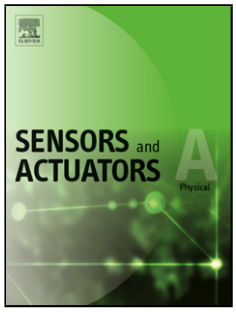

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Nonlinear Piezoelectric Energy Harvester with Ball Tip Mass

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HIGHLIGHTS

- A nonlinear piezoelectric energy harvester with a ball tip mass is proposed.
- The conventional structure that has a rigid tip mass performs relatively poorly.
- The proposed structure exhibits two resonant frequencies.
- These frequencies enable the structure to harvest considerable electrical energy.

Abstract

In this study, a nonlinear piezoelectric energy harvester (PEH) with a ball tip mass was designed and fabricated for broadband energy harvesting. The proposed nonlinear PEH exhibits two resonant frequencies (5 and 15 Hz) and can harvest a considerable amount of electrical energy, whereas a conventional PEH with a rigid tip mass only exhibits one (15 Hz). The minimum acceleration that can induce nonlinearity in the proposed PEH was determined to be 3 m s^{-2}. In order to maximize the electrical output of the proposed PEH, 0.1 mm was selected as the optimal vibration amplitude of the ball among three options (0.1, 0.5, and 1.0 mm). The maximum output power of the proposed PEH was measured as 13.5 mW at 15 Hz and at a load resistance of 30 kΩ, which is the matching load resistance calculated and verified with the experimental result. The output power of the proposed PEH was measured to be 1.8 mW at 5 Hz and 45 kΩ, whereas that of the conventional PEH at 5 Hz was 0.03 mW, implying that the proposed PEH possesses one additional resonant frequency over the conventional PEH. In addition, the proposed PEH performs significantly better than the conventional PEH in terms of broadband energy harvesting. At a power level of 100 μW, the proposed PEH at 3 m s^{-2} provides a bandwidth of 20 Hz, which is more than 133% wider than the 15 Hz provided by the conventional PEH. By utilizing the nonlinearity with a ball tip mass, the PEH vibration is capable of harvesting considerable electrical energy from more than two resonant frequencies.

Keywords: Energy harvesting; Piezoelectric materials; Vibration energy harvesting; Nonlinearity; Broadband; Tip mass