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Real-Time Mode Visualization System of Micro Piezoelectric Devices by Laser Speckle Interferometry

高周波マイクロ圧電デバイスの振動モード実時間可視化

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1. Introduction

Micro piezoelectric devices are widely used in electronic devices, in particular FBARs(film bulk acoustic resonators) will be important for minuiturization of electronic devises such as mobile phones. For example, in FBARs used in the GHz range, the size of the vibration department is approximately 200 μm and vibration displacement is at most 0.01 nm.

Recent advances in computer technology have enabled the application of finite element analysis to the design of piezoelectric resonators, and confirming the reliability of the calculated results is very important when designing such resonators. Comparing the mode shape predicted by analysis with the shape obtained experimentally is the best way to obtain positive proof of the design reliability. For this reason, a number of methods for plotting the vibration patterns of piezoelectric resonators have been developed and reported [1-6].

Previously developed methods for visualizing the mode shapes of high-frequency resonators used a combination of surface speckle interferometry and image processing [7-13]. They involve irradiating the roughly finished surface of a device with a collimated laser beam and capturing images of the speckle field generated on the surface with a video camera. The mode shapes are then obtained from the correlation between images taken when the resonator is in driving and non-driving states [14].

In this paper, we have developed a multiple interaction system for visualizing vibration modes with micro piezoelectric devices, i.e. FBAR, in quasi-real time without the need for precise optical adjustment.

2. Measurement Principle

Vibration displacement of FBAR is so small compared with AT-cut quartz that improvement of the measurement sensitivity is needed to measure the small vibration displacement.

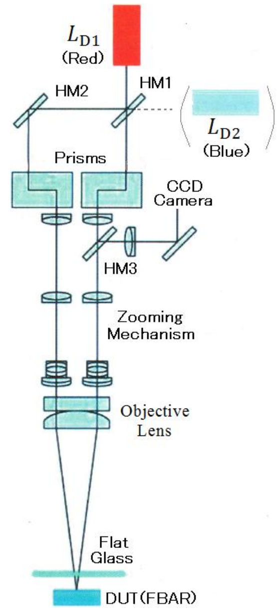

Fig. 1. Multiple interaction system

Figure 1 shows the proposed optical system of multiple interaction. Laser speckle interferometry uses interference of scattered light on the surface. Using HM1 (half mirror1), the laser beam is divided into two routes. Then, the difference of the optical path is caused. Due to the different paths, multiple interaction was caused and interaction of scattered light is frequently occurred. In accordance with this phenomenon, the measurement sensitivity was improved. L_{D2} is used for absolute measurement using two lasers [15]. In this experiment, L_{D2} was not used. An objective lens combined the beams of the two routes to cause multiple interaction on the surface of the DUT(device under test). A flat glass sheet placed parallel to the DUT surface enhanced the detection sensitivity for the out-of-plane component by reflecting the light scattered from the sample surface.

The laser, which has linear polarization, generated a visible-wavelength beam; the optical wavelength and power were 655 nm and 10 mw.

3. Evaluation

To evaluate the applicability of the proposed system, we applied it to the main mode of the 2 GHz FBAR. We compared the measurement results of the proposed system with the frequency characteristic of FBAR.

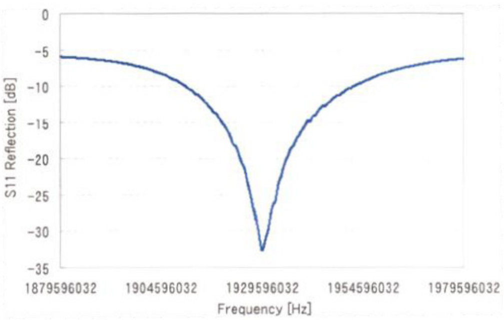

Fig. 2. Frequency characteristic of the 2 GHz FBAR

Figure 2 shows the frequency characteristic of FBAR. By this characteristic, we could find out that the resonant frequency was 1929 MHz. We measured the vibration modes at the resonant frequency and a non-resonant frequency to evaluate the sensitivity of this system. The sampling number was 30, and the driving power of the DUT was 15dBm.

Figure 3 shows the experimental results. Figure 3(a) shows a non-driving result. Comparing the results of non-multiple interaction 3(b) and multiple interaction 3(c) when the DUT was driving at the resonant frequency, the main mode can be measured by the proposed system. On the other hand, 3(d) shows the result at a non-resonant frequency that is 100 MHz away from the resonant frequency. We could not find the vibration part from this result. By the these results, improvement of the measurement sensitivity had been confirmed to enable measuring small vibration at the resonant frequency of the DUT.

4. Conclusion

We have developed a multiple interaction system to improve the sensitivity of measurement. By the proposed system, we could visualize the vibration mode of FBARs with a small vibration displacement.

For measuring smaller displacements, more improvement of the sensitivity is needed.

Acknowledgment

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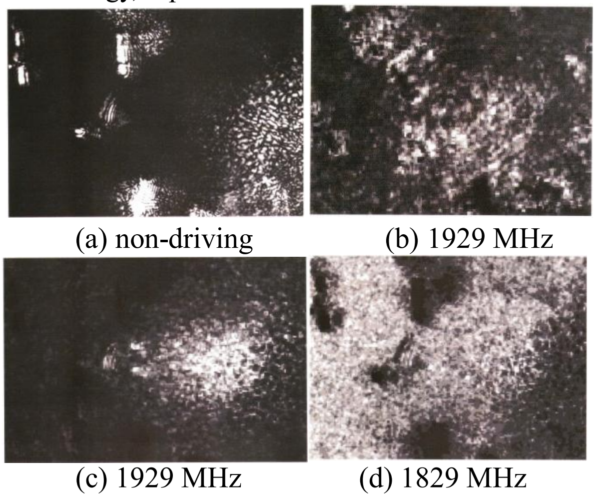

Fig. 3. Experimental results: (a) non-driving, (b) non-multiple interaction system at the resonant frequency, (c) multiple interaction system at the resonant frequency, (d) multiple interaction system at a non-resonant frequency

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