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Development of a Plate-type Ultrasonic Waveguide for Cooling Applicaions

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Abstract
Recently, microchip cooling incorporating ultrasonics has been studied elsewhere [1-3]. However these researches included increasing passive cooling effect by enhancing the convective heat transfer coefficient. In this paper, an ultrasonic waveguide for microchip cooling, which can be operated by 37.0 kHz frequency, was designed and fabricated for active cooling applications. In the development stage of the system, finite element analysis using ANSYS software was performed to design the waveguide. The predicted anti-resonance frequency value for a piezoelectric actuator with a cylindrically shaped aluminium (Al) waveguide, was 34.8 kHz, which was used as a design frequency. The system was fabricated using the results, and impedance characteristics were measured. As a result, the predicted anti-resonance frequency for the ultrasonic waveguide was also 34.8 kHz, which agreed well with the experimentally obtained value of 37.0 kHz with 6% error. considering these results, it is regarded that the developed ultrasonic waveguide can be applied to microchip cooling.

Keywords: Ultrasonic; Finite element method (FEM); Microchip cooling

1. Introduction

Until now, electronic chip cooling using ultrasonics has been investigated [1-3]. But previous researches are mainly dealing with increasing passive cooling effect by enhancing the convective heat transfer coefficient.

In this research, an ultrasonic waveguide for electronic chip cooling that is operated by 37.0 kHz operating frequency, was designed and fabricated. This cooling is different from passive mechanisms but it can cool actively. For the development of the system, finite element analysis using ANSYS software was performed. The anti-resonance frequency for a piezoelectric actuator was predicted, the result was used as a design frequency. Additionally, impedance characteristics of the system were predicted. The system was manufactured based on the analysis results. Impedance characteristics were measured and compared with the finite element method (FEM) value. Finally, the application probability of the developed ultrasonic waveguide to microchip cooling is discussed.

Figure 1. Ultrasonic waveguide for microchip cooling

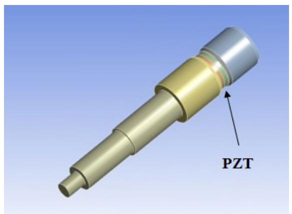

Figure 2. FEM analysis model of the PZT and the cylindrical waveguide

2. Plate-type ultrasonic waveguide for cooling

2.1. Working principle

The 37.0 kHz ultrasonic waveguide for cooling is mainly composed of two parts, the ultrasonic unit and the electric generator. The ultrasonic waveguide system is shown in Fig. 1. The ultrasonic waveguide is consisted of a cylindrically shaped aluminium (Al) waveguide and an Al circular plate on the top. Two lead zirconate titanate (PZT) actuator of ring shapes, are attached on the bottom. On the waveguide, a resonator and stacks can be installed, which can refrigerate. When power is supplied to the PZT actuator, the actuator vibrates and the displacement is transferred through the waveguide to the resonator part for cooling. in this work, the ultrasonic waveguide system is design and manufactured.

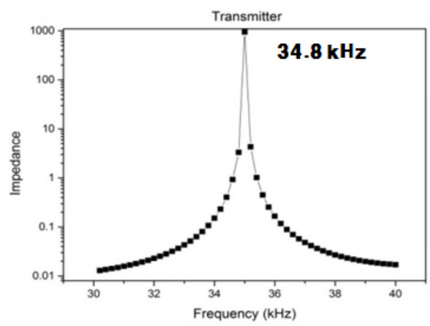

Figure 3. FEM result of the impedance graph for the PZT and the cylindrical waveguide

2.2. FEM design

The ultrasonic system was designed by FEM analysis using Ansys, which is commercial FEM software. At first, the PZT actuator with a cylindrical waveguide, was modeled with the analysis tool, as shown in Fig. 2. The analysis model was three-dimensional (3D) and the nodes of the top and bottom electrodes were coupled to apply voltages. And a series of calculations were performed from 30.0 kHz through 40.0 kHz. As a consequence, the highest impedance value was 34.8 kHz as shown in Fig. 3, which was decided as a design frequency.

Secondly, the whole system with the PZT actuator was modelled as shown in Fig. 4. The highest impedance value was also calculated as 34.8 kHz, which result is shown in Fig. 5.

At this time, displacement analysis was performed. Firstly, the PZT actuator and the waveguide were modeled. Modal analysis was performed and structural motion could be predicted. The FEM displacement analysis result at the operating frequency of 34.8 kHz is shown in Fig. 6. The red and bright part means high displacement, whereas, the blue and dark part low displacement.

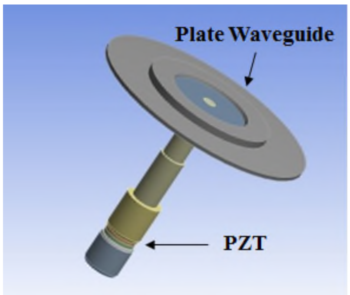

Figure 4. FEM analysis model of the system

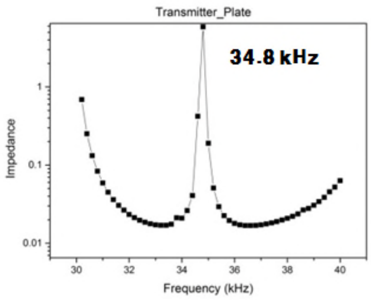

Figure 5. FEM analysis result of the impedance graph for the system

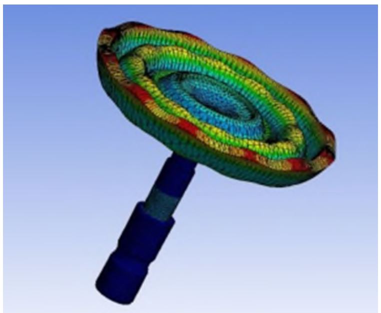

Figure 6. FEM displacement analysis result

3. Experiments

Using the analysis results, ultrasonic system was fabricated. The peak frequency value of impedance was measured to be 37.0 kHz of the system, which agreed well with predicted value with 6% error, as shown in Fig 7. This error is thought to be caused by machining accuracy. The system performance for dissipation of thermal energy will be investigated using the waveguide as a future work.

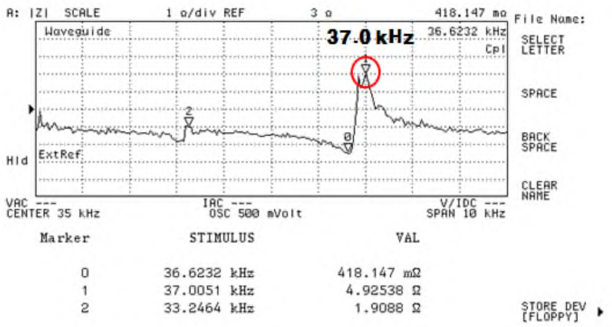

Figure 7. Experimental results of the impedance graph of the ultrasonic system

4. Conclusions

In this research, the ultrasonic waveguide for electronic chip cooling that is operated by 37.0 kHz operating frequency, was designed and fabricated for cooling actively. To develop the system, finite element analysis using ANSYS software was performed to design the waveguide. As a result, the predicted anti-resonance value of the piezoelectric actuator part with the cylindrical waveguide, was 34.8 kHz, which value was decided as the design frequency. After manufacturing the system, impedance characteristics were measured and compared. As a result, the predicted anti-resonance frequency for the ultrasonic waveguide was also 34.8 kHz, which showed good agreement with the experimental value of 37.0 kHz with 6% error. Reflecting the results, it is thought that the developed ultrasonic waveguide can be applied to microchip cooling.

References

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