Piezoelectric silicon energy harvester

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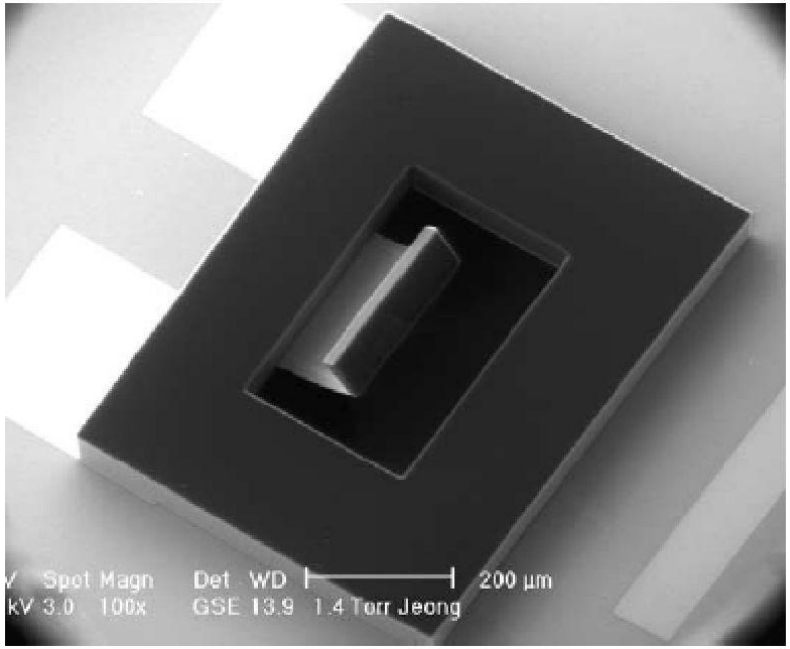
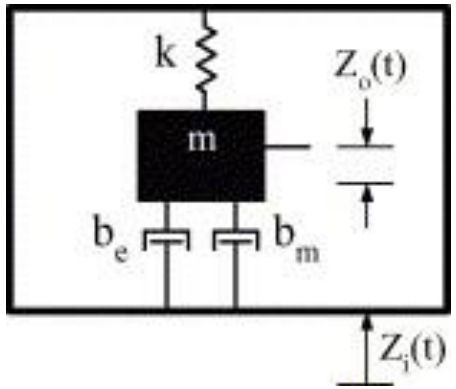
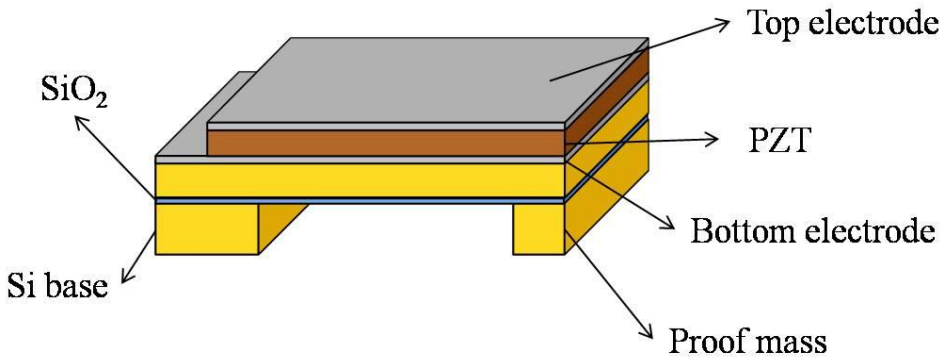
History and actual status



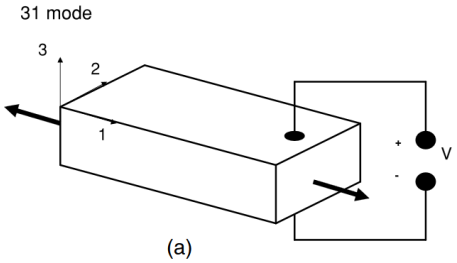
First MEMS based micro-scale power generator

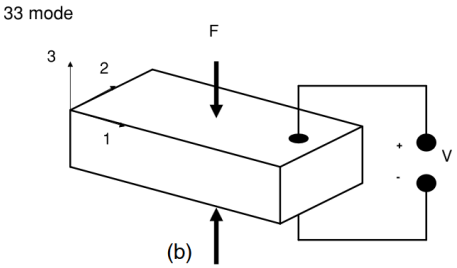
MEMS operation principle

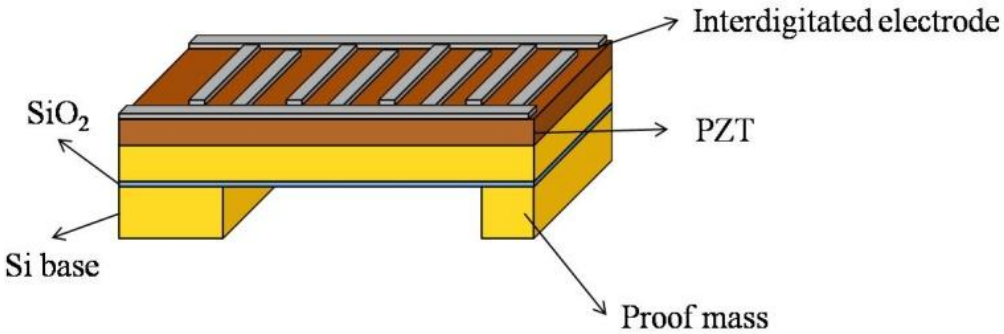




d_{31} mode

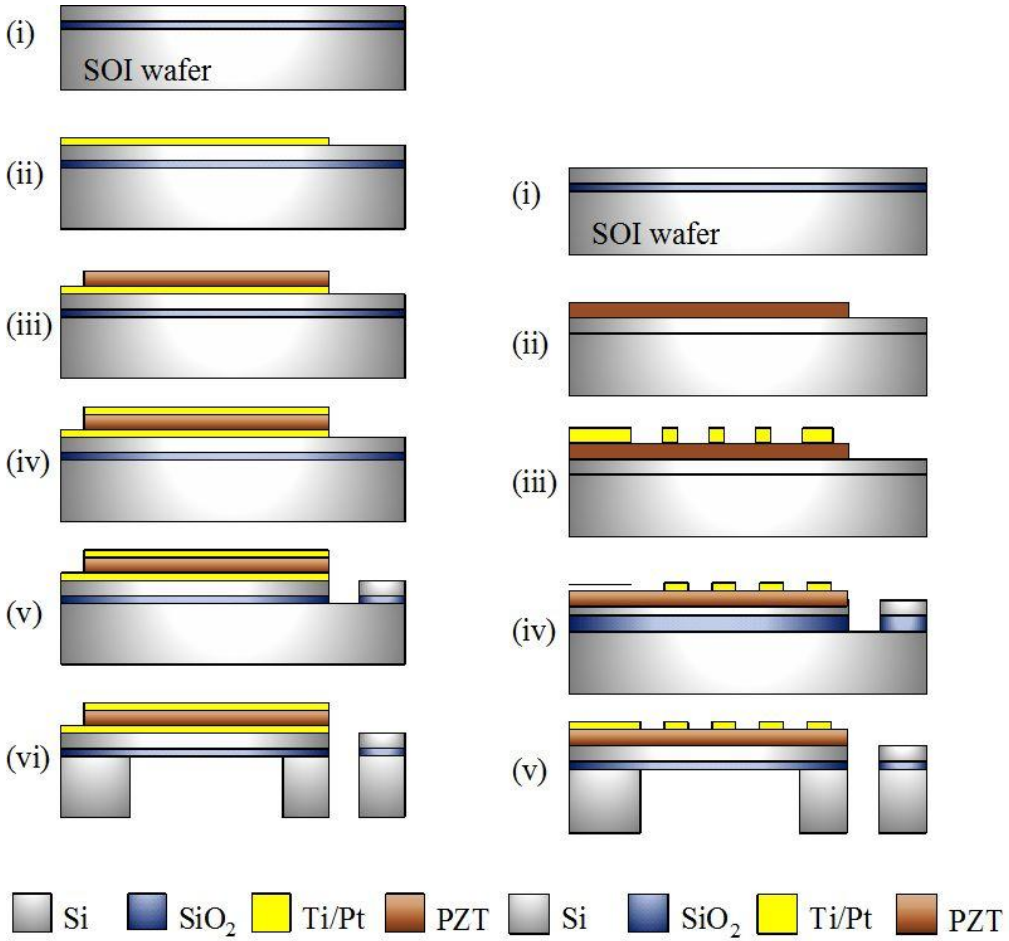






d_{33} mode

MEMS implementation



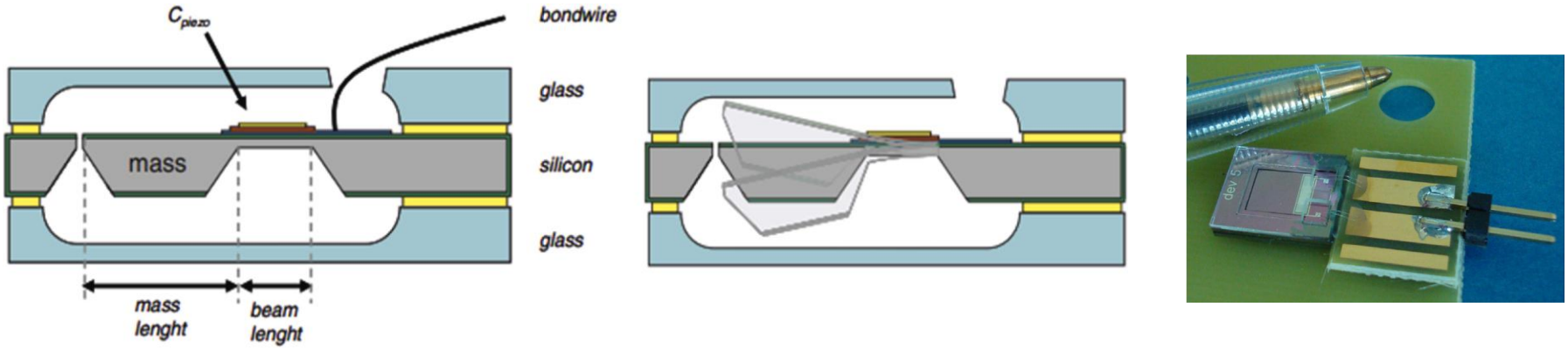
Fabrication processes of d_{31} (left) and d_{33} (right) devices

Characteristics

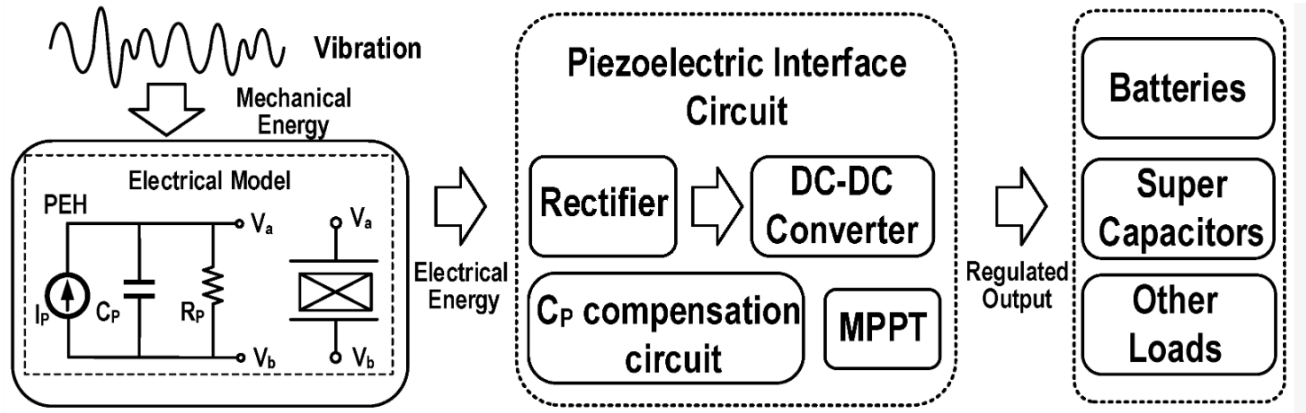
Piezoelectric materials	PZT, AlN, ZnO, BaTiO3, PVDF, KNN
Active area (mm^2)	0.96 - 120
Active volume (mm^3)	0.02 - 20.9
Acceleration (g)	0.2 - 4.0
Frequency (Hz)	76 - 1300
Power (μW)	0.63 - 205
Power density (μW/mm^3)	0.23 - 1100

Source: Kim et al., 2012, https://www.cambridge.org/core/journals/mrs-bulletin/article/abs/piezoelectric-mems-for-energy-harvesting/C4A013AC60BD7CA616D5F1ADC75E1DCA

Packaging and systems integration



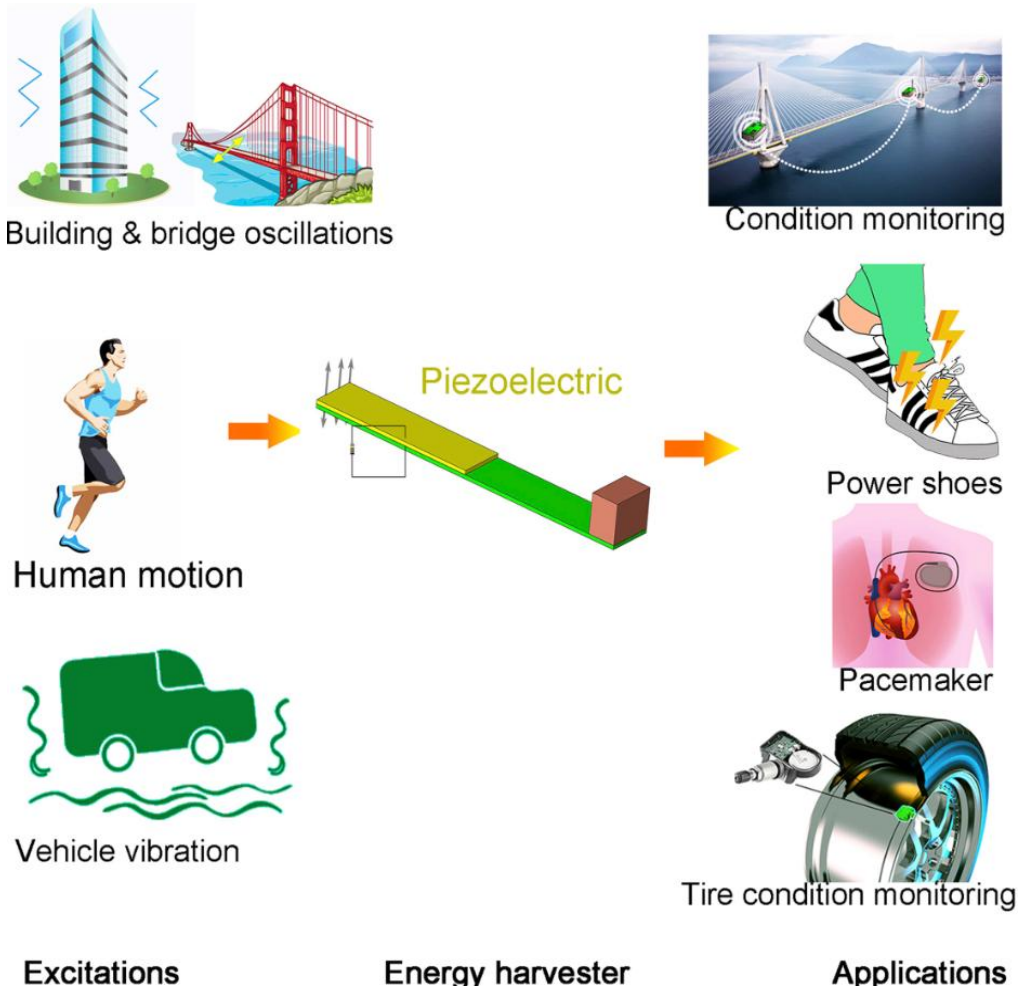
1) Typical piezoelectric energy harvester structure.



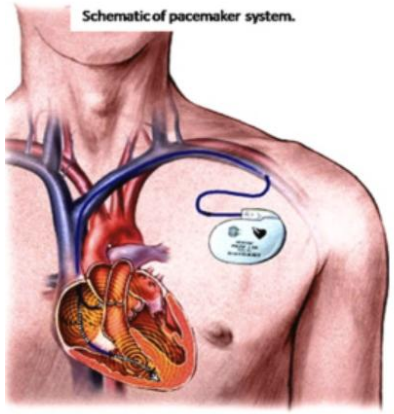
2) Block diagram of the piezoelectric energy harvesting system.

Sources: 1) Elfrink et al., 2009, https://iopscience.iop.org/article/10.1088/0960-1317/19/9/094005
2)Y. Yang et al., 2022, https://www.mdpi.com/2072-666X/13/7/1044

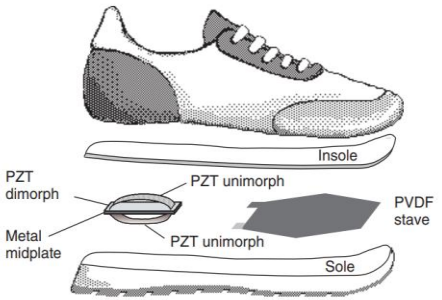
Products and current applications



1) The Typical Energy Harvesting Operation Process



2) Self-charging pacemaker



3) Piezoelectric-powered shoes

Sources: 1) Z. Yang et al. 2018, https://www.cell.com/joule/fulltext/S2542-4351%2818%2930126-0
2) Imran Hossain et al., 2023, https://www.sciencedirect.com/science/article/pii/S2590123023003912
3) Paradiso et al., 2001, https://resenv.media.mit.edu/pubs/papers/2001-Shenck-Paradiso.pdf

References

- **Cook-Chennault et al., 2008,** https://deepblue.lib.umich.edu/bitstream/handle/2027.42/64168/sms8_4_043001.pdf?sequence=1
- **Q. He et al., 2024,** https://pubs.acs.org/doi/10.1021/acsami.3c17037
- **Kim et al., 2012,** https://www.cambridge.org/core/journals/mrs-bulletin/article/abs/piezoelectric-mems-for-energy-harvesting/C4A013AC60BD7CA616D5F1ADC75E1DCA
- **Elfrink et al., 2009,** https://iopscience.iop.org/article/10.1088/0960-1317/19/9/094005
- **Y. Yang et al., 2022,** https://www.mdpi.com/2072-666X/13/7/1044
- **Z. Yang et al. 2018,** https://www.cell.com/joule/fulltext/S2542-4351%2818%2930126-0
- **Imran Hossain et al., 2023,** https://www.sciencedirect.com/science/article/pii/S2590123023003912
- **Paradiso et al., 2001,** https://resenv.media.mit.edu/pubs/papers/2001-Shenck-Paradiso.pdf
- **Jeon Y. B., Sood R., Jeong J. H., Kim S. G. (2005).** MEMS power generator with transverse mode thin film PZT. Sensors and Actuators A: Physical, 122(1), 16.
- **W. Jong & B. Shiun (2012).** Piezoelectric MEMS Power Generators for Vibration Energy Harvesting. Small-Scale Energy Harvesting, InTech. DOI: 10.5772/51997.
- **S. Roundy, P.K. Wright, & J. Rabaey.** A study of low-level vibrations as a power source for wireless sensor nodes.