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Development of Power Generation in Piezoelectric Energy Harvesting with Array Configurations

アレイ構造化による圧電振動発電装置の効率改善

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1. Introduction

In an energy harvesting system using piezoelectric materials, mechanical energy can be converted to electrical energy through the piezoelectric effect [1]. The aouthors have reported an energy harvesting using a vibration of piezoelectric polyurea thin films which can be fabricated on the micro array structure, and the experimental results implied that the higher energy density as an electric generator can be obtained with the shorter cantilever element of the polyurea film [2]. In this report, to realize the piezoelectric energy harvesting device with the larger volume energy density, the piezoelectric energy harvesting with array configurations was investigated.

2. Finite element analysis of piezoelectric energy harvesting with array configurations

The converted output electrical power generated through a mechanical vibration of a piezoelectric cantilever element was calculated via a finite element analysis (FEA). **Fig. 1** shows the simulation model of the FEA. The piezoelectric cantilever consists of a 1-mm-thick PZT plate with the length of l and width of w and an aluminum plate with the same configuration. The one end of the aluminum plate was fixed so that the element acts as a cantilever. A load resistance R_L and an input impedance (=1MΩ) of the oscilloscope for the voltage measurement were connected in parallel to the PZT plate. By applying the forced harmonic vibration in the vertical direction (z-direction in figure) at the fixed end, the power consumption on the load resistance can be calculated as the output power. To examine the efficiency of array configuration, the output powers of the devices with the variety of different array configurations were calculated. **Fig. 2** shows the relationship between the load resistance and the output power with several cantilever configurations calculated by the FEA. Output powers were calculated at each fundamental resonance frequency of cantilever, and the same vibration velocity was applied. The calculated results indicate the total output power in the same area, e.g., the output power on the element

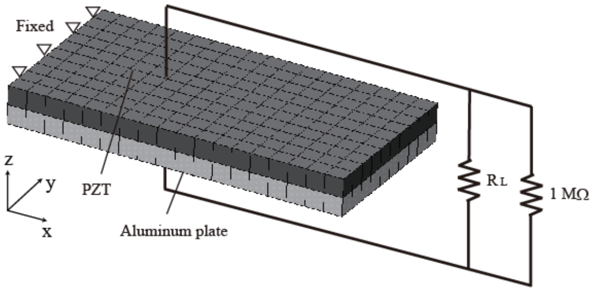

Fig. 1 Simulation model of the FEA.

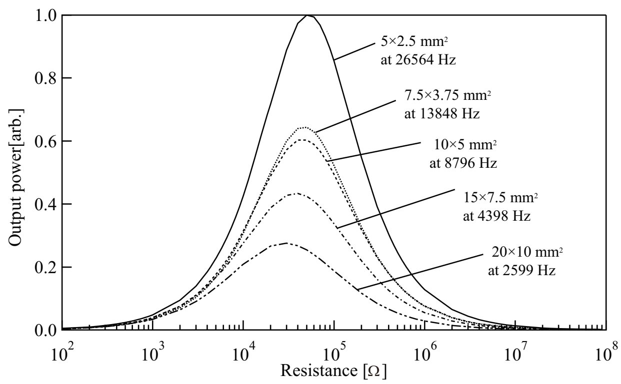

Fig. 2 Relationship between the load resistance and the output power calculated by the FEA.

with the area of 10×5 mm^2 was multiplied by 4 to compare with that on the element with 20×10 mm^2 since the area ratio is 1:4. The computed results imply the larger output power can be obtained with the smaller array configuration. The output power on the array configuration of cantilevers with 5×2.5 mm^2 is approximately 3.6 times larger than that of 20×10 mm^2.

3. Comparison of power generation with array configurations

Electric power generations of the piezoelectric cantilevers with different array configurations were compared. The configurations of the arrayed cantilevers were illustrated in **Fig. 3**. Two array configurations were employed: the larger

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one has two longer cantilevers with the area of 18×9.5 mm^2 and the smaller one has eight shorter cantilevers with the area of 9×4.25 mm^2. The thickness of aluminum cantilevers and PZT plates in two configurations were both 1 mm. The fixed end of the cantilevers was attached to an 11-mm-thick rectangular aluminum block to generate the fundamental flexural vibration mode along the cantilever. The harmonic vibration in the vertical direction was applied by a vibration generator, and the output voltage on the load resistance was measured by an oscilloscope whose input impedance of 1 MΩ through a voltage probe. The frequency characteristics of output voltage of the large array configuration with the load resistance of 10 MΩ are shown in **Fig. 4**. The vibration velocity of 1.25 mm/s was applied over measuring frequency and the output voltages of two cantilevers were shown. The resonance frequencies of two cantilevers corresponded and were approximately 2.05 kHz. Likewise, the resonance frequency of the small array configuration was 6.0 kHz. The output voltage was proportional to the applied vibration velocity. At these resonance frequencies, the output power was measured with varying the load resistance. **Fig. 5** shows the relationship between the load resistance and the output power with the vibration velocity of 0.7 mm/s. The computed results by the FEA were also shown. The experimental and calculated results show the same tendency: the optimal values of load resistance on the large and small array configurations were 39 and 51 kΩ, respectively, and the higher output power could be obtained with the smaller array configuration. The maximum output power of 2.8 mW was achieved. The difference between the experimental and computed results in the large configuration is attributed to the immobilization condition on the cantilever.

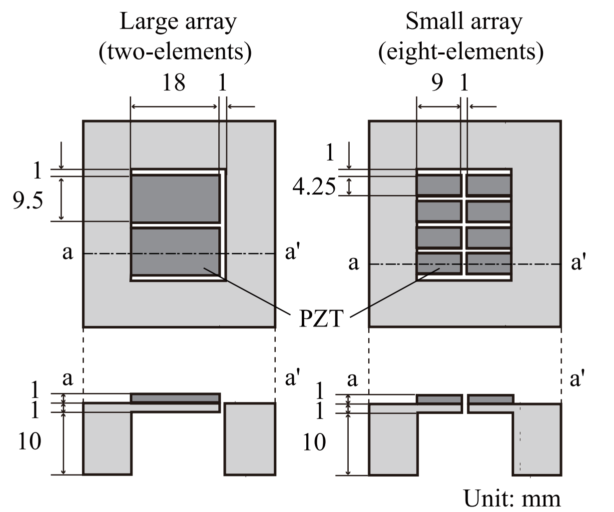

Fig. 3 Configurations of the arrayed cantilevers with PZTs.

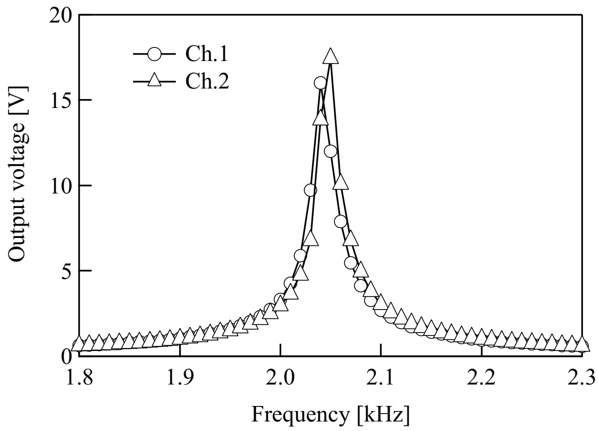

Fig. 4 Frequency characteristics of output voltage with the large array configuration.

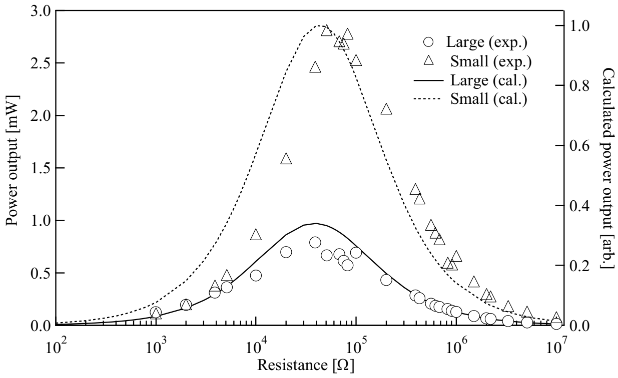

Fig. 5 Relationship between the load resistance and the output power of the large and small array configurations

4. Conclusions

Piezoelectric energy harvesting with the array configurations was discussed. The power generation efficiency of array configurations was calculated by the FEA, and the result implied the larger power can be obtained with the shorter cantilevers. Experiments were carried out with the piezoelectric arrayed cantilevers which consist of the PZT elements and aluminum plates. The experimental and computed results showed a good agreement, and the larger power could be obtained with the smaller array configuration.

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