Analysis of Mechanical Sensitivity of MEMS Pressure Diaphragm for Contact Formation

S.Shubham[1], M.Nawaz[1]
[1]Knowles Corporation, Chicago, IL, USA

INTRODUCTION: In this work a MEMS pressure diaphragm for enhanced mechanical sensitivity and contact formation analysis between the diaphragm and suspended rigid structure is presented under atmospheric load. The unique combination of different thicknesses of Polyimide and Metal materials in the diaphragm serves purpose of increasing sensitivity by Polyimide and holding of encapsulated pressure by the Metal. The sensitivity obtained after contact formation is compared with individual sensitivities of both structures.

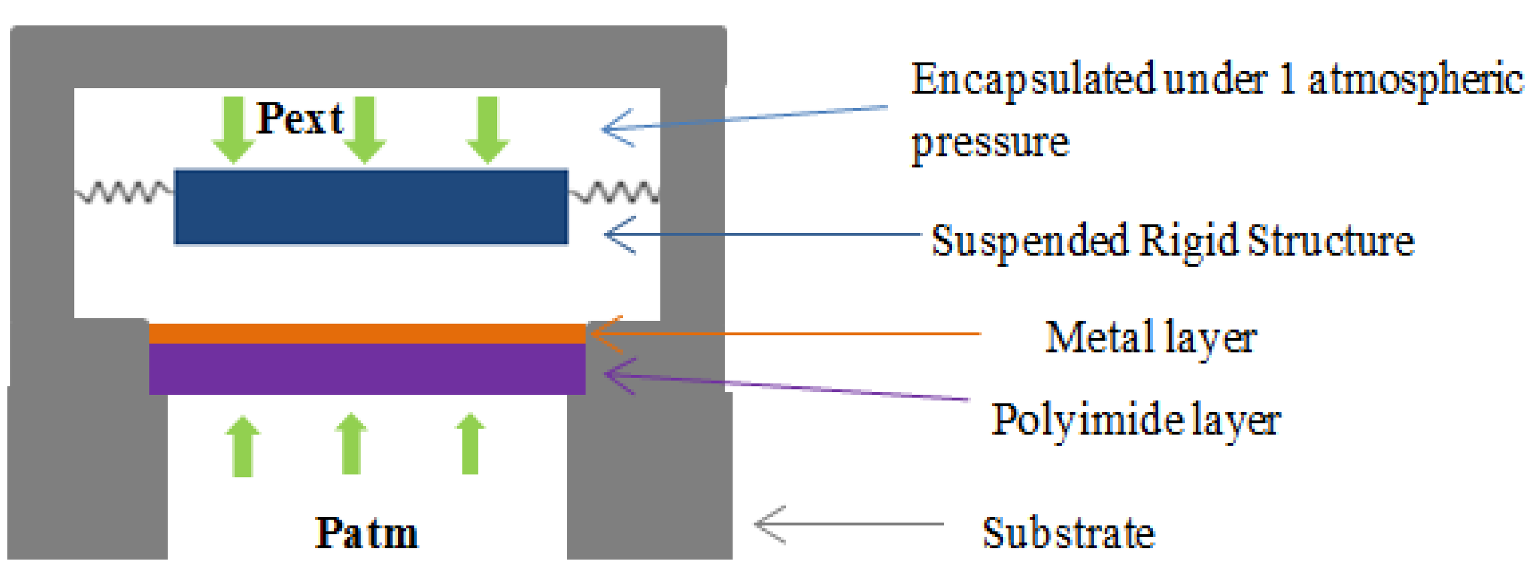

Figure 1. Diaphragm and Suspended Rigid Structure for MEMS Transducer

COMPUTATIONAL METHODS: In a 2D axisymmetric model, the diaphragm is fixed to the substrate and the rigid boss structure is suspended using a highly compliant spring placed on substrate edge. Contact simulation is used to solve the problem with Augmented Lagrangian algorithm which is more robust. Load ramping strategy is used to gradually ramp up the pressure loads for better convergence. The polyimide and metal layer is chosen as destination boundary and the suspended rigid structure as source boundary.
Sensitivity is defined as,

$$S_m = \frac{dw}{dP} \quad \text{and} \quad S_m = \frac{A}{8\pi\sigma h_d}$$

where w is deflection of diaphragm and P is pressure acting on diaphragm, A is diaphragm`s area, σ is stress and h_d is thickness of the diaphragm.

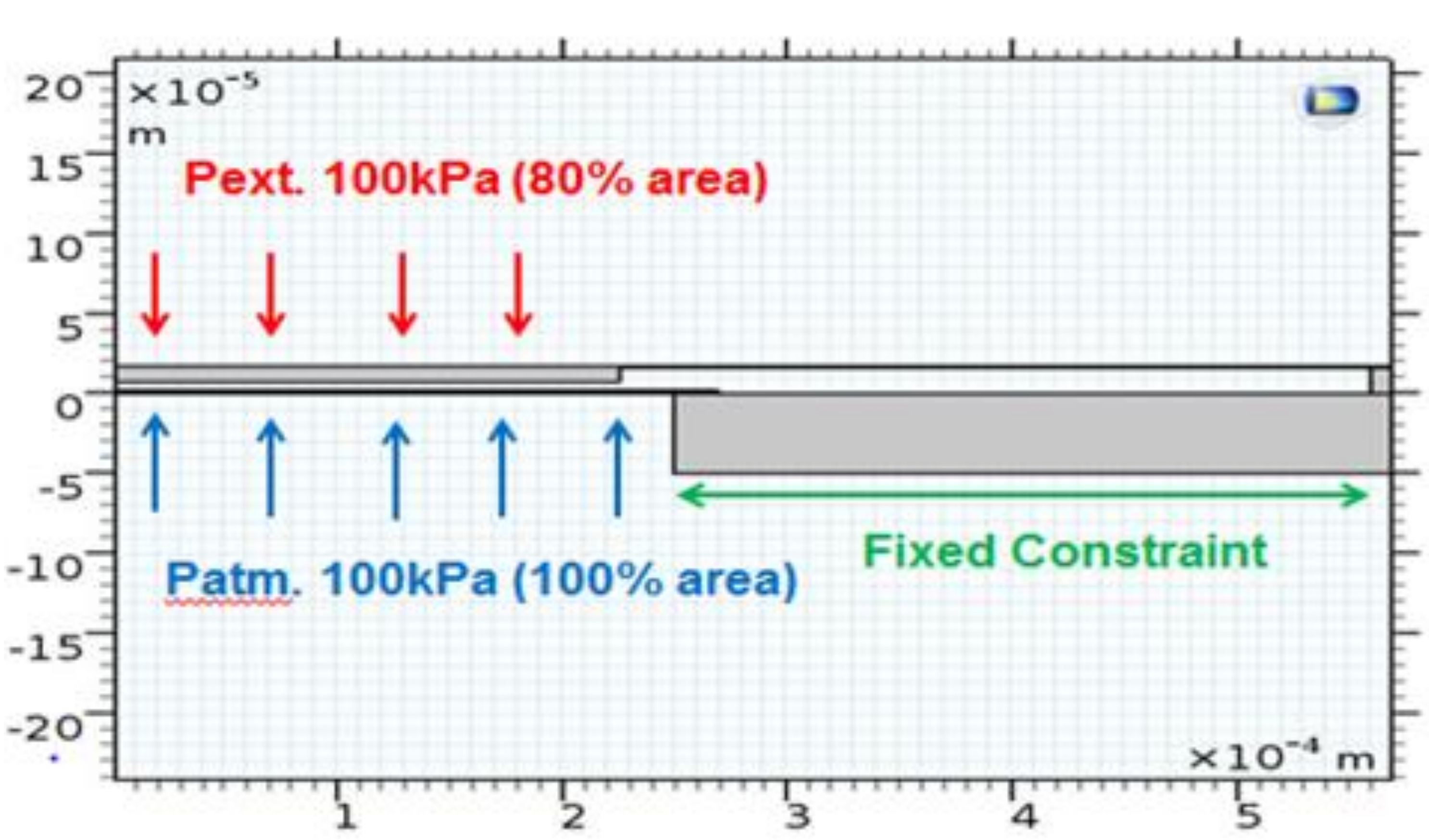

Figure 2. Simulation set up for contact formation with acting loads and specified boundary condition

RESULTS:

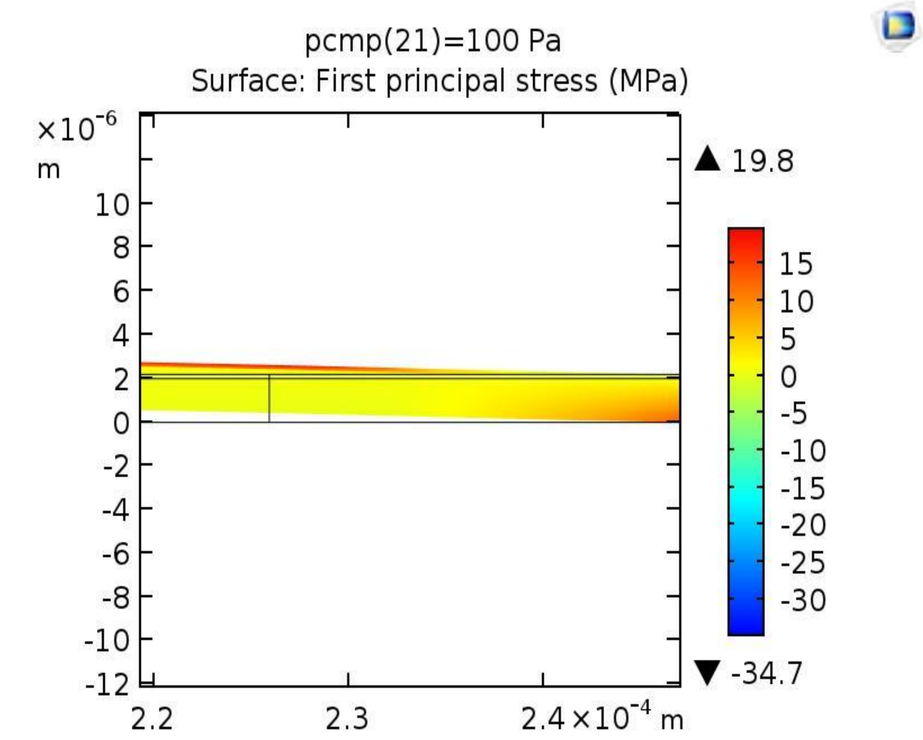

Figure 3. 1st Principal Stress Distribution for case without contacts and acting loads on diaphragm only

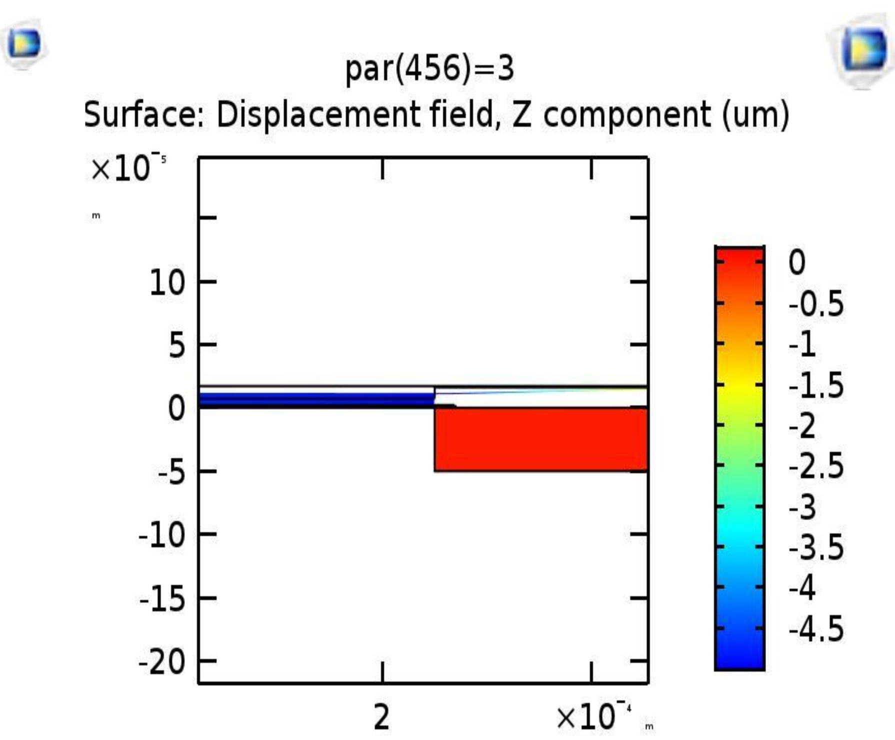

Figure 4. Surface displacement after 90 % contact formation area

Table 1. Dimensions and Results for design in figure 3

Rad [um]	Mat	hd [um]	Initial Stress [MPa]	Sm [nm/Pa]	Max. Stress [MPa]
250	PS	2.2	100	0.06	125
250	PS	2.2	1	0.38	33
250	PI	2.2	1	3.2	27.4
250	PI+M	2 + 0.2	1	2.4	19.8

Rad: Diaphragm Radius, Mat: Material, hd: Diaphragm thickness, PS: Polycrystalline Silicon, PI: Polyimide, M: Metal, Sm: Mechanical Sensitivity

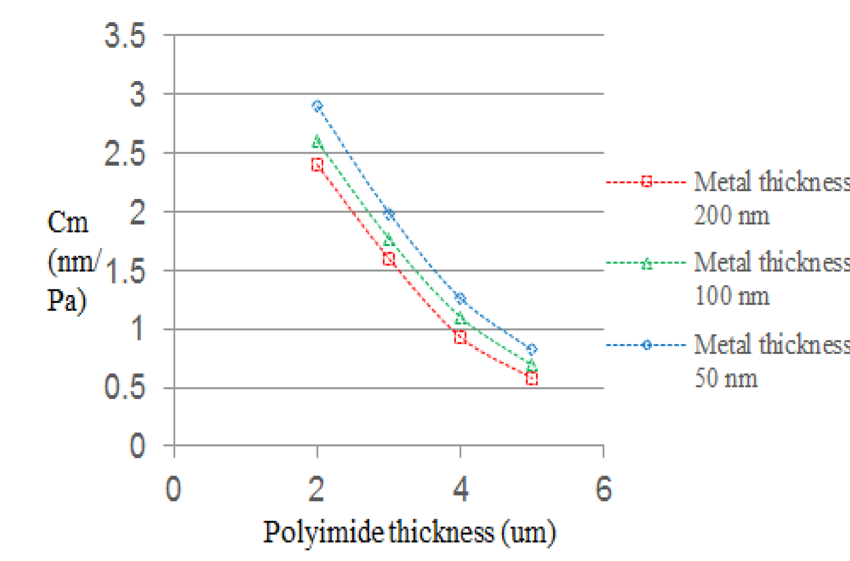

Figure 5. Variation of Compliance, Cm with Polyimide and metal thickness

Table 2. Sensitivity variation with contact radius for figure 4

Dia. Mat.	Rigid structure Mat.	Initial stress [MPa]	hd [um]	Contact rad. [um]	Sm [nm/Pa]
PI	PS	1	2.2	200 80%	0.2
PI	PS	1	2.2	225 90%	0.04
PI+M	PS	1	2.2	240 96%	0.01

Dia.Mat.: Diaphragm Material

CONCLUSIONS: To reduce stiffness of the diaphragm, the atmospheric pressure exerted on the second layer of polyimide generates concentrated stresses while exposing the rigid first metal layer to distributed stresses. The reason for significant difference between sensitivities in two tables can be pointed to the behavior of contact parts moving as thick structure unit after contact establishment and hence drops as contact area is increased.

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