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MICRO CANTILEVER ELECTROSTATIC ENERGY HARVESTER

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ABSTRACT

In this paper, we present a SDOF model of an energy harvester made up of microcantilever beams with tip mass. We investigate performance utilizing electrostatic actuation mechanism resulted from an electret layer patterned underneath the tip mass. The excitation force is transferred to cantilever beams through the vibration of the fixed end, i.e. the base of the beam. The model accounts for the mechanical and electric parameters as well as the coupling between them, and it includes design parameters by lumping them into nondimensional quantities, thereby allowing an easier understanding of their effects and the interaction between the mechanical and electric forces. We study the static behavior of deflection and electric charge as a function of the DC static voltage. In addition, we simulate the dynamic response, generate the frequency-response curves for a variety of conditions, and notice nonlinear effects.

1 Introduction

Development of wireless sensors has been a focus of several research groups. Many mechanisms of ambient energy harvesting have been investigated. These mechanisms can be categorized into solar energy, thermoelectric, acoustic, and mechanical vibrations. Mechanical vibration harvesters can be divided into two groups: non-resonant (low frequency vibrations) and resonant devices. For vibration energy harvesting, there are mainly three conversion mechanisms; electrostatic, electromagnetic, and piezoelectric. The power gained varies significantly based on structure size, type, and input vibration conditions. The biggest advantage of electrostatic converters is their potential for integration with microelectronics. Silicon micromachined electrostatic transducers are the backbone of MEMS technology. MEMS transducers use processes very similar to microelectronics. Therefore, because of the process compatibility, it is easier to integrate electrostatic converters based on MEMS technology than either electromagnetic or piezoelectric converters. Another advantage is that, unlike electromagnetic converters, appropriate voltages for microelectronics, on the order of two to several volts, can be directly generated.

Many of electrostatic micro power generators (MPGs) use electrets to induce charges stored in the capacitor and eliminate the need for an initial charge. Boland et al. [1] miniaturized an electret-based generator proposed by Tada [2], and the device output power is 25μW. Sterken et al. [3] proposed and fabricated an electret-based MPG using comb-finger variable capacitors and a 50μW output power was predicted.

Tsutsumino et al. [4, 5] developed an electrostatic MPG using electret-based parallel-plate capacitors. Using rectangular electrodes, $10 \times 20\text{mm}^2$, they realized maximum output power of 278μW. Edamoto et al. [6] constructed a fully functioning MPG by combining this electric system with a mechanical system. The movable electrodes were attached to an inertial mass suspended from soft parylene springs to create a low-frequency resonator [7]. The simulated output power was 12.5μW but it dropped to 0.28μW in th experiment due to fabrication-related reasons [8]. Mahmoud et al. [9] proposed another implementa-