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Proceedings of Symposium on Ultrasonic Electronics, Vol. 30 (2009) pp. 241-242
18-20 November, 2009

Mode Visualization System for Piezoelectric Resonators in High Temperature Environment
高温環境下における圧電振動デバイスのモード観測システム

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1. Introduction

Measuring the vibration mode shape is very important when designing piezoelectric resonators or vibration devices. Therefore, methods for plotting these mode shapes have been developed.(1-3) This paper describes a measurement system that has an ambient temperature change function and rapid mode visualization. A combination of a small oven with two transparent windows and a laser speckle interferometer(4-5) enables the visualization of the mode shapes of devices the under temperature changes.

2. Measurement system

A block diagram of the developed measurement system is shown in Fig. 1. The resonator is driven by a signal generator (SG), and the driving signal is tuned to the resonant frequency, which is changed by a software command. A charge-coupled device (CCD) video camera is used to capture the diffusion light component on the surfaces of samples. The LD's optical power and wavelength are 10 mW and 655 nm, respectively.

Vibration patterns are obtained as reciprocals of the correlation coefficients between the images of the resting and driving states. This system was improved so that the frequency synthesizer's output frequency automatically traces out the resonant frequency of the device under test even if the ambient temperature is changed.

A timing chart of the sample driving signal and image capture soft-triggers is shown in Fig. 2. The resonator sample is driven by an alternate frequency signal at the resonant and non-resonant frequencies of the sample. The video capture command is given 150 ms after the frequency change due to the frequency settling time of the signal generator and the resonator start-up/calm-down time. Images of the driving and resting states are thus alternately obtained.

The schematics of a small oven with windows are shown in Fig. 3. To maintain polarization of the laser beam, a polarizer is used as the incident window. The azimuth angle of the polarizer can be adjusted to satisfy linear polarization on the surface of the device under test.

The top window for observing the device is of 0.2-mm thick normal glass. Another polarizer is used to adjust the optical power, and to enhance the detection sensitivity of the optical intensity changes due to the vibration displacement.

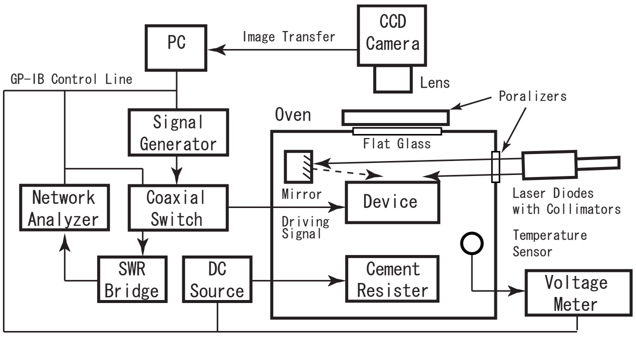

Fig. 1. Measurement system.

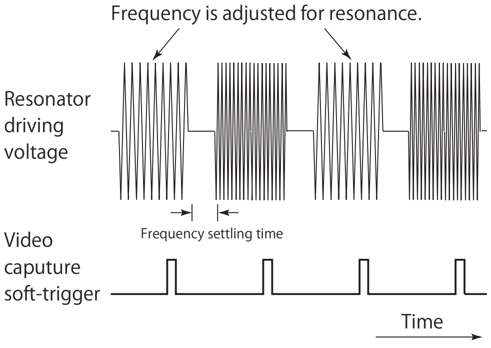

Fig. 2. Timing chart of measurement.

A cement resistor of $P_o = 5$ W is placed below the device as a heater. Although it is impossible to actively reduce the internal temperature of the oven by this configuration, the temperature is controlled by the input power of the resistor from room temperature to 75℃. The internal temperature is measured by a thermo sensor.

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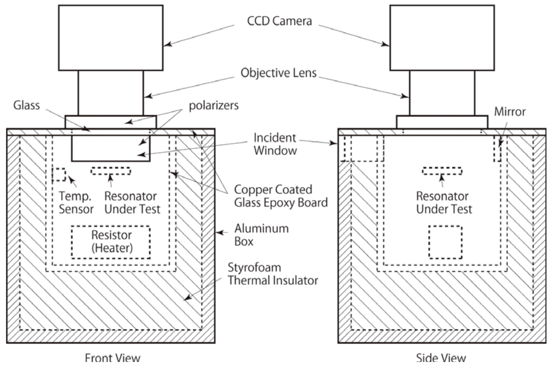

Fig. 3. Oven with transparent windows.

To reduce thermal conduction, copper-coated glass epoxy boards are used as the inside walls of the oven, and foamed polystyrene filled the space between the inside and outside walls.

4. Experimental results for continuous temperature change at high temperature

We used a 10 MHz circular AT-cut quartz resonator with a roughly finished surface (#4000) with partial electrodes. The bright area is the electroded region. The experimental results for fundamental thickness-shear mode at room temperature (22.1 ± 0.5℃) are shown in Fig. 4.

Individual pairs of 765 × 574 pixel images, i.e., images of the resonator-resting phase and resonator-driving phase, were taken 30 times for averaging. The total image capture time is about 10 sec for each measurement, and correlation processing takes 3 sec. The kernel, for calculating the correlation between the two obtained images in each pair consisted of 16 × 16 pixels, and was sufficiently smaller than the wavelength of the acoustic wave on the resonator surface. The output power of the SG was + 15 dBm. We can see from Fig. 4 that in-plane vibration displacement is trapped at the center of the electroded portion.

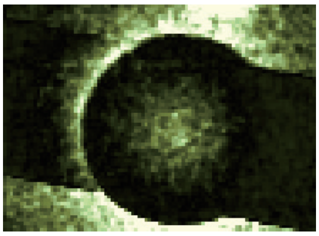

Fig. 4. Experimental result at 22.1℃.

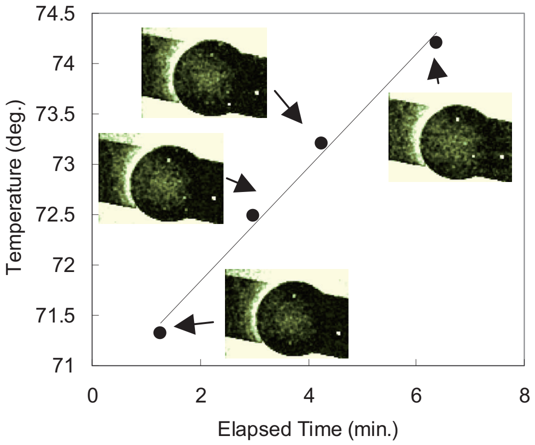

Fig.5. Experimental results for continuous temperature change at high temperature.

The experimental results of such measurements are shown in Fig. 5. The initial temperature was set at 70.3℃ and was increased to 73.2℃ at the rate of 0.56℃/min. From Fig. 5, it can be seen that the shapes of fundamental thickness-shear modes can be obtained by the proposed developed system even if the ambient temperature is continuously changed.

5. Conclusions

A full-field imaging system has been presented that measures the in-plane mode shapes of piezoelectric devices under ambient temperature changes. By use of a small oven with transparent windows, in-plane displacement on the surface of the device under test can be mapped for room to high temperatures. The developed system, which provides high data acquisition rates compared to mechanical scanning, can be applied for measurements under continuous temperature changes.

Acknowledgment

This work was partially supported by Grant-in-Aid for Scientific Research (C), No. 20560399, from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

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