Harmonic Simulation of Viscoelastic Polymer Microcantilever for Electrostrictive Energy Harvesters

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Abstract

Introduction
Electrostrictive polymers for energy harvesters have been of significant interest and research over the last few years. For energy harvester application they have been used for converting mechanical deformation into electricity. The stored energy basically depends on the mechanical strain induced into an electrostrictive polymer by the mechanical resonant vibration of a microcantilever supporting the electrostrictive layer. In this work, in order to obtain large strain, polymer materials, which have small Young's modulus, have been considered for the vibrating microcantilever. But the drawbacks of such materials are their viscoelastic properties which causes the major losses of the system. In this paper, microcantilever using viscoelastic polymers is simulated by two different vibration methods with COMSOL Multiphysics® to deduce the energy losses in the system and then the quality factor of the resonant phenomenon, which is an important parameter for the energy harvester design.

Use of COMSOL Multiphysics®
Figure 1 shows the COMSOL Multiphysics® model of the viscoelastic microcantilever (600 µm x 300 µm x10 µm) used in this work. For a viscoelastic material, the Young's modulus (E) is in a complex form: the imaginary part (E") reflects the viscous energy dissipated into the material and the real part (E') reflects the mechanical energy stored into the material. The material parameters of the polymer are as follows: its density ρ = 1190 kg/m3, Poisson's ratio ν = 0, its real and imaginary parts of Young's modulus are E' = 3 GPa and E" = (0.1 GPa, 0.4 GPa and 0.8 GPa), respectively. Figure 1 shows the two methods used with COMSOL Multiphysics® to deduce both the resonant frequency (fr) and the quality factor: Figure 1(a) is for an harmonic actuation force at the microcantilever free-end, Figure 1(b) is for an harmonic mechanical vibration of the support. These simulations allow to deduce fr, the total quality factor (Qtot) and also to separate the quality factor due to viscoelasticity of the microcantilever (Qviscoel) and the one due to the mechanical losses into the support (Qsupp).

Results
Theoretical equation for the quality factor due to viscoelastic losses in a viscoelastic microcantilever is Qviscoel = E'/E" which gives 30, 7.5 and 3.75 for the different materials considered in this work. In fact, the simulated total quality factors are the same as theoretical values in the case of actuation with a free-end force (i.e. Figure 2 for E" = 0.8 GPa with a force F = -6x10-3sin(ωt)). Figure 3 presents the results obtained in the case of an harmonic vibration of

the support, with vertical acceleration a = 9.8sin(ωt). There is a shift of fr for different values of E'': this is due to the mechanical energy lost into the system. Figure 4 shows the method used to discriminate the viscoelastic losses into the microcantilever (Qviscoel) and the losses into the support (Qsupp) with f0 the undamped natural frequency.

Conclusion
In this work, we have validated the use of COMSOL Multiphysics® to determine the different energy losses into a viscoelastic MEMS.

Figures used in the abstract

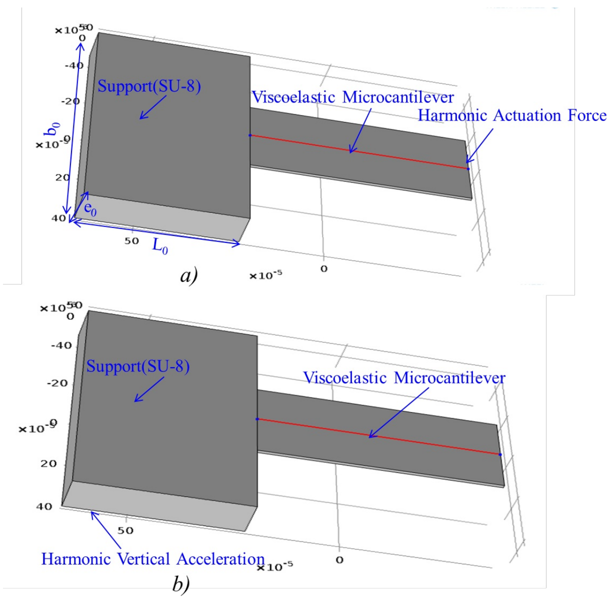

Figure 1: Schematic diagram of viscoelastic polymer microcantilever. Out of plane vibration generated by a) free-end force or b) by vertical vibration of the support.

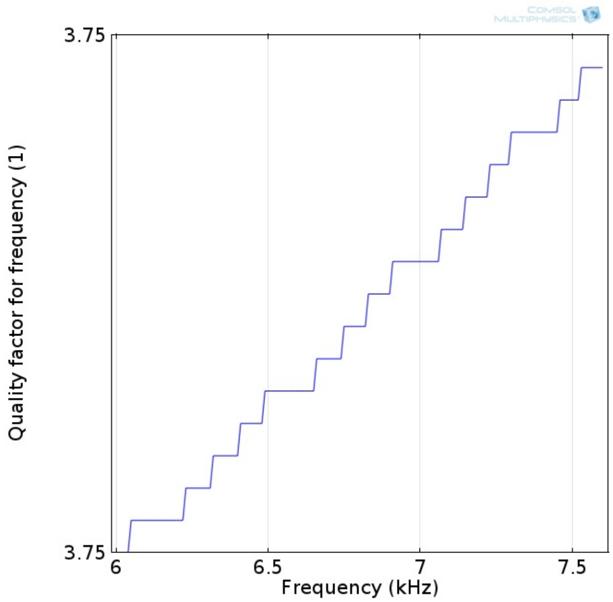

Figure 2: Quality factor (Qviscoel) with E'' = 0.8 GPa.

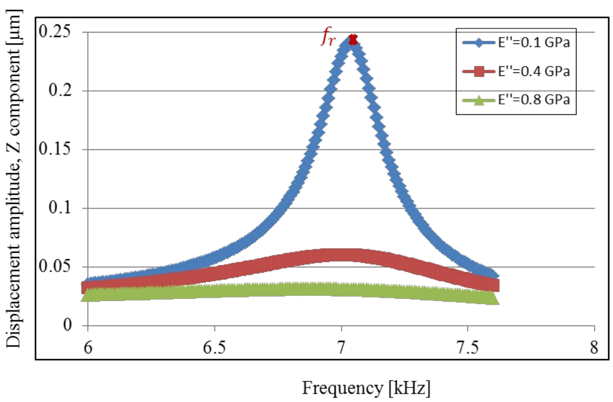

Figure 3: Displacement amplitude (µm) versus frequency (kHz) with support vibrations.

E" **(GPa)**	$\boldsymbol{Q_{viscoel}}$ (E'/E'')	$\boldsymbol{f_r}$ **(kHz)**	$\boldsymbol{Q_{tot}}$ $Q_{tot}=\frac{1}{\sqrt{2\left(1-\left(f_r/f_0\right)^2\right)}}$	$\boldsymbol{Q_{supp}}$ $Q_{supp}=\frac{Q_{tot}Q_{viscoel}}{Q_{viscoel}-Q_{tot}}$
0.1	30	7.04	19.35	54.56
0.4	7.5	7	6.64	58.11
0.8	3.75	6.87	3.53	60.6

Figure 4: Simulation results of the quality factor deduced by energy losses at the support of the cantilever (Qsupp).