

Comparaison between PDMS and PMMA for MEMS Applications

H. Bourbaba*, C. Benachaiba* and M. Bouanini*

*University of Bechar, LPDS Laboratory, Algeria
belhouaria@yahoo.fr

ABSTRACT

The elastomer applications for MEMS are recent technology, in this article we modeling PDMS membrane and PMMA membrane subjected to pressure force for microvalve applications. The behaviour of the membrane is described by a Neo-Hookean model. This hyperelastic model is widely used for a such material, it can provide a better understanding of deformation mechanisms.

Keywords: membrane, MEMS, elastometer, PDMS, PMMA, hyperelastic

1 INTRODUCTION

The list of the polymers is long, each they present very interesting mechanical advantages, in this article we interest more especially to two polymers extensively used in the MEMS, and more especially in microfluidique. The PDMS (PolyDiMethylSiloxane) and the PMMA (Polymethacrylate of methyl). The use of these materials, as the PDMS in micro technologies has been initiated by the group of Georges Whitesides[1] then because of the numerous qualities of this polymer, it became widespread for the micro fluidics applications.

The use of the PDMS is often a question of rapid prototyping[2-3]. In particular the PDMS is very simple to manipulate and permits to retort perfectly by milling of the micrometric motives. In addition to the simplicity of manipulation, the PDMS has the following properties: it is a hyperelastic polymer, it can undergo very big distortions therefore without deteriorating [4].

It is biocompatible and non porous to the liquids. The PDMS is the main support for the manufacture of fluidic microsystems.

The PDMS technology present however some inconveniences linked to the porosity of the material to its weak chemical resistance opposite the organic solvents in particular.

The PDMS used in our work is sylgrad 184[5], it is the standard material for the applications micro fluidics.

In spite of the advantages presented by the use of the PDMS in micro fluidics, a certain number of materials plastic are associated, have been used in answer to the evoked previously difficulties. It is the case of the PMMA. This polymer is spilled enough in MEMS technology, different production methods can be used for the realization of the micro fluidics devices. The composites studied

PMMA reinforced to the shock by particles of elastomer of polybutadiène [6].

In this work we interest to investigate the mechanical behavior of a hyperelastic membrane subject to pressures could drag some large deformation. The inflation of this membrane can be used to push some fluids by very high pressure, will use a Neo-Hookean model to simulate the mechanical behavior of the PDMS and PMMA material (The model is implemented in the software to finite element COMSOL). We present the numeric conditions (the effect of the step, thickness, maillage) to 'd to optimize the dimensionality of the membrane and to compare between the two materials at equal pressure. This modelling permits to establish the relations between the geometric features of the micro fluidics systems and the pressure applied on the membrane, and to compare between the materials in view the deformation amplitude.

2 MODELLING

2.1 Hyperelastic Model

A hyperelastic material is incompressible present a big deformation, the stress-strain relationship derives from a strain energy density function [7], in the Neo-Hookean model the strain energy density function, W expressed as:

$$W = \frac{1}{2}G(I_1 - 3) + \frac{1}{2}K(J - 1)^2 \quad (1)$$

Where:

I_1 is the strain invariant: $I_1 = \text{tr}C$

$J = \det(F)$

F is the deformation tensor.

C is Cauchy -Green tensor: $C = F^T F$

I is the second-order unit tensor.

E is the Green strain tensor: $E = \frac{1}{2}(C - I)$

The second Piola-Kirchhoff stress tensor can be expressed as

$$S = \frac{\partial W}{\partial E} \quad (2)$$

The Cauchy stress tensor can be expressed as [8] :

$$\sigma = \frac{1}{J} F S F^T \quad (3)$$

The shear modulus G and the bulk modulus K of the hyper elastic material are defined by the following relations:

$$G = \frac{E}{2(1 + \nu)} \quad (4)$$

$$K = \frac{E}{3(1 - 2\nu)} \quad (5)$$

Where E is Young's modulus and ν is t Poisson's ratio.

2.2 Numerical Simulation

The membrane dimension is: $800\mu \times 800\mu \times 20\mu$ loaded by pressure tension at center of membrane in z-direction, the fig. 1 the boundary conditions used in this simulation (for a quart of membrane) are shown in the fig. 1

The table 1 presents the elastic parameters of the PDMS and PMMA at 25°C.

Elastic parameters	PDMS	PMMA
$E(\text{MPa})$	4	2565
ν	0.48	0.32

Table 1: PDMS and PMMA parameters

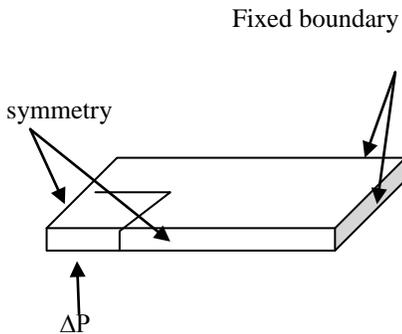


Figure1 : the boundary conditions for a quart of membrane

3 RESULT AND DISCUSION

The deformation of the PDMS membrane due to the applied load. Using the code COMSOL, the Neo-Hookean model is used to simulate the deformation. The vertical displacement on the surface of the PDMS membrane is shown in Figure 2, where the maximum vertical displacement of PDMS membrane under $P=10\text{KPa}$ is $79.12\mu\text{m}$.

In the same conditions the PMMA maximum vertical displacement is $1.67 \times 10^{-1} \mu\text{m}$ (Figure 3).

Figure 4 and 5 shows that maximum vertical displacement increase with increasing applied load. So we compared between the tow results we conclude that the PDMS is better then PMMA for microfluidics applications, where we need a large deformation with a small applied load. but we note that the ratio between deformation and the thickness do not pass 5 for do not destroyed the membrane .

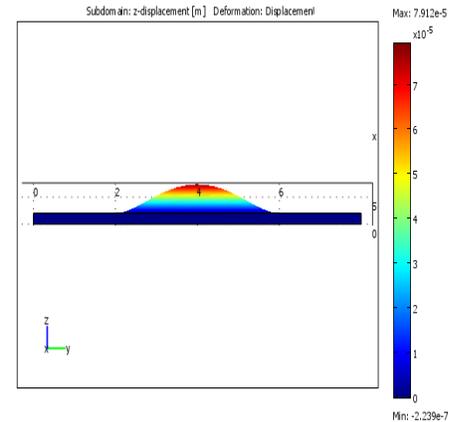


Figure 2 : the PDMS membrane deformation under the action $P=10\text{KPa}$

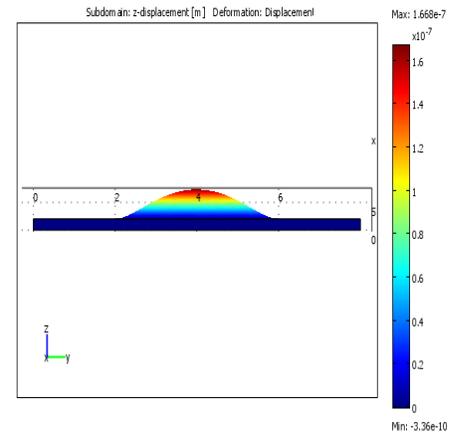


Figure 3 : the PMMA membrane deformation under the action $P=10\text{KPa}$

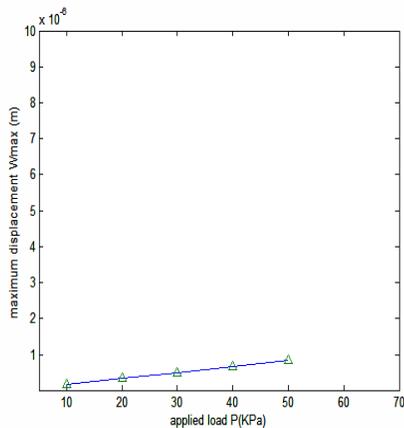


Figure 4 :Maximum displacement of the PMMA membrane under different loads

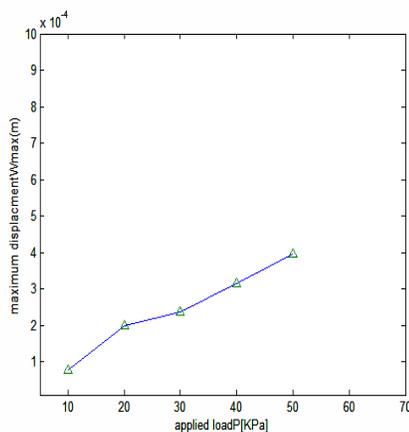


Figure 4 :Maximum displacement of the PDMS membrane under different loads

REFERENCES

- [1] Younan Xia and George M. Whitesides. "Soft Lithography," *Angew Chem.Int. Ed.*, 37 :550–575, 1998.
- [2] C.H. Wang, G.B. Lee, "Biosens. Bioelectron," 21(2005) 419-293.
- [3] A. Mata, A.J. Fleischman, S.Roy, "Biomed. Microdevices," 7(2005) 281-293.
- [4] M. Unger, H. Chou, T. Thorsen, A. Sherer, and S. Quake, " Monolithic microfabricated valves and pumps by multilayer soft lithography," *Science*,
- [5] G. Ardila Rodriguez, "Conception, simulation and fabrication of a micro actuator based on energetic material for microfluidic actuation", thesis 2008.
- [6] N. Belayachi, N. Benseddiq, M. Abdelaziz, "Numeric and experimental survey of the behavior of the polymeric shocks by an approach of homogenizationz," 18 French Congres of Mechanics, 2007, Grenoble.

- [7] R.W. Ogden, " Non –linear Elastic Deformation," Dover, New York,1997.
- [8] H. Daanouni, Y. Tillier, F. Bay, "numeric survey Of hyperelastic membrane subjected to muliaxial loadings," 19 French Congres of Mechanics, 2009, Marseille.