Air Damping Simulation of MEMS Torsional Paddle

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Abstract

MEMS devices as biosensors attract a lot of attention, as they are capable to monitor the interaction of the target molecules simultaneously with high resolution. A MEMS torsional paddle can be considered as a potential device for such bio/chemical sensing [1][Figure 1]. The resonant micro-paddle can detect induced mass adsorption onto its functionalized surface by measurement of the resonant frequency shift. One of the crucial goals in designing of a sensor is to have high performance device, which can meet the required sensitivity. For resonators the Quality factor can determine the sensitivity as it sets the frequency stability. For in air sensing the interaction of the resonant micro device with surrounding viscous medium leads to energy dissipation and results in lower Quality Factor compared to operation in vacuum. Prediction of the Quality factor is important in the design of such sensors.

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 Fluid-Structure Interaction interface of COMSOL Multiphysics®. The Navier-Stokes equation with required boundary conditions is implemented for modeling. The fluid motion for the micro paddle is lay down in continuum region due to dimension of the device and can be categorized as laminar and incompressible flow. The Quality factor of the device is determined by energy stored divided by energy loss due to air damping torque on its surfaces during one oscillation cycle [2, 3]. The damping torque can be resolved in two components; in phase and out of phase with the resonator's angular velocity, which are contributing the damping and additional mass loading, respectively [Figure 2]. It has been observed by decreasing the anchor length, i.e. higher torsional spring and resonance frequency can lead to higher Quality factor [Figure 3]. Moreover, positioning the anchor at the center of the paddle can increase the quality factor, as it provides uniform flow movement across the structure [Figure 4]. In this study we improve the quality factor and the device performance by applying various geometrical parameters in model.

Reference

1. B. Boonliang, et al., A focused-ion-beam-fabricated micro-paddle resonator for mass detection, Journal of Micromechanics and Microengineering, 18(1) , (2008)
2. A. K. Pandey, et al., Effect of pressure on fluid damping in MEMS torsional resonators with flow ranging from continuum to molecular regime, Experimental Mechanics, 48(1), 91-106, (2008)
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Figures used in the abstract

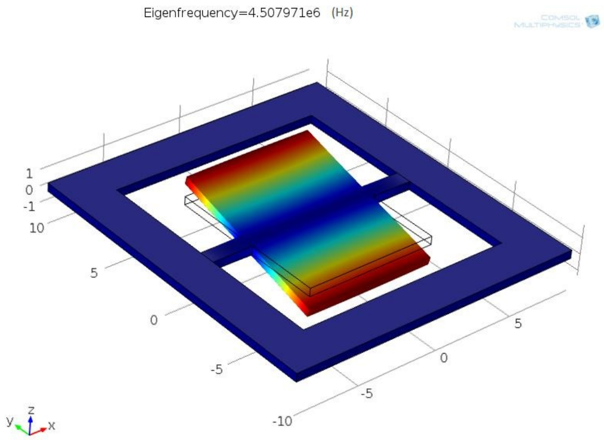

Figure 1: Eigenfrequency of torsional paddle, length × width × thickness=10×8×0.5 μm^3.

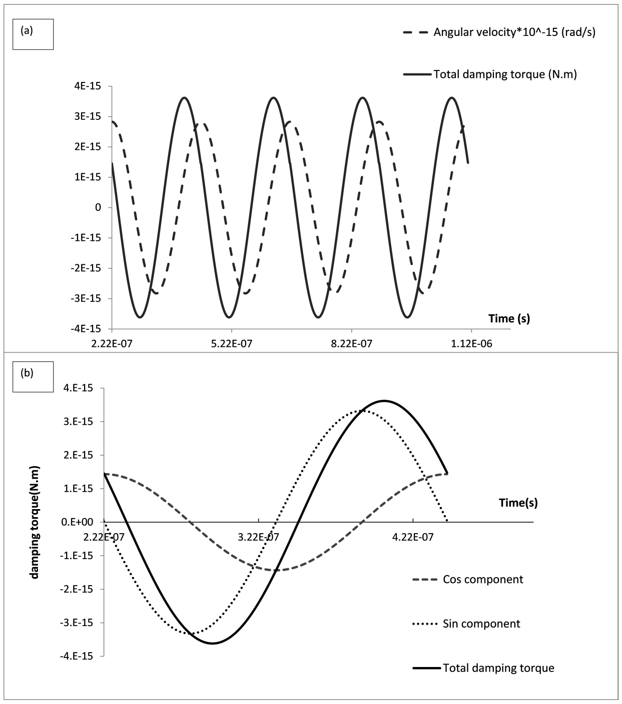

Figure 2: (a) Phase difference between the damping torque and angular velocity, (b): sine and cosine components of damping torque.

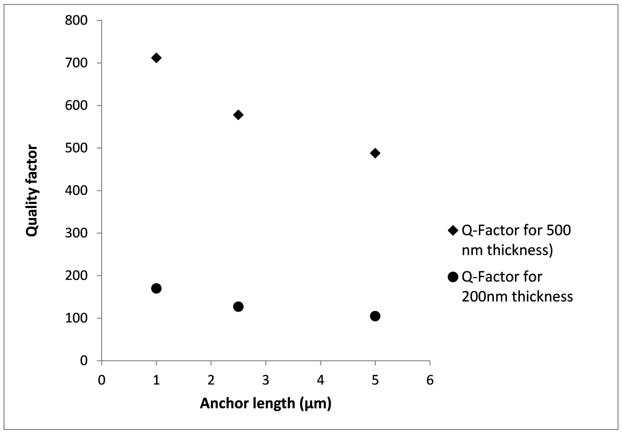

Figure 3: Quality factor versus anchor length for torsional paddle.

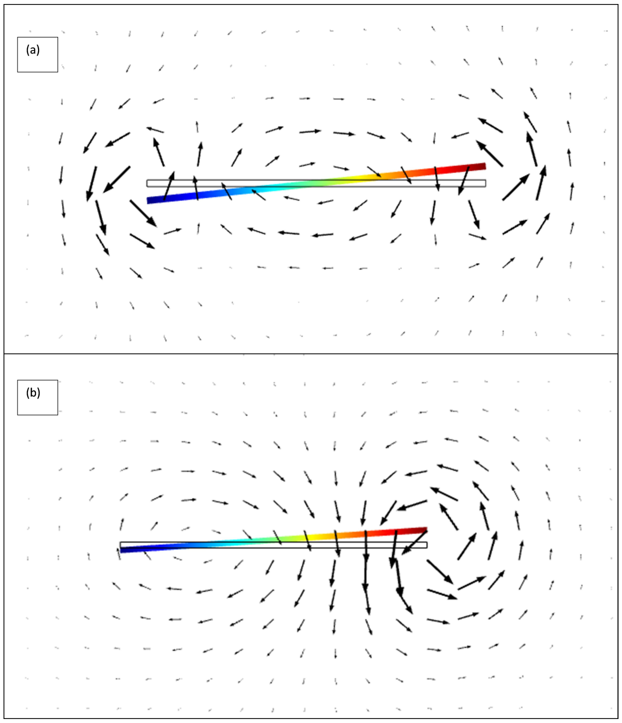

Figure 4: Air flow distribution around the paddle (length× width× thickness, 10×8×0.2 μm^3), (a) anchor at the center, (b) anchor offset from the center.