MICRO-ELECTRO-MAGNETIC VIBRATION ENERGY HARVESTERS: ANAL-YSIS AND COMPARATIVE ASSESSMENT†

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1. Abstract

The development of Micro-electro-magnetic Vibration Energy Harvesters (MEMVEHs) plays a crucial role in advancing self-powered nanophotonic, nanoelectronic, and na-nosensor systems. As energy autonomy becomes critical for miniaturized devices, MEMVEHs offer a sustainable power source for low-power nanodevices operating in wireless sensor networks, wearable electronics, and biomedical implants. This study pro-vides a comparative assessment of MEMVEH technologies and evaluates their integration potential within next-generation nanoscale systems, enabling enhanced performance, longevity, and energy efficiency of emerging nanotechnologies.

Electromagnetic vibration energy harvesters (EMEHs) based on microelectromechanical systems (MEMS) technology are promising solutions for powering small-scale, autono-mous electronic devices. In this study, two electromagnetic vibration energy harvesters based on microelectromechanical (MEMS) technology are presented. Two models with distinct vibration structures were designed and fabricated . A permanent magnet is con-nected to a silicon vibration structure (resonator) and a tiny wire-wound coil as part of the energy harvester. The coil has a total volume of roughly 0.8 cm3. Two energy harvest-ers with various resonators are tested and compared.

Model A's maximum load voltage is 195 mV, whereas Model B's is 440 mV. A maximum load power of 91.56 μW was produced by Model A at 327 Hz a. At 338 Hz, Model B pro-duced a maximum load power of 182.78 μW while accelerating by 0.4 g. Model B features a larger working bandwidth and a higher output voltage than Model A. Model B per-forms better than Model A in comparable experimental settings. Simple study revealed that Model B's electromagnetic energy harvesting produced superior outcomes. Addi-tionally, it indicates that a non-linear spring may be able to raise the output voltage and widen the frequency bandwidth.

2. Fabrication Process

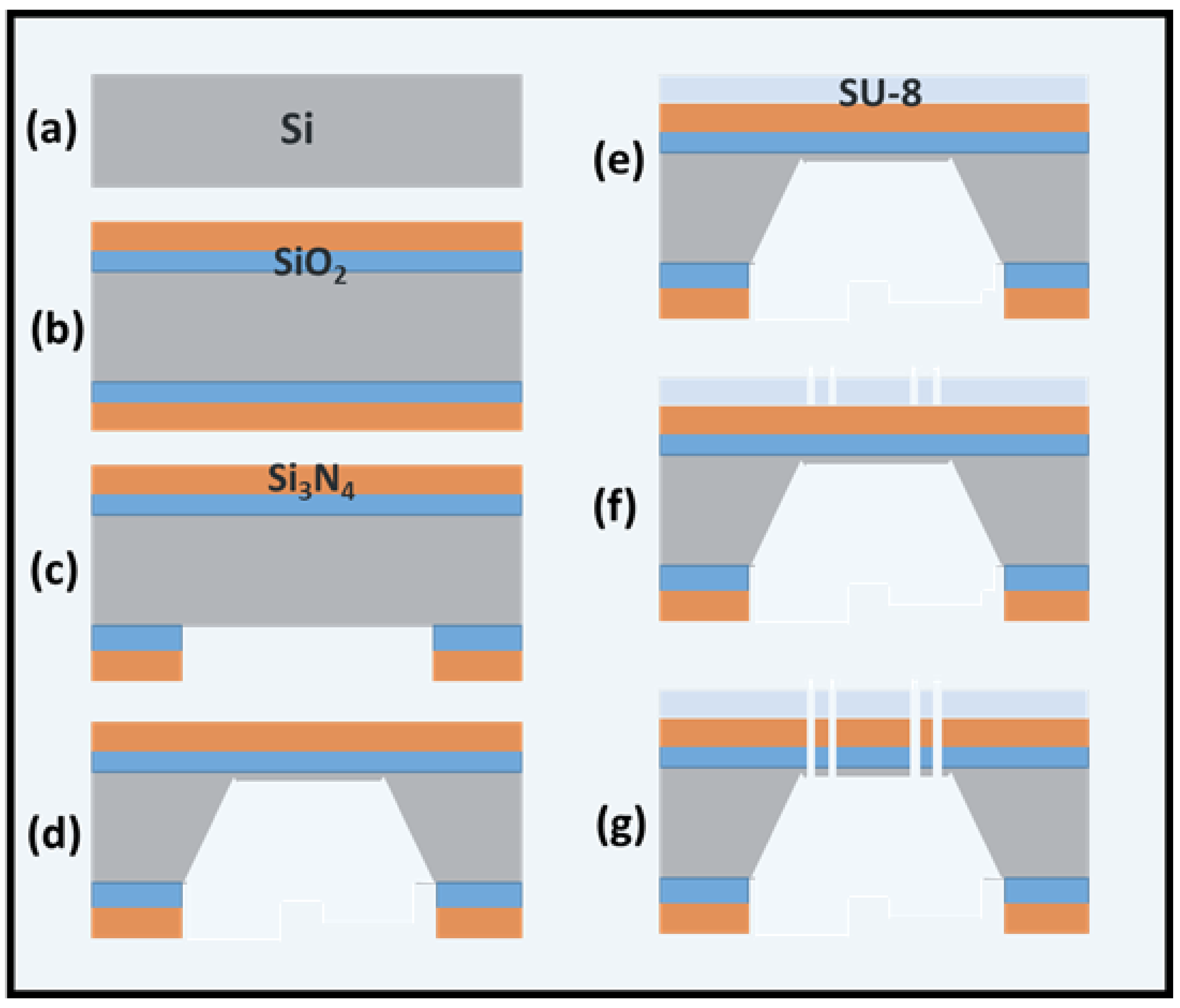

Figure 3: Procedures used to fabricate the suspension microstructure. (a) A 4-inch <100> silicon wafer; (b) Si3N4 and SiO2 are deposited on both sides of the silicon wafer; (c) the backside is patterned; (d) wet etching; (e) the front side is spun with SU-8 photoresist; (f) the front side is patterned; (g) the device is released by dry etching on the front side.

3. Results

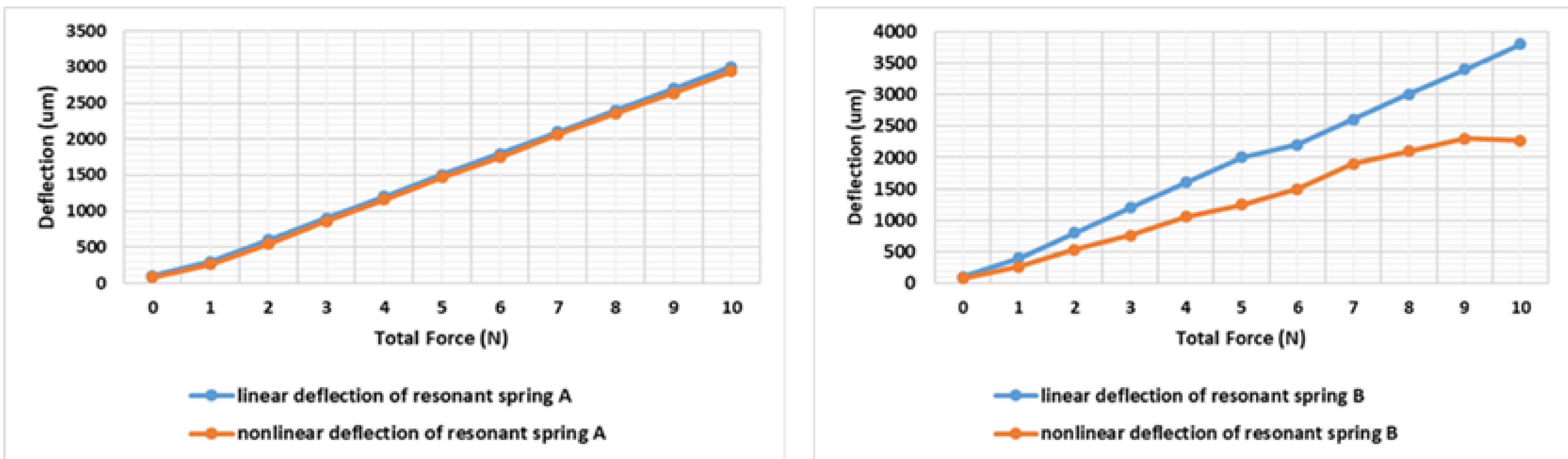

Figure 2: (a) Resonant spring A's linear and nonlinear deflection under load was simu-lated. (b) Spring B's linear and nonlinear deflection under load was simulated.

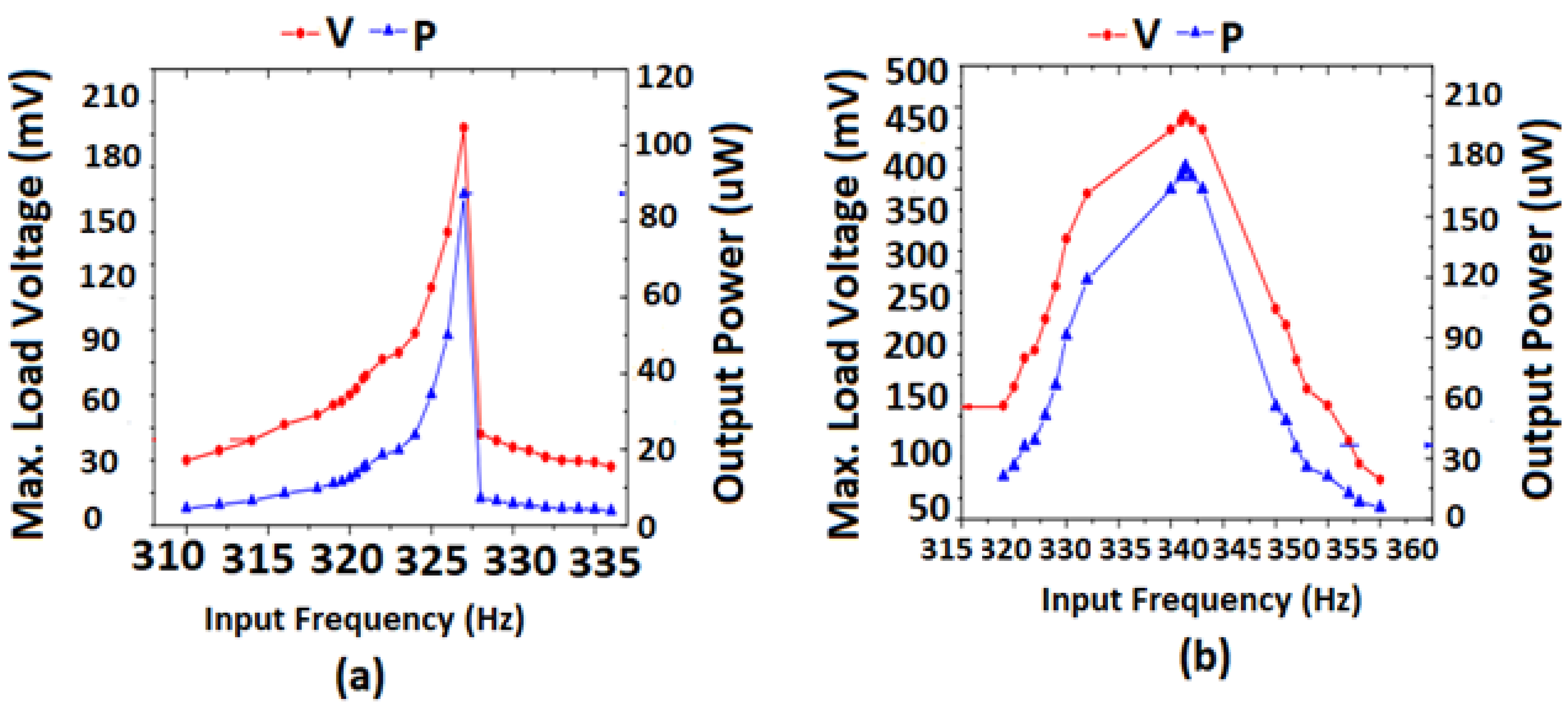

Figure 4: Prototype A's load voltage and maximum power variation with fre-quency (a) and prototype B's load voltage and maximum power variation with fre-quency (b).

4. Conclusion

The energy harvesters have a volume of 0.9 cm³. Dynamic characteristics of different designs were simulated using COMSOL software, and the finite element analysis (FEA) results were used to guide experimental validation. Under an acceleration of 0.5g, Prototype A achieved a maximum load power of 91.56 μW across a 405 Ω load at 327 Hz, while Prototype B delivered a higher maximum load power of 182.78 μW at 338 Hz. Prototype B demonstrates a wider operational bandwidth and higher output voltage compared to Prototype A under similar experimental conditions. These results indicate that the damping ratio and resonance frequency significantly influence the output voltage of electromagnetic vibration energy harvesters

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