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Study of MEMS Resonator with Different Stress level and its Applications

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Abstracts

In this paper we present the general idea about the stress levels of mems resonator with different type of materials used in designing of MEMS resonator. Today with development of nanotechnology MEMS resonator is to be designed and used as an oscillator. Because this is due to their excellent features like small size (in microns), large frequency-quality factor product, low power consumption, low cost batch fabrication.Instead of this, quartz oscillator are large in size (in centimeters).According to different properties of mems materials, the stress level of MEMS resonator is to be changed because the displacement of the cantilever beam is to be varied. So, by altering the material properties of MEMS resonator beam displacement can be increased.

Keywords: MEMS, COMSOL, FEM.

Introduction

MEMS resonators have been widely used as a key component in MEMS devices, such as in micro gyroscopes, micro mirror and RF systems as an oscillator, filter, switch. A resonator is a system that has selective response at a specific frequency or frequencies. These behaviors are called resonances and the frequencies at which they occur are called resonant frequencies. The exact behavior at different resonant frequencies may vary depending on the principle of operation, geometry, material properties, etc. Resonators are actuated electro statically to oscillate at their natural resonant frequency. Micro-electromechanical silicon resonators provide an interesting alternative for quartz crystals as accurate timing devices in oscillators for modern data and communication applications. The compact size, feasibility of integration with IC technology and low cost are major advantages. Because of the resonators are small in size so they have to be driven close to nonlinear regions to store enough energy for a sufficient signal to noise ratio. Depending on the resonator material, different stress level may be dominant in the resonator dynamic behaviour.

Design and numerical modelling

A MEMS resonator consists of a proof mass and its supporting legs. Then we fixed the size of the proof mass and evaluate the design for the legs supporting it. Simply a generative representation was used to encode the construction of a single leg design and then four copies of these legs were attached to fixed points on the proof mass. At the other end of each “leg” an anchor is placed. When ac voltage signal is to be applied at electrode then due to the electrostatic force the beam will bend and beam will oscillates. MEMS resonators are basically time based generators whose operating principle is similar to the mechanical tuning fork which is used to tune musical instruments .MEMS Resonator is normally used in analog systems, communication systems, switches etc. The oscillations in a resonator can be either electromechanically or electromagnetic. MEMS Resonator have high quality factor as compared to crystal oscillator. Crystal oscillator is bulky and cannot be integrated in IC technology.

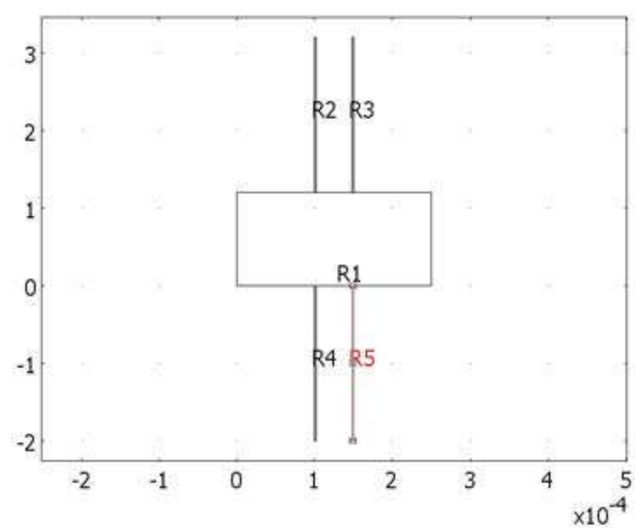

Fig: 1 Thin film resonator with four cantilever beams

In optimizing the design of MEMS resonator that is robust against scattering of material properties, design dimensions, properties of technology or ambient conditions all that properties have to be considered with their distribution functions. For a lateral resonator with four cantilever-beam springs, the resonant frequency is

$$f_0 \approx \frac{1}{2\pi}\sqrt{\frac{4Etb^3}{mL^3}+\frac{24\sigma_r tb}{5mL}}$$

Where m is the mass of the resonator plate, E is Young's modulus, t is the thickness, L is the length, b is the width, and sigma r is the residual stress in the cantilevers. The stress is typically a sum of external stresses, the thermal stress, and intrinsic components. Assuming the material is isotropic, the stress is constant through the film thickness, and the stress component in the direction normal to the substrate is zero. The stress-strain

$$\sigma_r = \left(\frac{E}{1-\nu}\right)\varepsilon$$

relationship is the where v is Poisson's ratio.

- If the material used is polysilicon .The width of the cantilever has been changed to 10 micrometer. This affects the first resonance frequency than any other design parameter. The reliability and robustness of this kind of resonator is characterized by resonant frequency greater than or equal to18 KHz.

Table: 1 Design parameters of polysilicon

Design parameters	Value
Young's modulus E (GPa)	155
Density rho (kg/m3)	2330
Poisson's ratio	0.23
Residual stress sigma (MPa)	50
Deposition Temperature T1 (K)	605

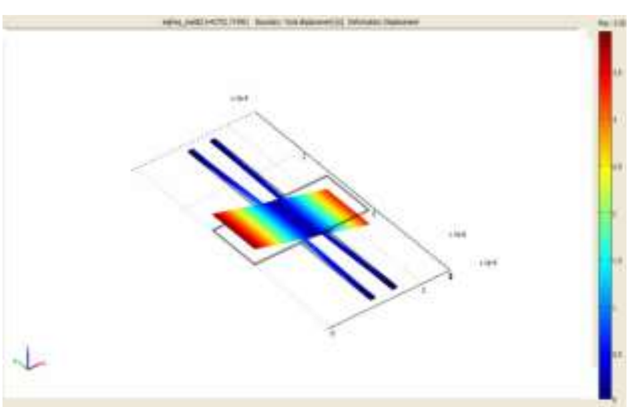

Fig 2:-Resonant frequency for polysilicon

The first resonant frequency 42 KHz obtained for polysilicon for modified width is shown in the figure:-

Like polysilicon the si material is used .The width of the cantilever has been changed which is less then 10 micrometer. By using Si material for the designing of MEMS resonator, the resonance frequency is to be obtained is 43 kHz but if we use silicon nitride then stress is lower as compare to Si.

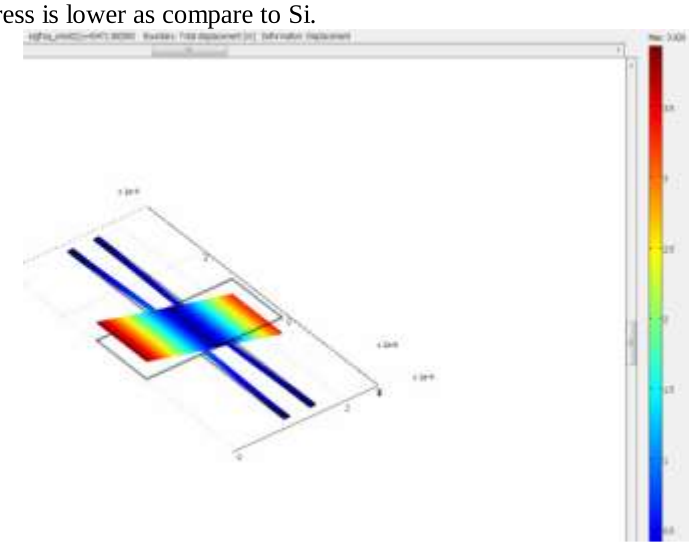

Fig 3: Resonant frequency for silicon

If aluminum is to be used as a designing material then the resonance frequency is to be obtained is 18 kHz. When the cantilever beam of resonator is to be increased then the resonance frequency is also increased and stress level is to be decreased at a certain extent.

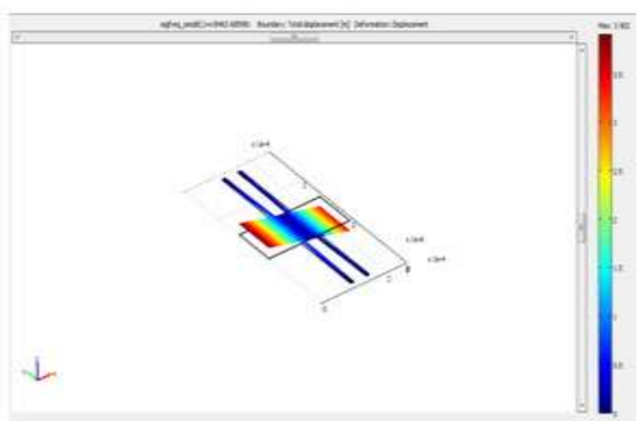

Fig 4: Resonant frequency for Al

Simulation results

There are using various material which shows the variation in stress level by varying resonance frequency so the quality of the material must be need to analyzed for proper designing of MEMS resonator. After analyzing we find that polysilicon is best suited for MEMS applications. Because of the presence of granules structure, it makes flexible and low stress level.

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Though the metals are used for contacts, polysilicon is best for this application. Thus the increased width and polysilicon as material is best suited to increase the reliability and robustness of the MEMS resonator.

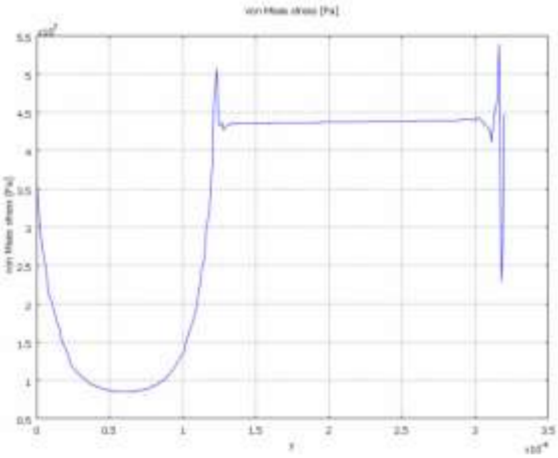

Fig 5:- Displacement verses stress plot of polysilicon

Thus the analysis of different materials and their effect on stress level resonant frequency has been analyzed. The increase in width of the cantilever increases the resonant frequency. This reduces the stress effect to a certain level.

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