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Acoustic Energy Harvesting Using Polyvinylidene Fluoride (PVDF) and PVDF-ZnO Piezoelectric Polymer

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Abstract : Acoustic energy that exists in our everyday life and environment have been overlooked as a green energy that can be extracted, generated, and consumed without any significant negative impact to the environment. The harvested energy can be used to enable new technology like wireless sensor networks. Technological developments in the realization of truly autonomous MEMS devices and energy storage systems have made acoustic energy harvesting (AEH) an increasingly viable technology. AEH is the process of converting high and continuous acoustic waves from the environment into electrical energy by using an acoustic transducer or resonator. AEH is not popular as other types of energy harvesting methods since sound waves have lower energy density and such energy can only be harvested in very noisy environment. However, the energy requirements for certain applications are also correspondingly low and also there is a necessity to observe the noise to reduce noise pollution. So the ability to reclaim acoustic energy and store it in a usable electrical form enables a novel means of supplying power to relatively low power devices. A quarter-wavelength straight-tube acoustic resonator as an acoustic energy harvester is introduced with polyvinylidene fluoride (PVDF) and PVDF doped with ZnO nanoparticles, piezoelectric cantilever beams placed inside the resonator. When the resonator is excited by an incident acoustic wave at its first acoustic eigen frequency, an amplified acoustic resonant standing wave is developed inside the resonator. The acoustic pressure gradient of the amplified standing wave then drives the vibration motion of the PVDF piezoelectric beams, generating electricity due to the direct piezoelectric effect. In order to maximize the amount of the harvested energy, each PVDF and PVDF-ZnO piezoelectric beam has been designed to have the same structural eigen frequency as the acoustic eigen frequency of the resonator. With a single PVDF beam placed inside the resonator, the harvested voltage and power become the maximum near the resonator tube open inlet where the largest acoustic pressure gradient vibrates the PVDF beam. As the beam is moved to the resonator tube closed end, the voltage and power gradually decrease due to the decreased acoustic pressure gradient. Multiple piezoelectric beams PVDF and PVDF-ZnO have been placed inside the resonator with two different configurations: the aligned and zigzag configurations. With the zigzag configuration which has the more open path for acoustic air particle motions, the significant increases in the harvested voltage and power have been observed. Due to the interruption of acoustic air particle motion caused by the beams, it is found that placing PVDF beams near the closed tube end is not beneficial. The total output voltage of the piezoelectric beams increases linearly as the incident sound pressure increases. This study therefore reveals that the proposed technique used to harvest sound wave energy has great potential of converting free energy into useful energy.

Keywords : acoustic energy, acoustic resonator, energy harvester, eigenfrequency, polyvinylidene fluoride (PVDF)
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