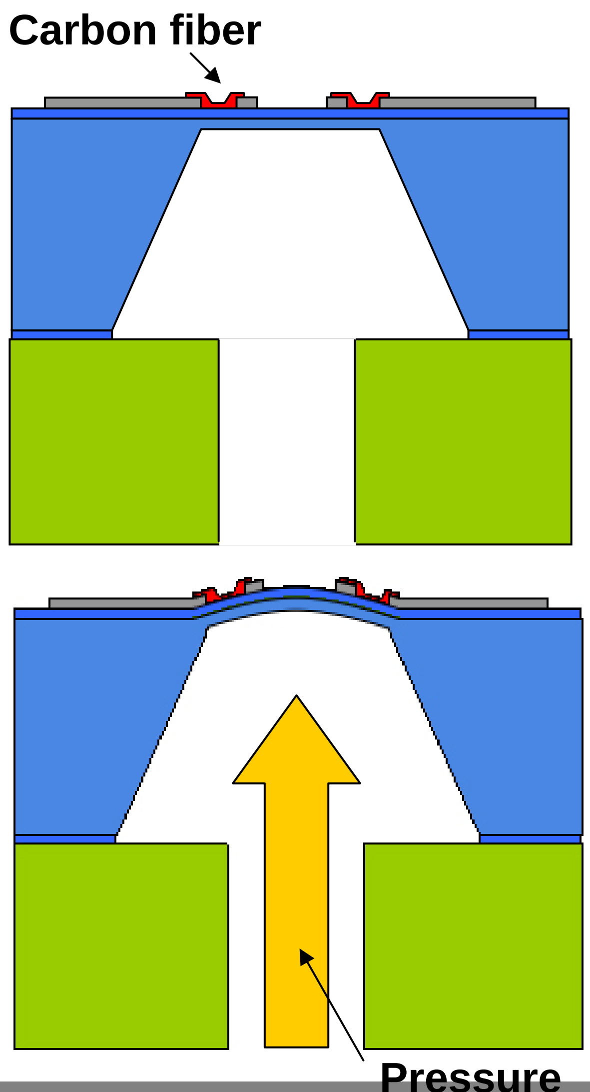


Simulation result of diaphragm stress using ANSYS.

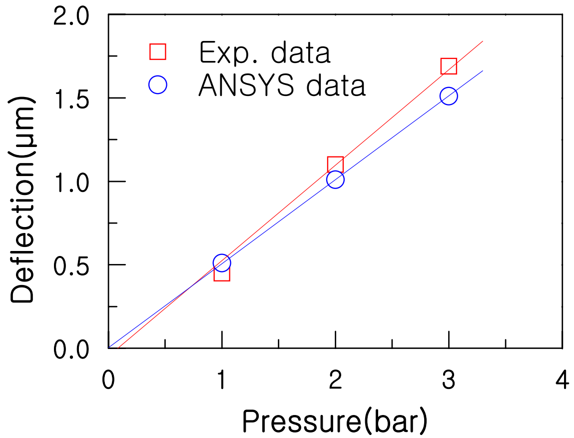
Simulation result of diaphragm strain at X-X' section

A measurement setup

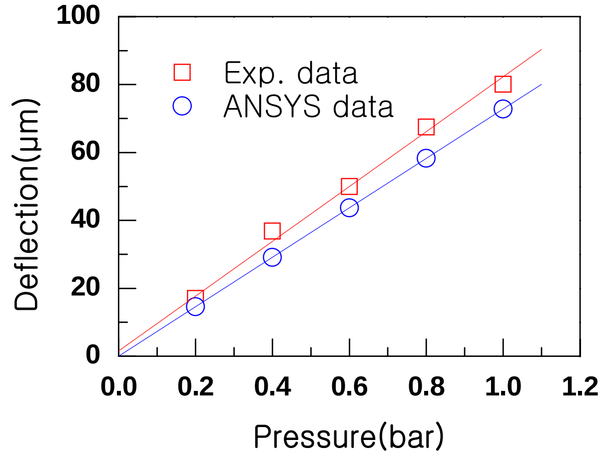




Diaphragm deflection as a function of pressure



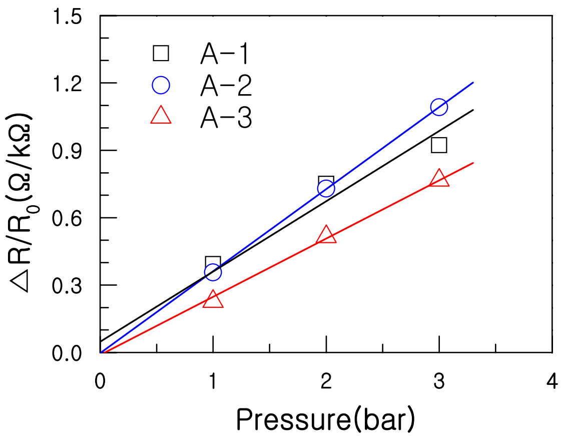
(a)



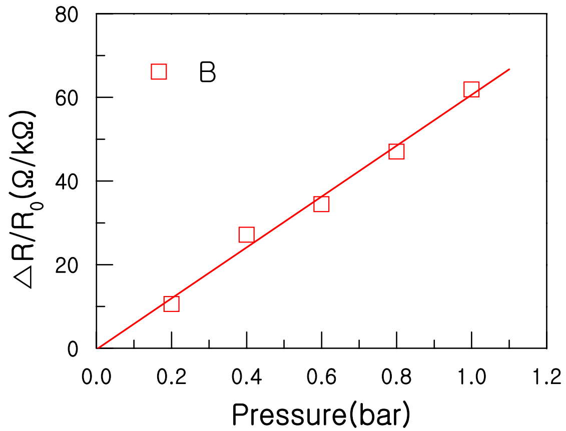
(b)

Diaphragm thickness
(a) : 21 цm
(b) : 3 цm

Change in resistance of a carbon fiber according to applied pressure



(a)

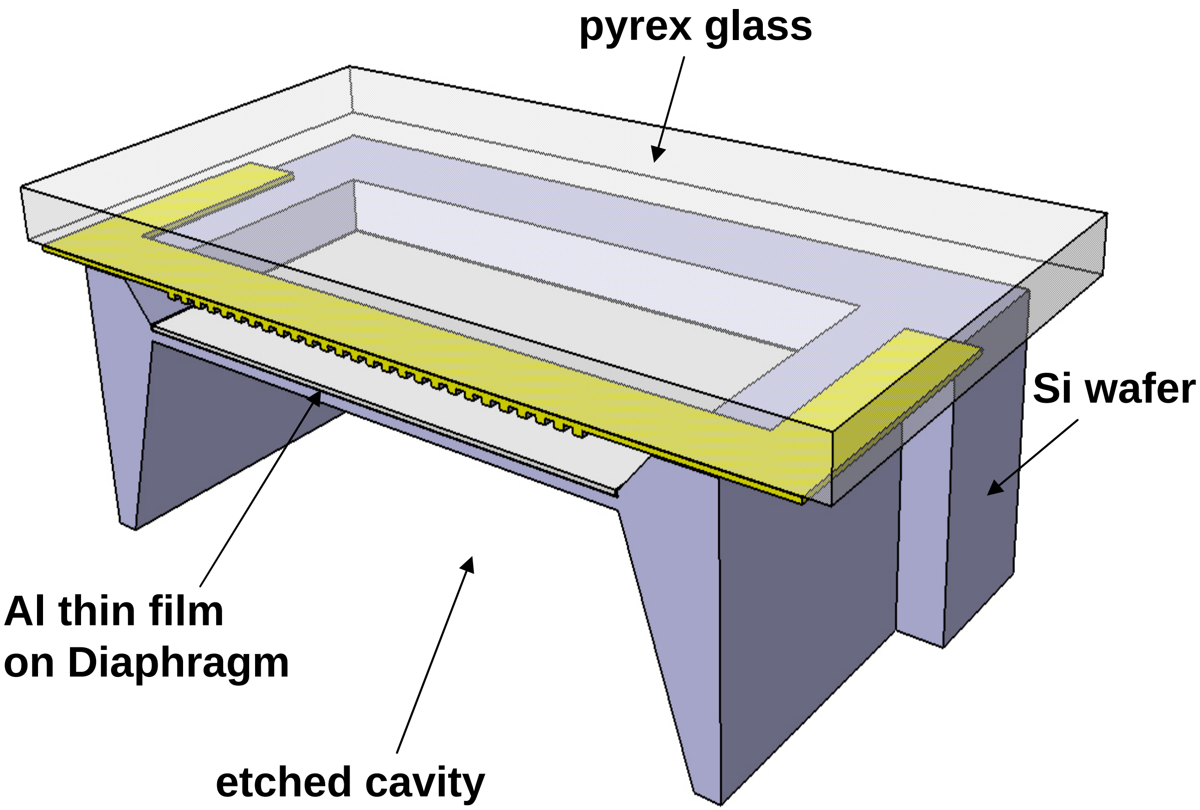


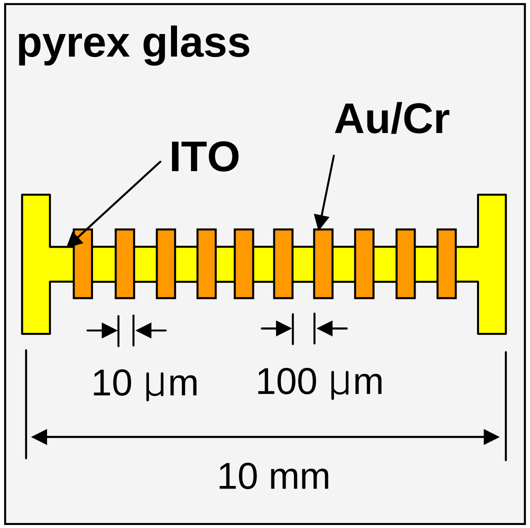
(b)

Diaphragm thickness
(a) : 21 цm
(b) : 3 цm

A MEMS pressure sensor using an array of micro-switch

Design of a pressure sensor using an array of micro-switch



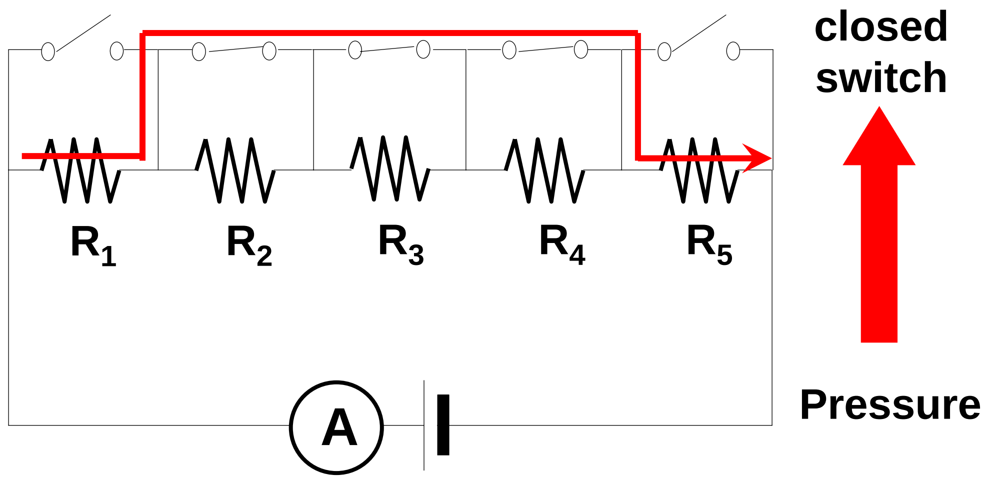


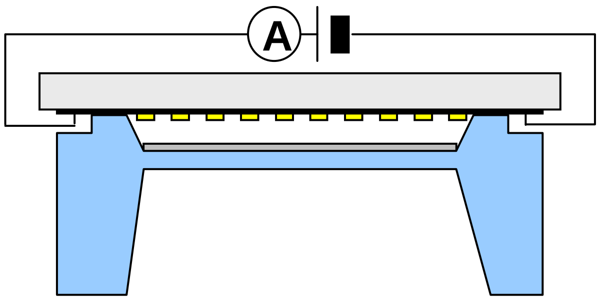
Specifications

- Sensor size : 11 × 11 mm^2
- Diaphragm thickness : 40 μm
- Diaphragm size : 8 × 8 mm^2
- Electrode gap : 80 μm
- Au/Cr thickness : 0.11 μm
- Al thin film thickness : 0.1 μm
- ITO resistance : 4 ~ 4.5 KΩ

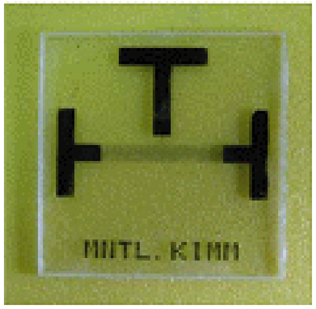
A MEMS pressure sensor using an array of micro-switch

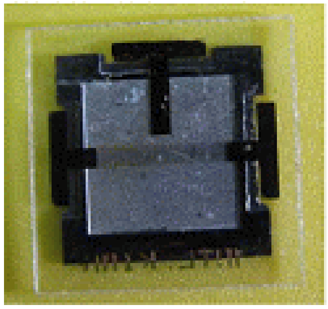
Operation principle of the pressure sensor

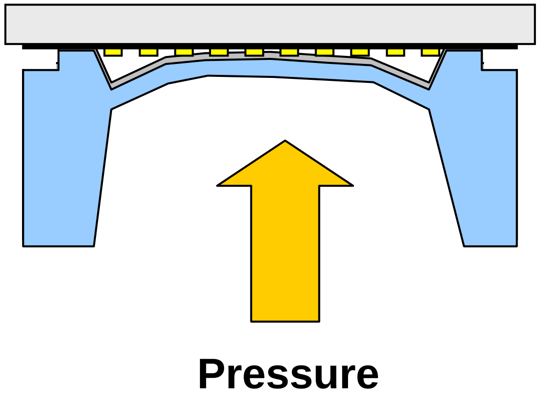




Optical images of the fabricated pressure sensor based on an array of micro switch







A MEMS pressure sensor using an array of micro-switch

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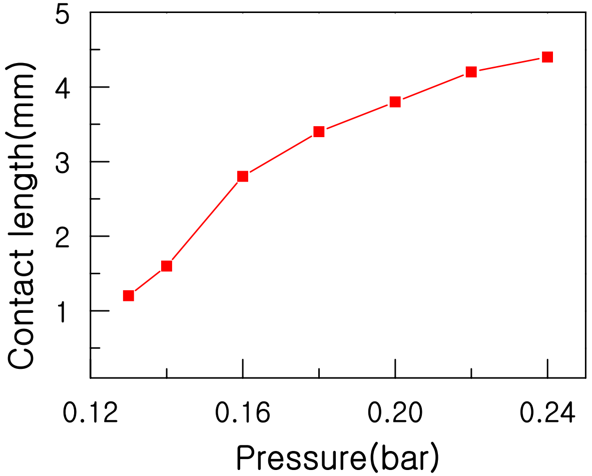
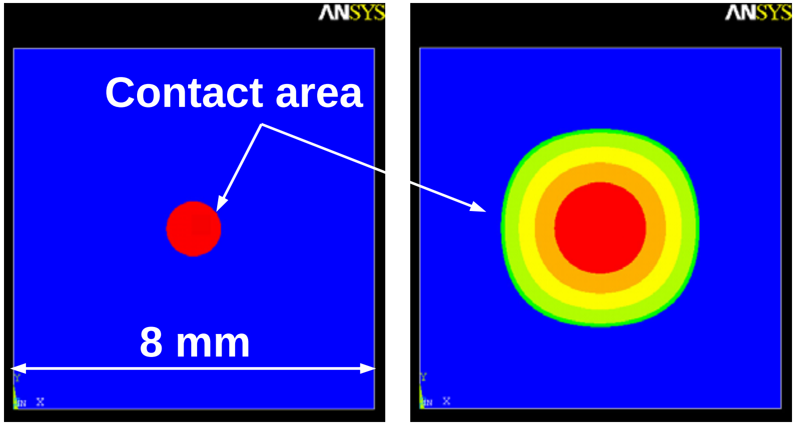
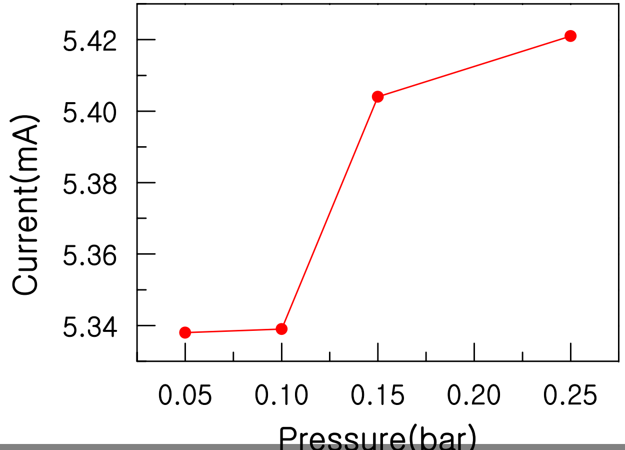
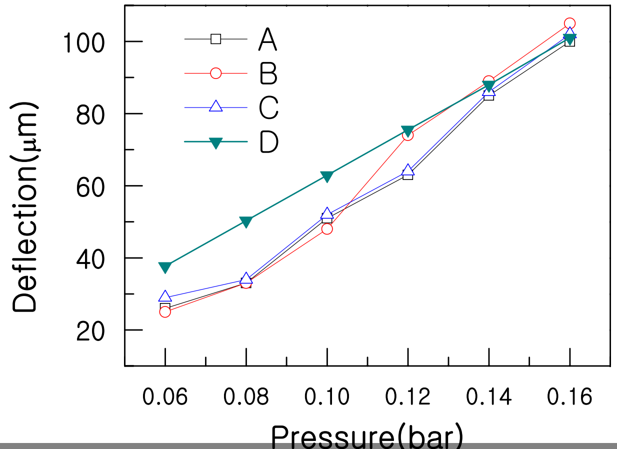
Simulation results of contact area





Output current and Si diaphragm deflection as a function of pressure





A : Exp. data 1
B : Exp. data 2
C : Exp. data 3
D : FEM data