VIBRATIONAL ENERGY HARVESTING MICROGENERATORS BASED ON PIEZOELECTRIC THICK FILMS AND MEMS

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Summary
Energy harvesting spans a large variety of technologies and devices that transform low-grade energy sources such as solar energy, environmental vibrations, thermal energy and human motion into usable electrical energy. In this work the energy source is vibrations that are transformed by the energy harvesting micro-generator into a usable electrical signal. The micro-generator comprises a silicon cantilever with integrated PZT thick film deposited using screen printing. The results reported here include generated power versus excitation frequency, and the influence of parameters such as presence and value of a proof mass located at the tip of the cantilever, value of the electrical load resistance and shape of the cantilever (e.g., rectangular or trapezoidal). Furthermore, devices based on pressure treated thick film materials are tested and compared with the standard commercial InSensor® PZT thick films. It is found that the structures based on the pressure-treated materials exhibit superior properties in terms of energy density.

Motivation and results
The development towards smaller devices with more functions integrated calls for new and improved manufacturing processes. The screen-printing process is quite well suited for miniaturised and integrated devices, since thick films can be produced in this manner without the need for further machining. As an example of such a miniaturised device, a MEMS accelerometer based on PZT thick film has been presented in the past [1]. Due to the rapid development of ultralow-power electronic devices, the energy harvesting technology has become a very attractive solution for a wide variety of applications, e.g. structural health monitoring, embedded test & evaluation, and condition based maintenance of roads, buildings, ground vehicles and aircraft [2].
The presented energy harvesting device comprises a silicon cantilever, bottom electrode, PZT thick film and top electrode. Examples of dimensions are given in Fig. 1. The sample has been clamped at one end and mounted on a mechanical shaker, imposing a sinusoidal acceleration at the base of the cantilever (Fig. 2). Structures of the same shape and dimensions have been manufactured using two kinds of PZT thick film, standard grade and high-performance (pressure-treated) grade, in order to directly compare the performance of the materials (Fig. 3). The conclusion of this comparison is that the device based on high-performance PZT thick film produces a constant output power that is significantly higher (by a factor of up to 3.7) than the standard one. This is also supported by a theoretical analysis, where the output power of a flexural energy harvesting device is proportional to $(d_{31})^2/\varepsilon_r$ where d_{31} and ε_r are the transversal piezoelectric charge coefficient and the dielectric permittivity of the piezoelectric thick film, respectively. The influence of the seismic mass on the output power is also studied experimentally and the results are presented in Fig. 4. By optimising the geometry, a charge sensitivity of up to 3 nC s^2 m^{-1} has been obtained, whereas the maximum open-circuit voltage and output power (at optimal load) measured at resonance were 3.9 V and 16 µW, respectively. These values were obtained with a rectangular cantilever with a mass-beam length ratio of 70 %.

References
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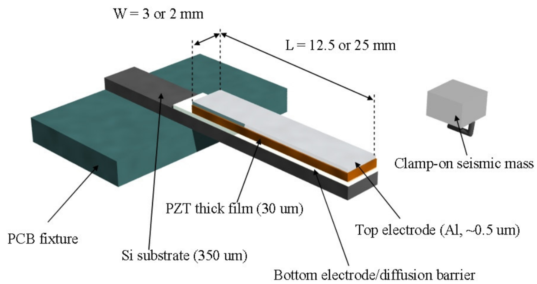

Fig. 1. General structure of the cantilever-shaped energy harvesting generators.

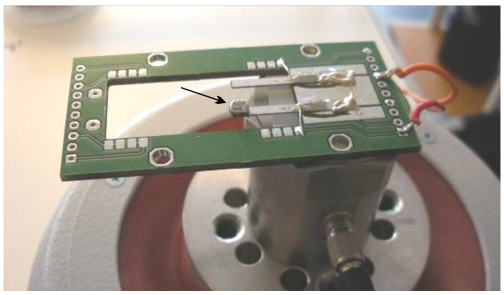

Fig. 2. Measurement setup, showing the test fixture with two cantilevers mounted on the shaker system, one of them with visible clamp-on seismic mass.

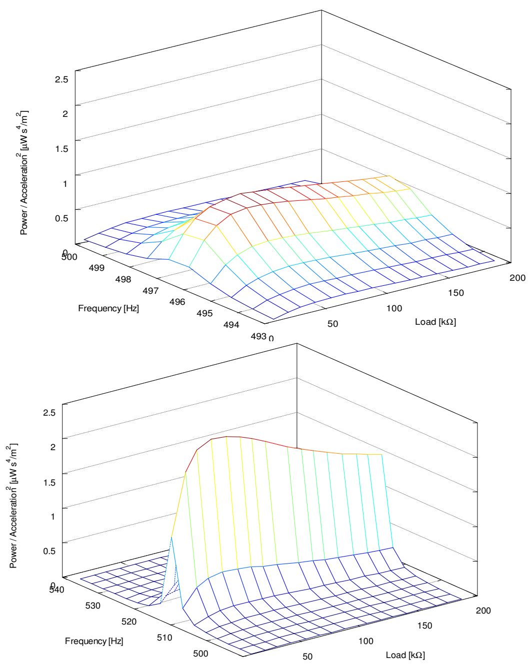

Fig. 3. Normalised power output (RMS) as a function of the excitation frequency and resistive load, for 12.5x2 mm^2 structures based on standard PZT (top) thick film and high-performance thick film (bottom).

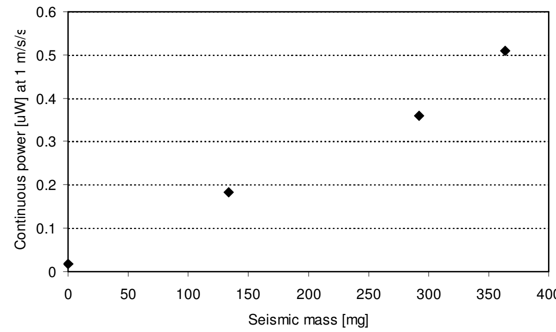

Fig. 4. Output power vs. seismic mass at 1 m/s^2 of bending element based on PZT standard thick film.