Performance Analysis of Hygroscopic Swelling in MEMS Sensor using Different Polymers Materials

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Abstract— **MEMS is a comparatively new research field, which is more secured with silicon treating as compared to all of the initial packaging technologies. Today, hygroscopic swelling is one the most important parameter in packaging MEMS devices. In microelectronic circuits, MEMS and other electronic devices are often molded with different Mold Compound (MC) to guard the devices and their interconnection with the board. The polymers are subject to moisture absorption and hygroscopic swelling. So, in this paper hygroscopic swelling in the mold compound is reduced by using different materials like Polyurethane, Polyimide and PTFE. Here, the result is analyzed at 60% humidity and 140 mol/m^3 saturation concentration. Also, the initial moisture concentration after molding is set to 40 mol/m^3 and temperature is taken at 25 deg C.**

Keywords— MEMS, Hygroscopic, Mold compound , Moisture.

I. INTRODUCTION

MEMS could be a relatively new field that is tied hence intimately with semiconductor process that most of the main bundling advances can apparently use "off-the-rack" bundling "acquired" from the semiconductor gadgets field. Bundling of hardware circuits is that the science associate in creating specialty of making interconnections and a worthy in operation surroundings for prevalently electrical (and inside the instance of MEMS, electromechanical) circuits to technique or potentially store information. Bundling shows itself in novel and particular manifestations that cunningly accommodate and fulfil what give off an impression of being proportionally select application needs and imperatives presented by the laws of nature and along these lines the properties of materials and procedures. All applications might be summed up in 3 terms: esteem, execution and responsibleness. Bundling will range from the benefactor to midrange frameworks to the superior/unwavering quality applications. It ought to be noticed that no sharp limits exist between the classes, exclusively a slow move from enhancement for parameters that administration execution and cause the incentive to expand. Up and down, the responsibleness ought to try and be thought of. The parameter that is think about most nowdays is hygroscopy swelling in bundling MEMS gadgets.

Hygroscopy is that the advancement of drawing in and holding water atoms from the incorporating air, that is some of the time at customary or temperature. This is frequently accomplished through either retention or surface absorption with the take up substance changing into physically adjusted fairly. This may be an ascent in volume, bubbling reason, consistency, or option physical trademark or property of the substance, as water particles will end up suspended between the substance's atoms inside the strategy.

A greatly abnormal state of dimensional and misshaping dependability is required for MEMS sensors gadgets regardless of outside natural conditions. Nonetheless, wetness that infiltrates into the bundling will cause a ruinous disappointment all through the get together technique and task, such as "popcorning" or delamination. In open-pit plastic bundles, the bundling material is a considerable measure of in danger of wet assimilation on account of the nonattendance of trim compound embodiment. Besides, the glues are alluded to as a great deal of deliquescent than trim mixes with a considerable measure of exceptional wet ingestion and hygroswelling. amid this paper entirely unexpected buildup materials are thought about for MEMS detecting component.

II. MODEL DEFINITION

Integration in microelectronic circuits, MEMS and other electronic devices are often molded with different Mold Compound (MC) to guard the devices and their interconnection with the board. The polymers are subject to moisture adsorption and hygroscopic swelling, which can cause delamination between the Mold Compound and the board or to incorrect behavior of MEMS components. This paper studies how the moisture adsorption of different Mold Compound affects the response of a MEMS pressure sensor for a period of one year.

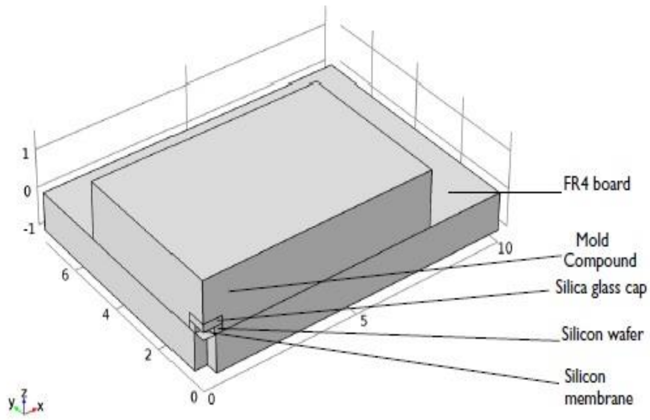

Figure 1: Component Geometry

It is sufficient to model a quarter of the whole structure due to the symmetry (Figure 1). The geometry is composed of:

• A FR4 board, on which the die is glued.

• The pressure sensor die made of: -

A silicon component with a processed membrane. The membrane is modeled with a shell interface. The strain on the membrane surface is used to measure the pressure.

- A silica glass capping

• A Mold Compound that covers the die and a large part of the board. When external pressure is applied on the bottom face of the membrane, the membrane deforms, and the strain is measured by means of a Wheatstone bridge made of piezoresistors.

Table 1: Parameters for Device Design

Name	Expression	Description
L	20[mm]	Length of the device
W	15 [mm]	Width of device
L_MC	15[mm]	Length of mold compound
W_MC	10[mm]	Width of mold compound
L_die	1.2[mm]	Side length of sensor
L_memb	0.7[mm]	Side length of membrane
L_hole	0.8 [mm]	Side length of hole in FR4
T_FR4	1[mm]	Thickness of FR4
T_Si	0.2 [mm]	Thickness of silicon
T_memb	0.02[mm]	Thickness of membrane
T_glass	0.2[mm]	Thickness of glass wafer
T_MC	1.5[mm]	Thickness of Mold

The initial moisture concentration after molding is set to 40 mol/m^3. This value can be also taken as reference for hygroscopic swelling because all the stresses are assumed relaxed just after molding. In order to avoid problems that can be caused by the discontinuity of concentration at initial state, the concentration boundary condition is applied smoothly, and a boundary layer type mesh is used near those boundaries.

The response of a MEMS pressure sensor is computed for a period of one year.

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As hygroscopic swelling induces a one-way coupling between concentration and mechanics, the concentration is calculated in a first time-dependent study, and then the structural domains are computed in a stationary study. This sequential approach reduces the computation time compared to a single solution including all physical interfaces.

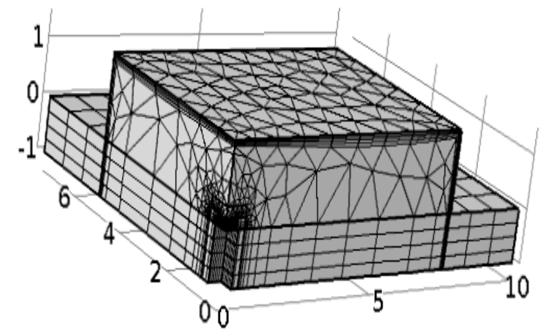

Figure 2: Meshing

III. RESULTS

An exceptionally high level of dimensional and distortion stability is essential for MEMS sensors devices irrespective of external environmental conditions. To reduce hygroscopic swelling in the mold compound by using different materials is studied and compared. They are Polyurethane, Polyimide and PTFE. They result is analyzed at 60% humidity, the saturation concentration is taken as140 mol/m^3.The initial moisture concentration after molding is set to 40 mol/m^3 and tempreture is taken at 25 deg C.

Polyurethane Mold Compound

Polyurethane is a type of polymers which can be used as mold compound for mems devices.

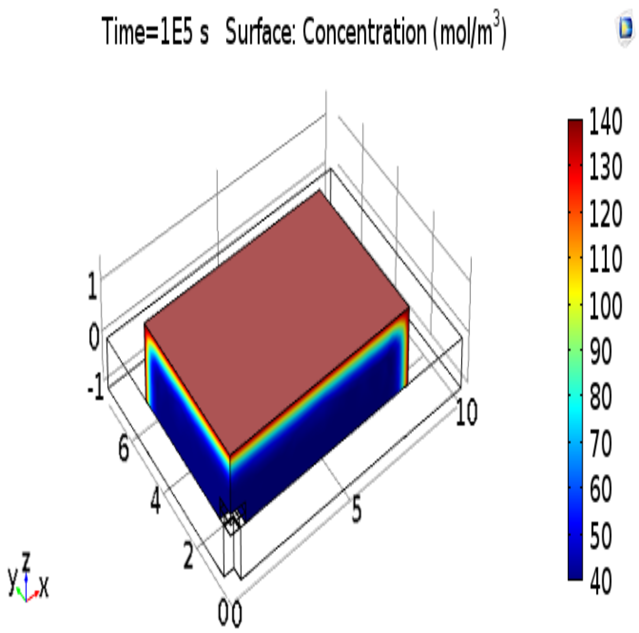

Figure 3: moisture diffuses after 2 days

The moisture diffuses progressively in the Polyurethane. After 2 days, the moisture has already reached partially the top face of the die.

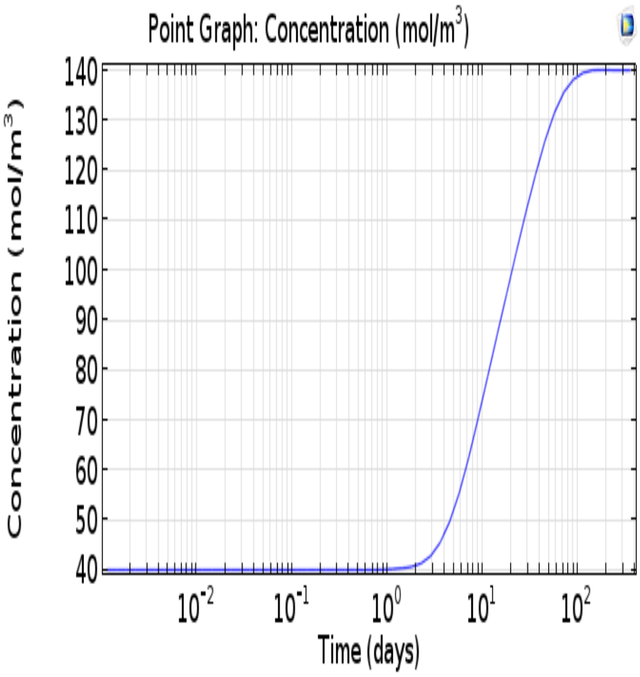

Figure 4: Moisture concentration at die location over time for Polyurethane

The concentration at the die location starts to increase after 2 days until approximately 100 days.

This is confirmed by the mass uptake shown in Figure 5, where the maximum value is reached after the same time.

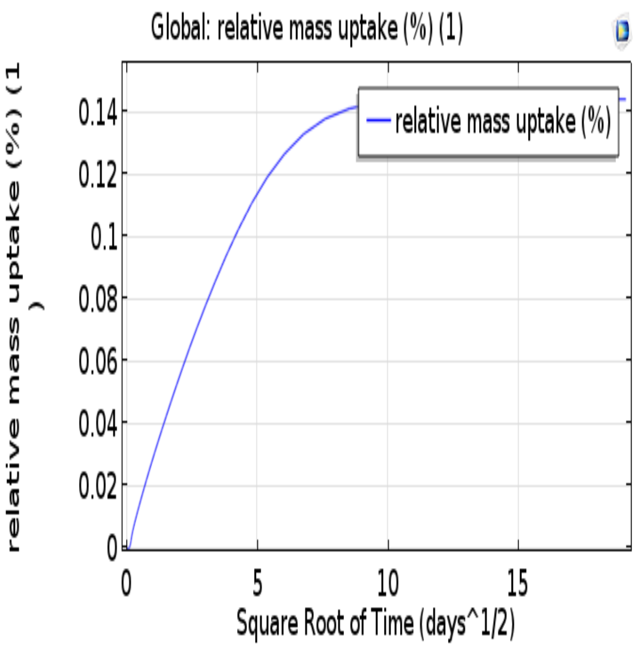

Figure 5: Total mass uptake in the Polyurethane

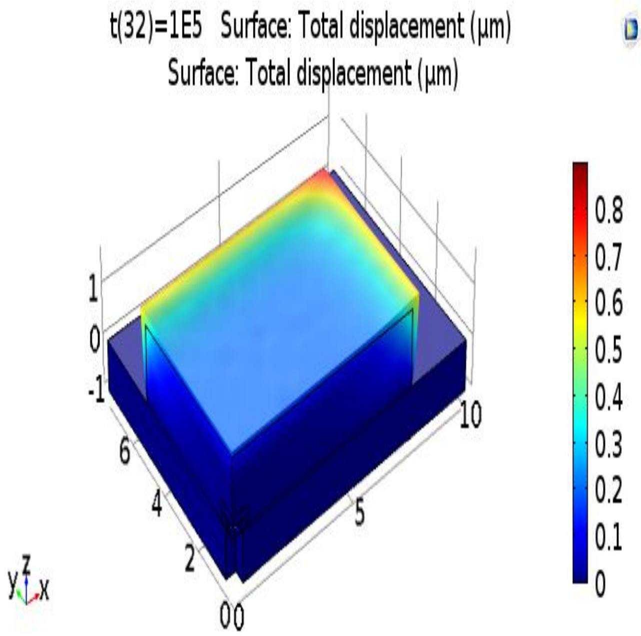

Figure 6: Displacement after 2 days in Polyurethane

The displacement after 2days is shown as 0.8 um. The progressive moisture diffusion is also noticed on displacement plots after hygroscopic swelling calculation: the Polyurethane swells only on its boundaries during the first days. (Figure 6), and it swells everywhere after one year (Figure 7). During the first time, the expansion on the exterior boundaries implies a stretching on the membrane and thus an increase of the measured strain. Then, the expansion of the center implies compression on the die and a decrease of the strain along the axes.

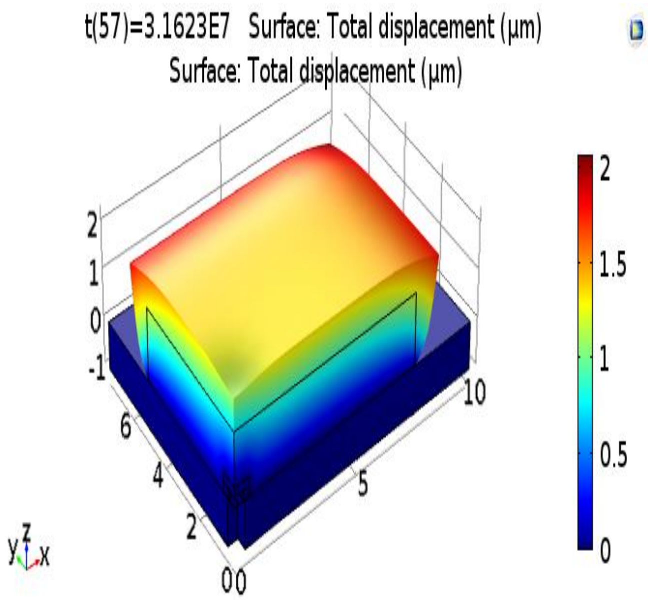

Figure 7: Displacement after 1 year in Polyurethane

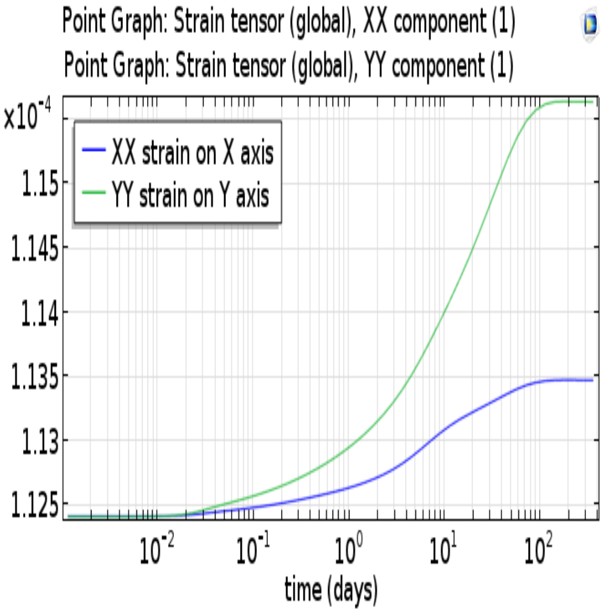

Figure 8: Evolution of measured strain on membrane axes Polyurethane

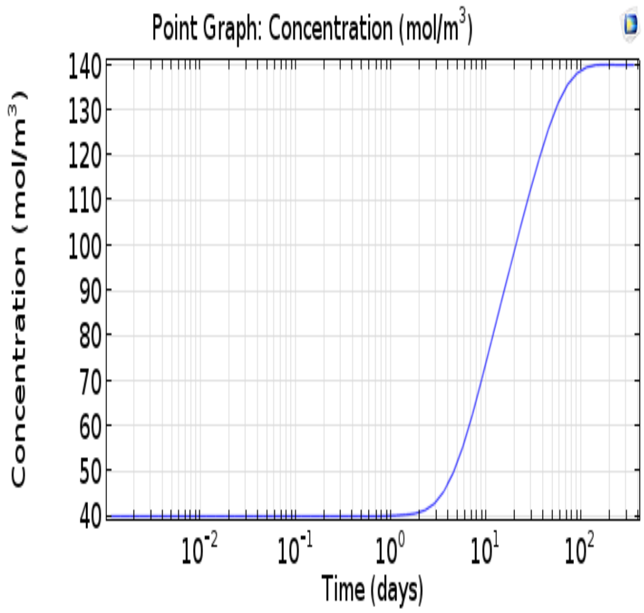

Figure 10: Moisture concentration at die location over time for Polyimide

PolyImide Mold Compound

Polyimide is a type of polymers which can be used as mold compound for mems devices.

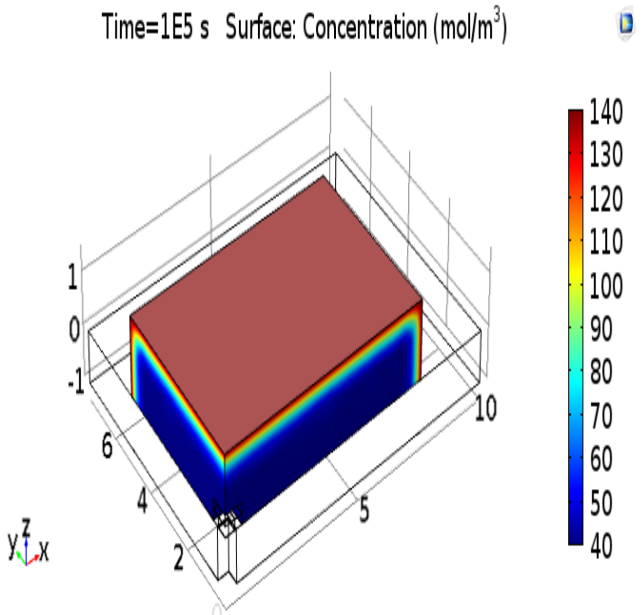

Figure 19 moisture diffuses after 2 days Polyimide

The moisture diffuses progressively in the Polyimide. After 2 days, the moisture has already reached partially the top face of the die.

The concentration at the die location starts to increase after 2 days until approximately 100 days.

This is confirmed by the mass uptake shown in Figure 10, where the maximum value is reached after the same time.

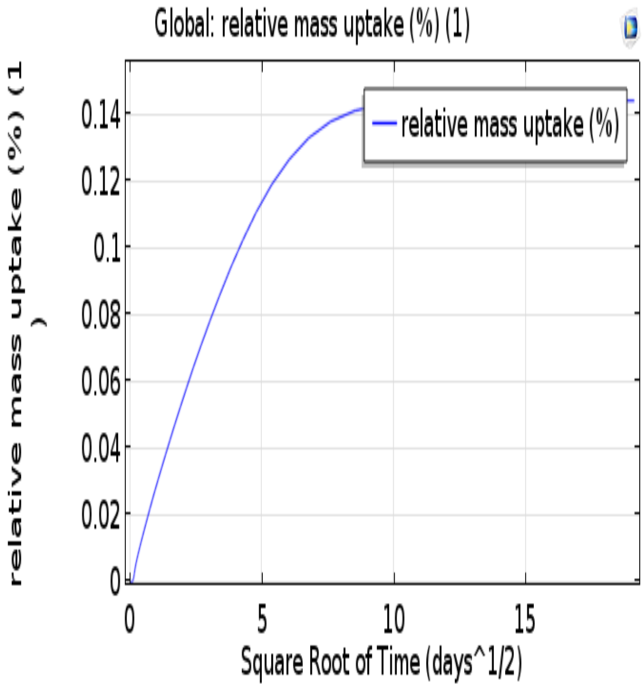

Figure 11: Total mass uptake in the Polyimide

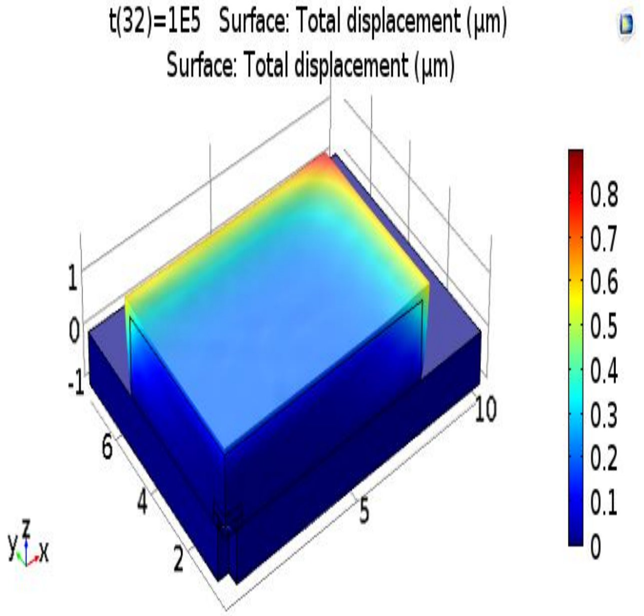

Figure 12: Displacement after 2 days in Polyimide

The displacement after 2days is shown as 0.8 um. The progressive moisture diffusion is also noticed on displacement plots after hygroscopic swelling calculation: the Polyimide swells only on its boundaries during the first days. (Figure 12), and it swells everywhere after one year (Figure 13). During the first time, the expansion on the exterior boundaries implies a stretching on the membrane and thus an increase of the measured strain. Then, the expansion of the center implies compression on the die and a decrease of the strain along the axes, Figure 14.

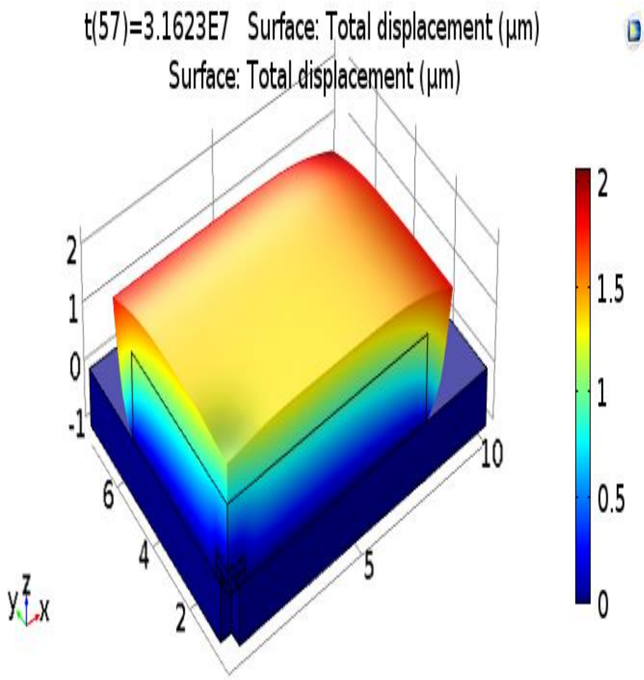

Figure 13: Displacement after 1 year in Polyimide

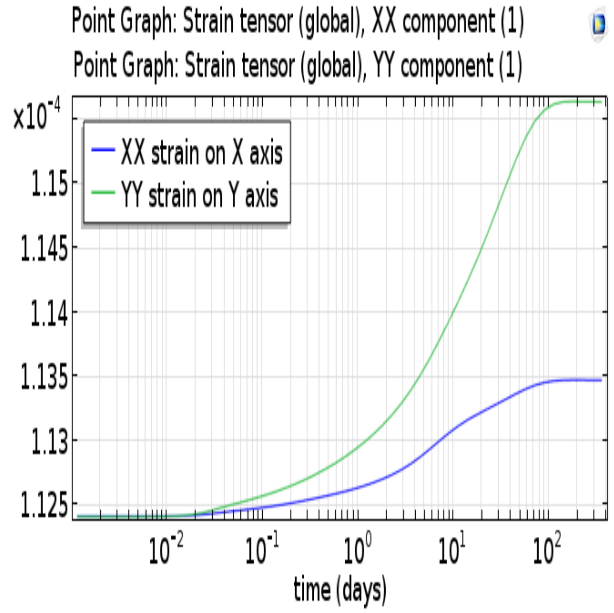

Figure 14: Evolution of measured strain on membrane axes Polyimide

PTFE Mold Compound

PTFE is a type of polymers which can be used as mold compound for mems devices.

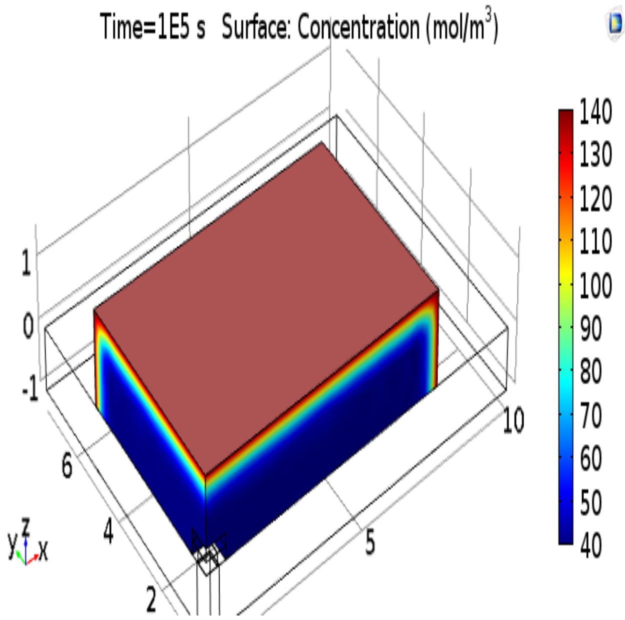

Figure 15: Moisture Diffuses after 2 days PTFE

The moisture diffuses progressively in the PTFE. After 2 days, the moisture has already reached partially the top face of the die.

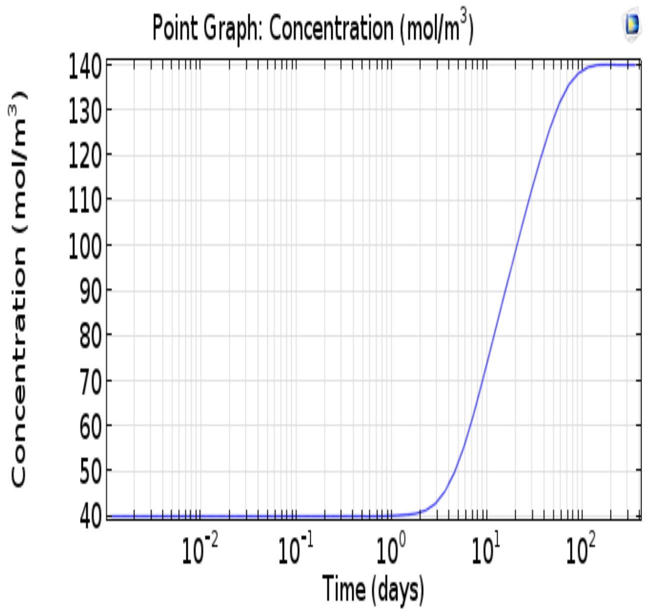

Figure 16: Moisture concentration at die location over time for PTFE

The concentration at the die location starts to increase after 2 days until approximately 100 days.

This is confirmed by the mass uptake shown in Figure 17, where the maximum value is reached after the same time.

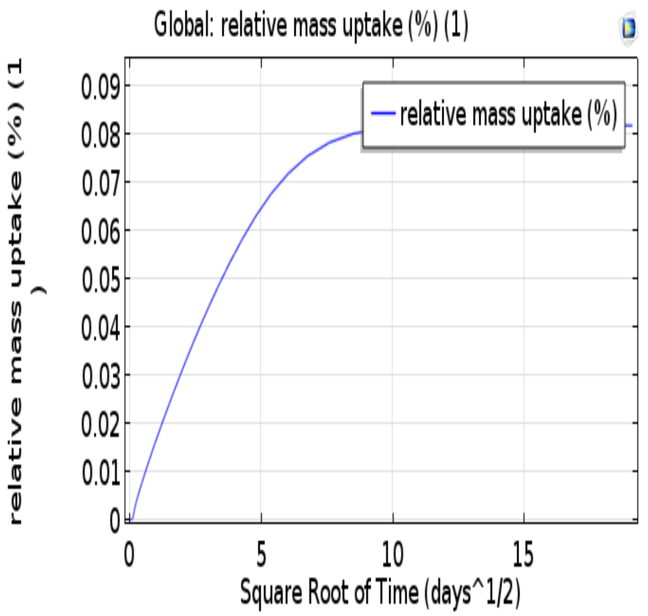

Figure 17: Total mass uptake in the PTFE

Mass uptake is less in PTFE as compared to other polymers and epoxy.

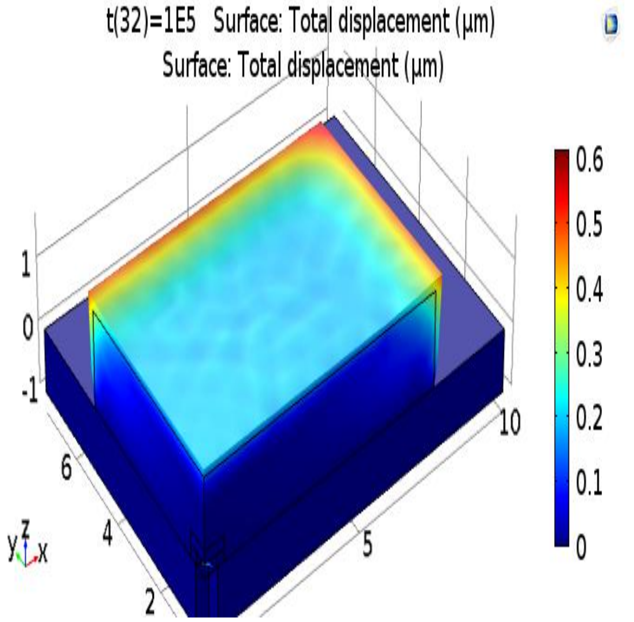

Figure 18: Displacement after 2 days in PTFE

The displacement after 2days is shown as 0.6 um which is less than other polymers. The progressive moisture diffusion is also noticed on displacement plots after hygroscopic swelling calculation: the PTFE swells only on its boundaries during the first days. It swells everywhere after one year. During the first time, the expansion on the exterior boundaries implies a stretching on the membrane and thus an increase of the measured strain. Then, the expansion of the center implies compression on the die and a decrease of the strain along the axes.

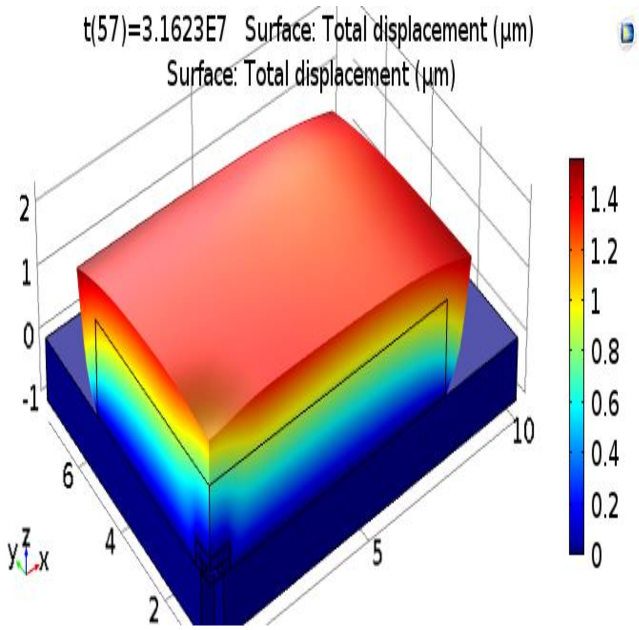

Figure 19: Displacement after 1 year in PTFE

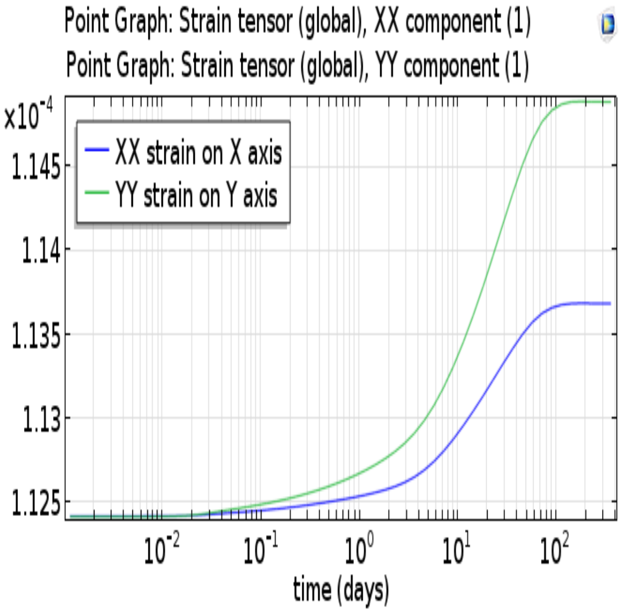

Figure 20: Evolution of measured strain on membrane axes PTFE

PTFE is better mold then other polymers which are compared in this paper.

IV. CONCLUSION

The moisture adsorption and hygroscopic swelling have significant effect on the sensor sensibility, which have to be taken in account during the measurements, or when designing the sensor. The displacement after 2days is shown as 0.6 um which is less than other polymers. The progressive moisture diffusion is also noticed on displacement plots after hygroscopic swelling calculation: the PTFE swells only on its boundaries during the first days. It swells everywhere after one year. During the first time, the expansion on the exterior boundaries implies a stretching on the membrane and thus an increase of the measured strain. Then, the expansion of the center implies compression on the die and a decrease of the strain along the axes.

V. REFERENCES

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