Harmonic Simulation of Viscoelastic Cantilevers for Electromechanical Vibration Energy Harvesting

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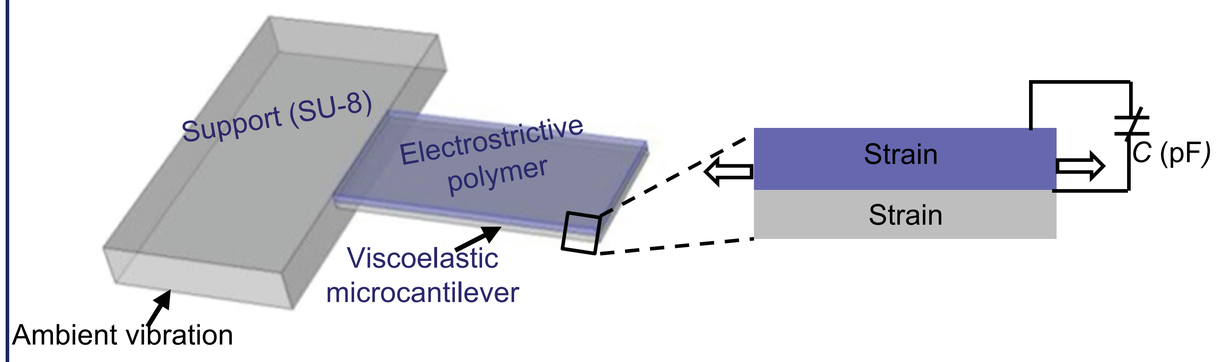
Aims : Harmonic simulation of viscoelastic cantilevers with COMSOL to deduce the resonant frequencies, the energy losses and the quality factors

Introduction:

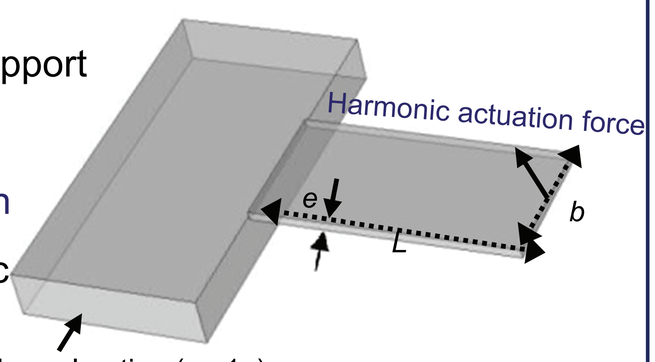
- Electromechanical vibrating energy harvesting using electrostrictive material



- Viscoelastic polymer cantilevers: Large strain
  Low quality factor
- Electrostrictive polymer layer: Large sensitivity strain
  High permittivity

Use of COMSOL multiphysics:

- Beam: L= 600 µm, b= 300 µm and e= 10 µm
  ρ= 1190 kg/m^3, $E=E'+jE''$ (E'=3 GPa and E''=0.1 GPa,0.4 GPa,0.8 GPa)
- SU-8: ρ= 960 kg/m^3, E= 3 GPa.
- Two actuation methods :
  1- Harmonic actuation force (support fixed) ➔ Viscoelastic losses
  2-Harmonic vertical acceleration
  ➔ Support losses + viscoelastic losses



Analytical model of quality factors:

- The total quality factor : $Q_{tot} = \dfrac{1}{\sqrt{2\left(1-\left(\dfrac{f_r}{f_0}\right)^2\right)}}$

  1- f_r is the resonance frequency
  2- f_0 is the undamped natural frequency
- Viscoelastic losses➔ $Q_{viscoel} = \dfrac{E'}{E''}$
- Support losses➔ $\dfrac{1}{Q_{supp}} = \dfrac{1}{Q_{tot}} - \dfrac{1}{Q_{viscoel}}$

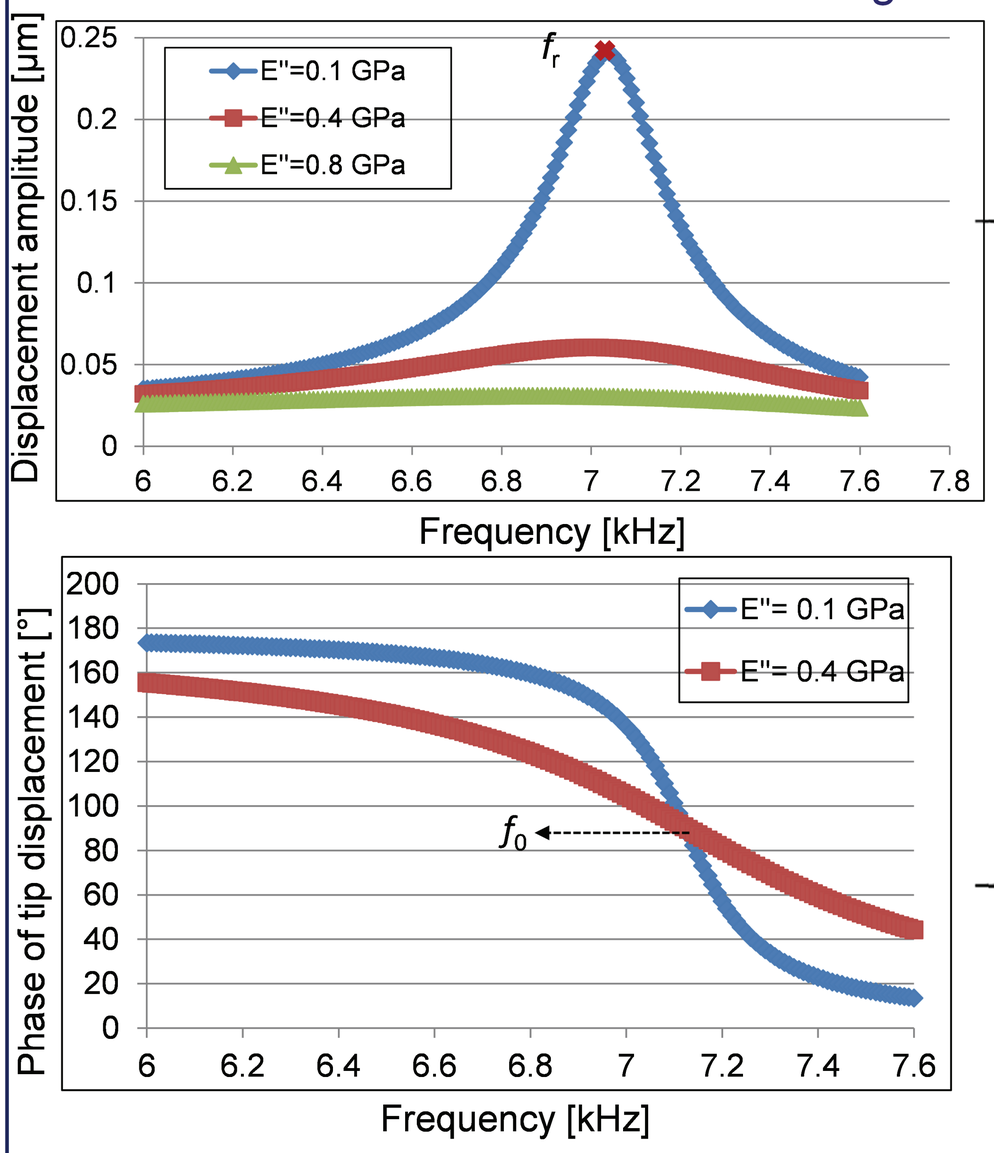
Results and Discussions:

- Harmonic actuation force: $F = -6\times10^{-3}\sin(\omega t)$

E'' (GPa)	$Q_{viscoel}$ (Theo)	$Q_{viscoel}$ (Sim)
0.1	30	30
0.4	7.5	7.5
0.8	3.7	3.7

➔Good agreement between COMSOL simulation and theory
➔ $E'' \uparrow \Rightarrow Q_{viscoel} \downarrow$

- Harmonic vertical acceleration: a= 1g



$Q_{tot}(f_0, f_r)$

E'' (GPa)	f_0 (kHz)	f_r (kHz)	Q_{tot}	Q_{supp}
0.1	7.0417	7.0370	19	55
0.4	7.0400	7.0000	6.6	58
0.8	7.0120	6.8700	3.5	60

➔ $Q_{supp} \approx 60$

For low value of E'' ➔the support losses cannot be neglected

Conclusions

- The viscoelastic losses and the support losses have been determined by harmonic simulation in COMSOL
- The quality factors associated to viscoelastic losses obtained by COMSOL simulation are validated with analytical model
- The supports losses cannot be neglected for a low value of imaginary Young's modulus of the viscoelastic polymer

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