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RESONANCE FREQUENCY AND YOUNG'S MODULUS OF COMPOSITE POROUS SILICON/SILICON CANTILEVER BEAMS

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ABSTRACT

Porous Silicon is generally formed by electrochemical etching of silicon in HF based electrolyte and has many applications. The pore geometry and morphology can be easily tailored by varying the formation parameters. Pore formation reduces the Young's modulus of the material resulting in a more flexible composite structurres of silicon and porous silicon [1]. We use surface micromachined cantilever beams to extract the Young's Modulus of the porous layer. Silicon and polysilicon cantilever beams are fabricated first and then the porous layer is formed on the beam surface by vapor etching which eliminates the use of electrical contacts.

The mask contains two sets of cantilever beams of 20 and 30 μm width. Phosphorous doped polysilicon film of 2 μm thickness on 1.6 μm thermal oxide has been used. Polysilicon is patterned using Reactive Ion Etching (RIE) with SF_6 plasma. In the release process, the oxide below the beam is etched using BHF leaving free standing beams. Same proces was also used on silicon on insulator (SOI) wafers for silicon beams.

For the formation of the porous layer using vapor etching, a mixture of HF, nitric acid and acetic acid in the ratio of 40 : 5 : 5 ml is used. A sacrificial silicon sample is dropped in this solution resulting in dense vapors. The sample with cantilever beams is held over the vapors to form porous layer.

On the released beams resonance frequency is measured before and after pore forming using a Doppler Vibrometer and these values are shown in Table 1. This shows some interesting results. In the case of 5 seconds etching, all beams show same trend of increase in frequency. In the case of 10 seconds etching, 200 and 300 μm beams show decrease in frequency, whereas 350 μm beams show increase in frequency. The reasons for this can be many. There are three possible effects due to the porous layer formation: 1) Mass reduction due to pore formation increases the frequency 2) Porous layer reduces the Young's modulus which will decrease the resonance frequency 3) Porous layer gets oxidized easily at room temperature resulting in increased mass and reduced

frequency. From Table 1 we can understand that, for 5 second etching the first factor should be dominating over the other two, whereas in the case of 10 second last two should be dominating over the first. To study this, a simulation has been performed on the composite beam using COVENTORWARE MEMS device simulator package. For a composite beam with two layers, expression for resonance frequency is given by eq. (1),

$$f = \frac{0.16}{L^2}\sqrt{\frac{E_1 t_1^3 + E_2 t_2^3}{t_1\rho_1 + t_2\rho_2}} \quad (1)$$

Table 1 Resonance frequency for different beam lengths before and after porous layer formation

Vapor etching time	Measured resonance frequency (kHz) for Beam length of					
	200 µm		300 µm		350 µm	
	before	after	before	after	before	after
5	74	78	37	43	30	43
10	76	70	36	39	30	46

Resonance frequency Simulation of the Composite beam: A simple two layer model as shown in Figure 1 is used to simulate the composite beams. Total beam thickness of (t_1+t_2) is maintained constant at 1.8 µm which is the final beam thickness. The beam length and width are 200 and 30 µm respectively. The Young's modulus of the bottom layer is kept constant at 160 GPa and is varied for the top porous layer from 25 to 190 GPa. Changing the Young's modulus of top layer corresponds to varying porosity. The plot of simulated frequency as a function of Young's modulus is shown in Figure 2.

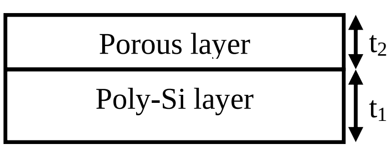

Figure 1. Porous/poly Si composite beams

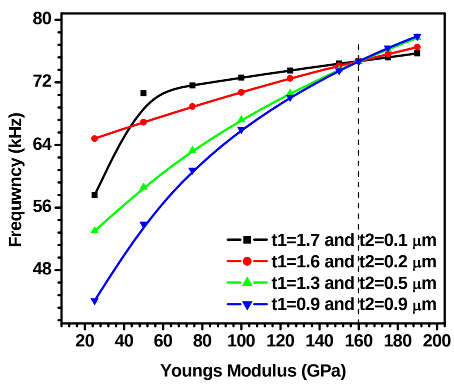

Figure 2. Plot of simulated frequency verses Young's modulus

Results and Discussion: For a porous beam formed on SOI sample with 10 second intense vapor etching the measured frequency value is used in Eq. (1) to give Young's modulus for porous layer as 65.6 GPa. Extraction of Young's modulus for polysilicon sample and simulation of the beam taking all the issues discussed above are in progress.

REFERENCE

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