DTU Nanotech
Department of Micro- and Nanotechnology

Design, fabrication and characterization of piezoelectric power harvesters realized with silicon micromachining and screen-printing technologies

M. Guizzetti*, T. Zawada*, K. Hansen*, R. Xu, A. Lei**, A. C. Stoot**, A. Thyssen**, O. Hansen**, E.V. Thomsen**, K. Birkelund****

*CTS | Ferroperm, Denmark,

**Department of Micro- and Nanotechnology, Technical University of Denmark, DTU Nanotech, Kgs. Lyngby, Denmark

Introduction

- In the last years a lot of attention has been focused on the possibility to harvest free energy from the environment and convert it into electrical energy for powering wireless sensors [1-2]. This allows to avoid the use of batteries, realizing an autonomous system that can theoretically operate indefinitely without requiring maintenance and costs for batteries replacement. Among the different low grade power sources freely available in the environment, sunlight, mechanical vibrations and thermal gradients are considered the most [3]. The presented work focuses on mechanical vibrations due to their widespread diffusion (industrial machines, buildings, infrastructures, aircraft, automotive, human movement). Mechano-electric energy conversion can be performed exploiting different principles (electromagnetic, electrostatic and piezoelectric). Piezoelectric effect is the most promising for the high power density, wide availability of fabrication technologies, miniaturization capability and silicon technology compatibilty, allowing to realize small power sources [4].
- In this work piezoelectric MEMS (MicroElectroMechanical Systems) devices have been designed, fabricated and characterized, as vibration power harvesters. The devices have been realized using silicon micromachining technology, in combination with PZT thick films that have been deposited by a screen-printing technique.

Power harvesters fabrication

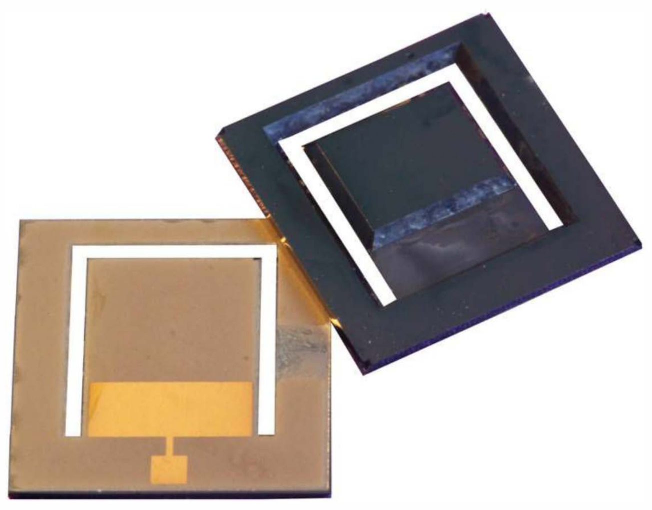

Fig. 1. Realized power harvester device

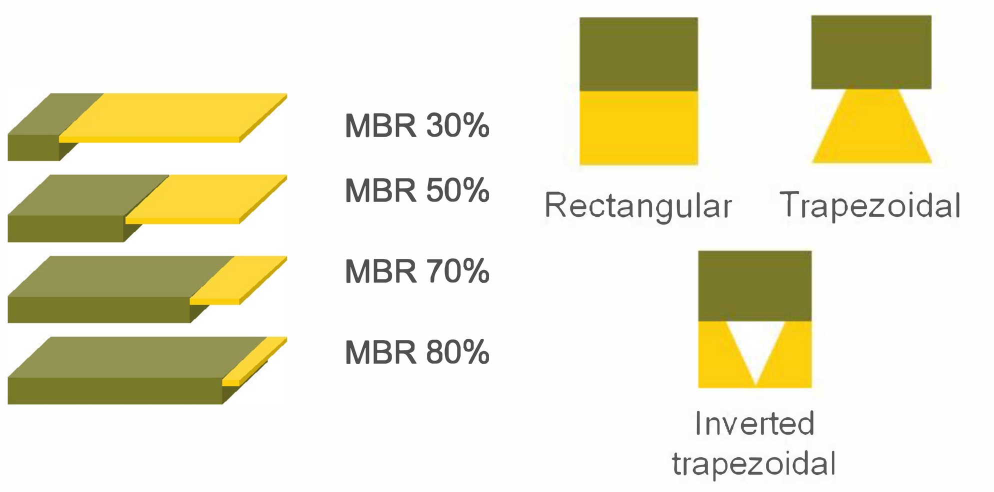

Fig. 2. Mass-beam lenght ratios and shapes used for the harvesters.

- The designed harvesters consist of silicon cantilevers fixed at one end having a silicon proof mass at the opposite end (Fig. 1). The devices have a total planar dimension of 10x10 mm^2, while the mass-beam length ratio (MBR) was varied from 30% to 80% (Fig. 2). A bottom electrode has been used as a diffusion barrier as well. On the top of it PZT thick film has been screen-printed.
- Rectangular, trapezoidal and inverted trapezoidal cantilever shapes have been designed comparing their power conversion performances (Fig. 2).

Experimental results

- The devices were glued to PCB fixtures and then mounted on a shaker, imposing a sinusoidal vertical acceleration at the base of the cantilever. A reference accelerometer was fixed to the shaker in order to measure the vertical acceleration. All the measurements were performed with the amplitude of the acceleration set at 0.5 *g* with the device working at the resonance frequency.
- Typical values for the measured capacitance of the devices vary from 1.0 nF to 5.8 nF, resulting in equivalent internal impedances from 110 kΩ to 2200 kΩ. The generated charge was measured obtaining charge sensitivities up to 37 nC/*g*. The open-circuit output voltage was also measured by means of a high-input buffer obtaining amplitude values up to 3 V. Measured maximum output power is in the range 12 μW ÷ 16 μW, while resonance frequency varies from 75 Hz to 250 Hz.
- The best performances have been obtained with the rectangular shape having a MBR of 50% and 70%. The devices with MBR of 50% generate a higher output charge (Fig. 3) while those with MBR of 70% have a higher output voltage (Fig. 4). The lower resonance frequency is given by the trapezoidal and inverse trapezoidal shapes while considering the rectangular devices it is obtained with a mass-beam length ratio of 50%.

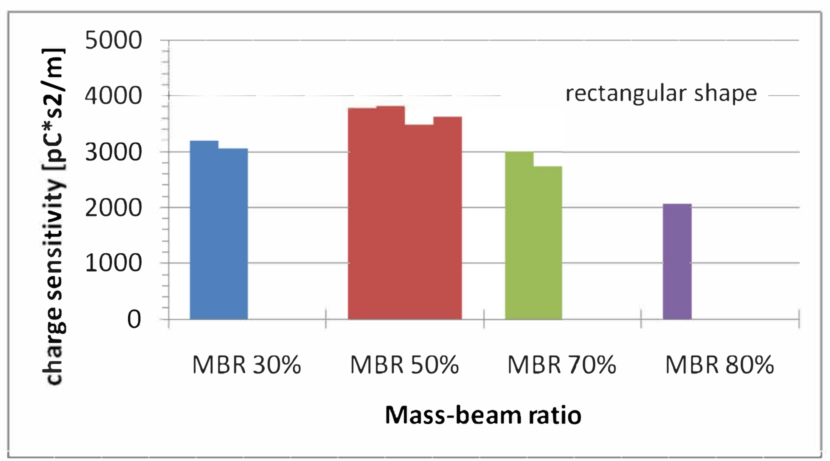

Fig 3. Measured charge sensitivity for rectangular shape harvesters versus mass-beam length ratio, at the resonance.

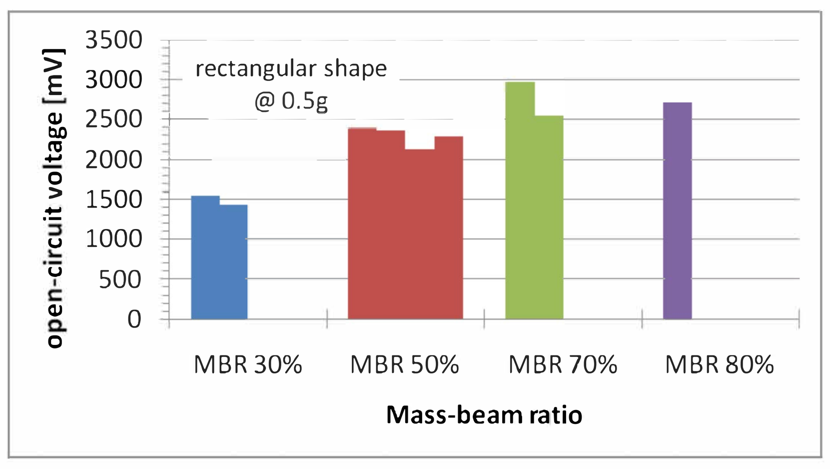

Fig 4. Measured open-circuit output voltage for rectangular shape harvesters versus mass-beam length ratio, at the resonance.

Summary and conclusions

- PZT thick film based power harvesters were designed, fabricated and tested as vibration power harvesters. Fabrication was done by means of silicon micromaching technology and screen-printing technique.
- Rectangular shape harvesters with mass-beam length ratio of 50% and 70% gave the best performances in terms of output power.
- Open-circuit output voltages and output powers up to 3 V and 16 μW respectively were obtained, exciting the harvesters at the resonance with an acceleration of 0.5 *g*.

References

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[4] K. A. Cook-Chennault et al., "Powering MEMS portable devices - a review of non-regenerative and regenerative power supply systems with special emphasis on piezoelectric energy harvesting systems", Smart Materials and Structures vol 17, 2008, pp. 1-33.

Acknowledgements

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