Air Damping Simulation of MEMS Torsional Paddle

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Introduction

A MEMS torsional paddle (Figure 1) can be considered as a potential device for bio/chemical sensing [1]. The Quality Factor (QF) is inversely proportional to energy loss of the resonator and can determine the sensitivity.

Prediction of the QF is important for optimization and precise dynamic performance analysis of such a sensor. In this study the geometrical effect (anchors' length, position and device thickness) on air damping and Quality factor of the torsional paddle are investigated using COMSOL Multiphysics® 4.4.

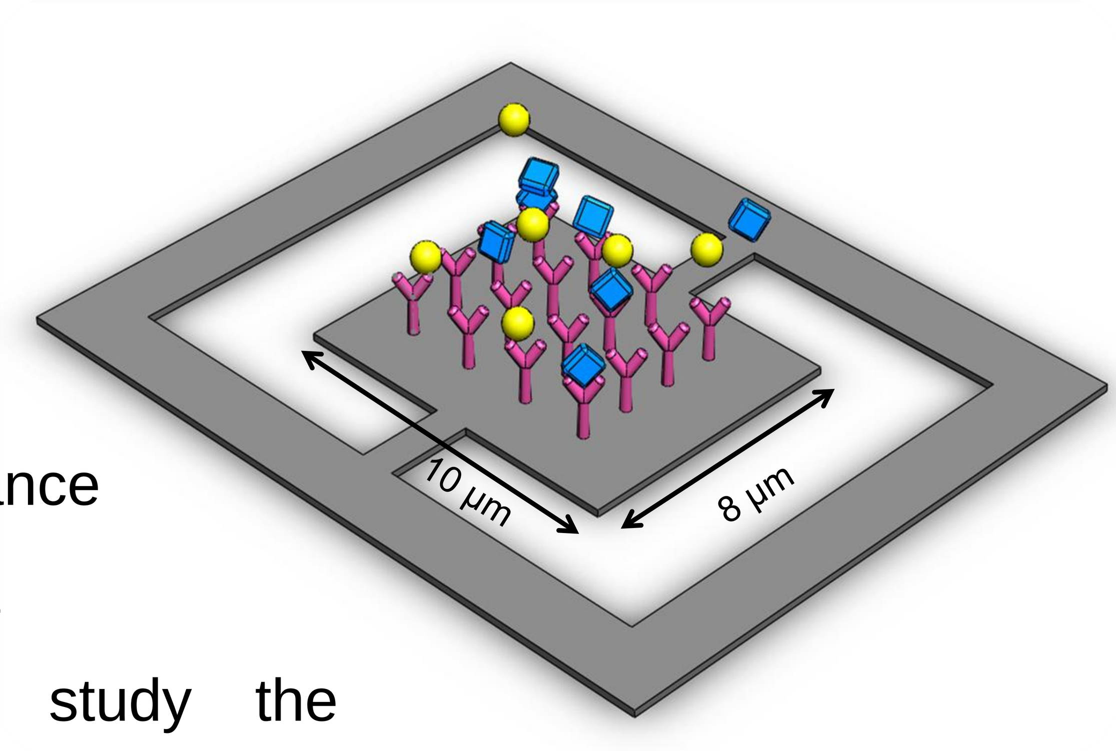


Figure 1. MEMS Torsional paddle

Computational method

- The Fluid-Structure Interaction interface was used.
- 2-D model was developed. Angular displacement $\theta(t) = \theta_0 \sin(\omega t)$ is applied on opposite sides to produce the moment (Figure 3).
- Fluid is in continuum regime and classified as a laminar and incompressible fluid.
- Time domain analysis was performed.

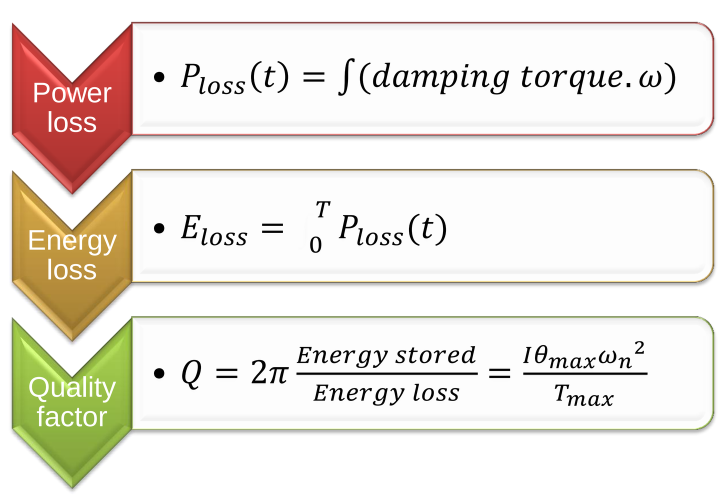
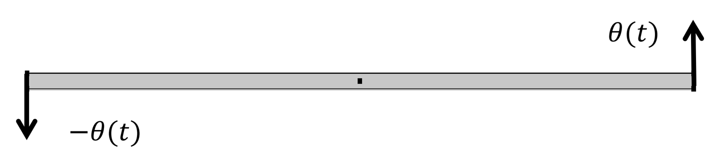


Figure 2. Steps to calculate the Quality factor



$$\rho \frac{\partial \boldsymbol{u}_{fluid}}{\partial t} = \nabla.[-p\boldsymbol{I} + \mu(\nabla \boldsymbol{u}_{fluid} + (\nabla \boldsymbol{u}_{fluid})^T)] + \boldsymbol{F}$$

$$\rho \nabla.\boldsymbol{u}_{fluid} = 0$$

$$-\nabla.\sigma = \boldsymbol{F}v$$

Figure 3. Applying angular displacement

Refrence

[1] Boonliang, B. , et al. , "A focused-ion-beam-fabricated micro-paddle resonator for mass detection." Journal of Micromechanics and Microengineering **18**(1), (2008)

Results

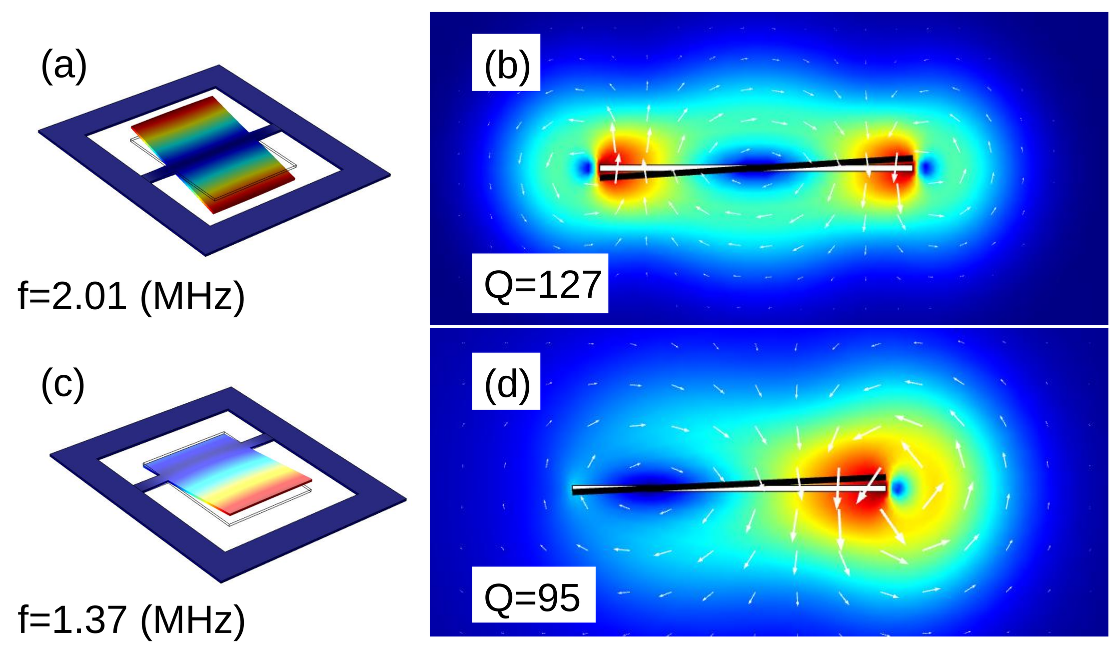


Figure 4. Eigenfrequency and air flow distribution around the paddle (length × width × thickness=10 × 8 × 0.2µm³),(a,b) anchors at the centre, (c,d) anchors offset from the centre.

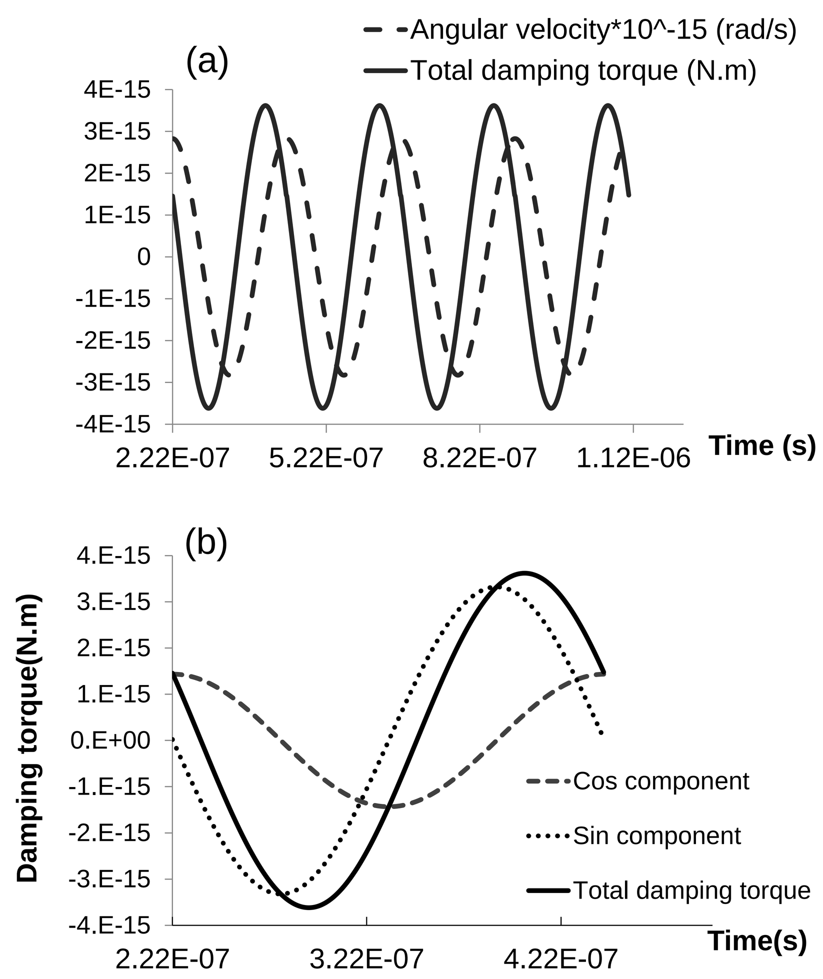


Figure 5. (a) phase difference between the damping torque and angular velocity, (b) sine and cosine components of damping torque

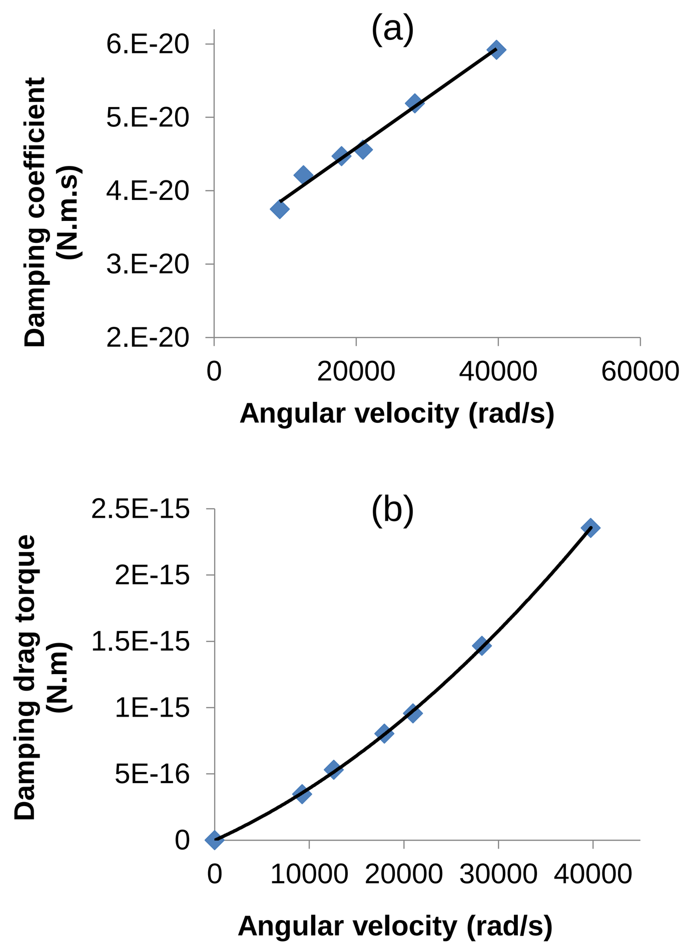


Figure 6. (a) Damping coefficient versus angular velocity, (b) damping torque versus angular velocity

L (µm)	t (nm)	f (MHz)	T(max) (N.m)	D (N.m.s)	QF
1	200	2.86	8.03E-16	4.47E-20	170
2.5	200	2.01	5.31E-16	4.21E-20	127
5	200	1.47	3.48E-16	3.75E-20	105
1	500	6.33	2.36E-15	5.92E-20	712
2.5	500	4.50	1.47E-15	5.19E-20	578
5	500	3.34	9.57E-16	4.56E-20	488

Table 1. Summarized simulation results (L=anchors' length, t=thickness, f=resonance frequency, T(max)=damping torque, D=damping ratio, Q=quality factor

L (µm)	t (nm)	Sensitivity (Hz/fg)
2.5 (asymmetric)	200	5.58
2.5	200	8.17
2.5	500	10.88

Table 2. Summarized sensitivity value for paddle

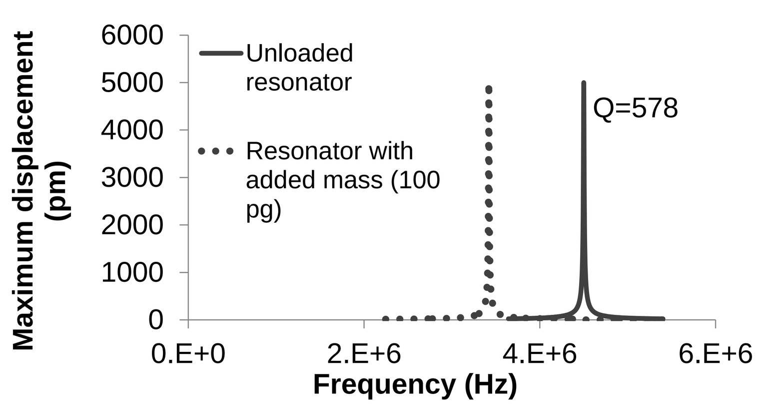


Figure 7. Response curve for loaded and unloaded micro paddle

Conclusion

The effect of geometrical parameters on the behavior of the MEMS torsional resonator was investigated. It was shown that by changing these parameters the quality factor could be enhanced which consequently could have significant results on the sensitivity of the sensor. The fabrication of the resonator by Focused ion beam would be the next step to verify these results.

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