PZT thick film energy harvesting devices – modelling and preliminary experimental results

Guylaine Poulin[1], Tomasz Zawada[2], Rasmus Lou-Moeller[2]

[1] LUSSI (Univ. of Tours, CNRS FRE 2448), Rue de la chocolaterie, BP3410, 41034 Blois cedex, France
[2] InSensor A/S, Hejreskovvej 18A, Kvistgaard, DK-3490, Denmark

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ABSTRACT

Over the past ten years, the concept of harvesting mechanical energy in human environment has been arousing renewed interest in powering electronic devices whose power consumption is under continuous improvement due to introduction of ultra low power solutions. The demand for renewable electrical energy sources is also increasing in applications such as consumer electronics, medical electronics (hearing aids, pacemakers, smart implants) or medical imaging (intra-body inside the human body). Finally, harvesting the vibration of industrial machinery can supply wireless sensors located in places where human intervention for replacement batteries is difficult or impossible.

Piezoelectric materials are better suited to miniaturization than conventional technologies such as electromagnetic or electrostatic generators, which have lower power densities and are more difficult to integrate into microsystems. The feasibility of energy harvesting using piezoelectricity has been already demonstrated, but three major difficulties can be identified as follows: the choice of the piezoelectric material best suited for a given mechanical source and electrical load; the design of the vibrating structure (geometry and vibration mode); efficient energy conversion electronics. The two first items will be presented in this paper, through a theoretical and experimental study of a PZT thick film on Silicon based energy harvesting device.

The presented energy harvesting device comprises a Silicon cantilever with the dimensions equal to 25x3 mm^2 (160 µm thick), bottom electrode, PZT thick film (40 µm thick) and top electrode. The sample has been clamped at one end and mounted on a shaker, imposing a sinusoidal acceleration at the base of the cantilever. The generated power versus frequency of the excitation has been investigated. The influence of different parameters has been studied: presence and value of a proof mass located at the tip of the cantilever, influence of the level of excitation, impact of the electrical load. The obtained results have been compared with the existing ones basing on the value of power density. For the presented piezoelectric energy harvesting device the ratio is significantly higher than those of other reported solutions, showing outstanding performances of the PZT thick film based device.

The devices have been studied using analytical and numerical models. The obtained theoretical results stay in a very good agreement with the measurements. Therefore the optimization of the design can be carried out in order to maximize the electrical power and/or the life time of the device. In particular, two different designs are proposed in response to two distinct specifications: the frequency of the mechanical excitation is low (e.g. human movement) or relatively high (e.g. ambient vibration).

It must be pointed out that the obtained theoretical as well as the experimental results confirm that the PZT thick film technology is a very attractive alternative to the other piezoelectric solutions in the field of energy harvesting, and especially suited for integration with MEMS or other microsystem technologies.