Self-sustained thermally induced gas-damped oscillations of bimetal cantilevers with application to the design of a new pyroelectric micro energy harvester

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Low efficiency is the main drawback of many MEMS thermal energy harvesters. Recently, energy harvesting micro-devices that operate using the pyroelectric effect gained attention due to their potential superior performance. Operation of these devices is based on the cyclic motion of a pyroelectric capacitor that operates between a high temperature and a low temperature reservoirs. In this paper, we investigate the dynamics of oscillations of a pyroelectric capacitor self-sustained by thermally actuated bimetal micro-cantilevers, a topic which is so far under investigated. In addition to highlighting key thermodynamic aspects of the operation, we explore conditions for self-sustained oscillations and discuss the viability of operation at the mechanical resonance frequency. The analysis is presented for a new design inspired by the device proposed in Hunter *et al* (2011 *SPIE Defense, Security, and Sensing* (International Society for Optics and Photonics) p 80350V); Hunter *et al* (2012 *SPIE Defense, Security, and Sensing* (International Society for Optics and Photonics) p 83770D), where in contrast, our proposed design boasts the following features: the pyroelectric capacitor remains parallel to the heat reservoirs, by virtue of its symmetric support by two bimetallic cantilever beams; in addition, the cyclic operation of the device does not require physical contact, thus lowering the risk of mechanical failure. To adjust the damping force imparted by the surrounding gas, the thermal reservoirs are equipped with trenches. To study the dynamic operation of the device, we developed a physically based reduced order, yet accurate, model that accounts for the heat transfer between and within the different components, and for the various forces including the gas damping force. The model is embedded within an optimization algorithm to produce optimal designs over the range 26 °C–38 °C of temperature difference between the two reservoirs. The corresponding range of harvested power density is 0.4–0.65 mW cm^{-2}.