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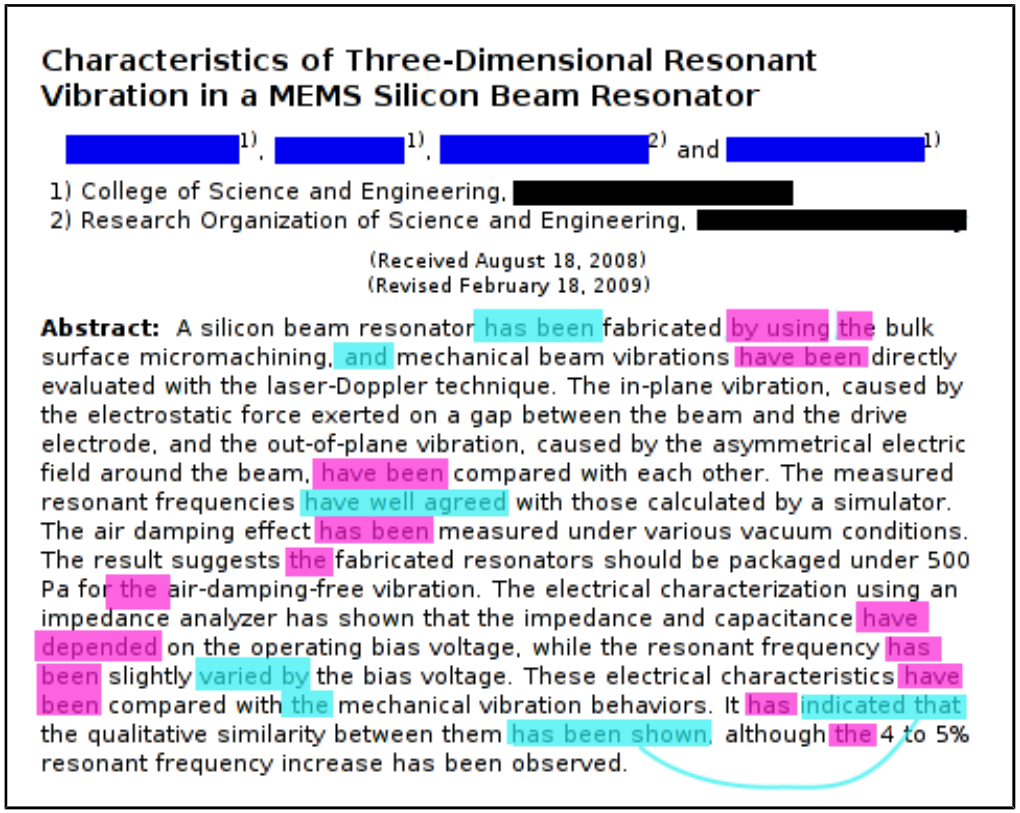

Characteristics of Three-Dimensional Resonant Vibration in a MEMS Silicon Beam Resonator

[redacted][1)], [redacted][1)], [redacted][2)] and [redacted][1)]

1) College of Science and Engineering, [redacted]
2) Research Organization of Science and Engineering, [redacted]

(Received August 18, 2008)
(Revised February 18, 2009)

Abstract: A silicon beam resonator has been fabricated by using the bulk surface micromachining, and mechanical beam vibrations have been directly evaluated with the laser-Doppler technique. The in-plane vibration, caused by the electrostatic force exerted on a gap between the beam and the drive electrode, and the out-of-plane vibration, caused by the asymmetrical electric field around the beam, have been compared with each other. The measured resonant frequencies have well agreed with those calculated by a simulator. The air damping effect has been measured under various vacuum conditions. The result suggests the fabricated resonators should be packaged under 500 Pa for the air-damping-free vibration. The electrical characterization using an impedance analyzer has shown that the impedance and capacitance have depended on the operating bias voltage, while the resonant frequency has been slightly varied by the bias voltage. These electrical characteristics have been compared with the mechanical vibration behaviors. It has indicated that the qualitative similarity between them has been shown, although the 4 to 5% resonant frequency increase has been observed.

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Abstract: A silicon beam resonator was fabricated by bulk surface micromachining; subsequently mechanical beam vibrations were directly evaluated with the laser-Doppler technique. The in-plane vibration, caused by the electrostatic force exerted on a gap between the beam and the drive electrode, and the out-of-plane vibration, caused by the asymmetrical electric field around the beam, were compared with each other. The measured resonant frequencies were found to be in close agreement with those calculated by a simulator. The air damping effect was measured under various vacuum conditions. The result suggests that fabricated resonators should be packaged under 500 Pa for air-damping-free vibration. The electrical characterization using an impedance analyser showed that the impedance and capacitance depend on the operating bias voltage, while the resonant frequency was slightly dependent on the bias voltage. These electrical characteristics were compared with coincident mechanical vibration behaviours and a qualitative similarity between them was demonstrated, although a 4 to 5% resonant frequency increase was observed.

Document rewritten

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(Received August 18, 2008)
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Abstract: The three-dimensional mechanical beam vibrations in a silicon beam resonator, fabricated by bulk surface micromachining, were directly evaluated via the laser-Doppler technique. In-plane vibrations and out-of-plane vibrations were compared; in-plane vibrations generated by the electrostatic forces in the space between the resonator beam and the drive electrode; out-of plane produced by the asymmetric electric field around the beam. The observed resonant frequencies were in close agreement with prior simulation results. Air damping effects were measured over a range of pressures: to remove air damping effects fabricated resonators should be packaged in a 500 Pa environment. Electrical impedance and capacitance depended strongly, though resonant frequency only slightly, on the basis voltage of the impedance analyser used. Upon a comparison between the electrical and mechanical vibration behaviours a qualitative similarity was demonstrated, although the resonant frequency increased by 4 to 5%.

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