2P1-6

Investigation on Lamb Wave Propagation in Anisotropic Plate using Large Aperture Line Focused (PVDF) Transducer

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1. Introduction

Ultrasonic waves are widely used to determine the characteristics of materials without destruction. Among them, guided waves are especially used to examine a thin plate. The guided wave is generated by the combination of incident wave and reflected wave when the wave propagates through a thin layered material. Lamb wave is one special kind of the guided wave. When two surfaces of the plates are very close to each other, two surface waves interfere to form Lamb wave.

In this research, we've explored the propagation of Lamb waves in each direction from 0° to 360°. We used large aperture line focused (PVDF) transducer to send and receive signals from [100] silicon wafer. By repeating the construction of V(f, z) curve while rotating the specimen, we could get a dispersion curve for every direction of wave propagation. Properties of Lamb wave in the other materials and wafer orientation will be discussed in further studies.

2. Experimental setup and waveform processing

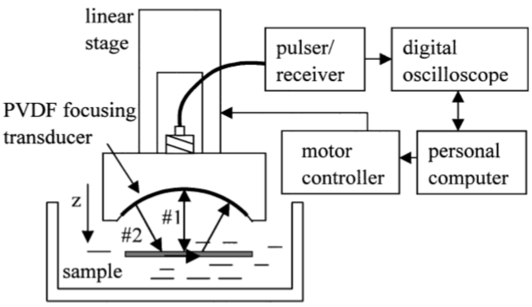

Fig. 1. Experimental setup

The experimental setup to measure the Lamb wave is shown in Fig. 1. It includes a large aperture lined focused PVDF transducer, a servo-motorized linear stage, a pulser/receiver, a digital oscilloscope, a motor controller, and a personal computer. The pulser/receiver send signals to the transducer to make it generate a pulsed wave incident on the sample. Then, the reflected wave returns to the transducer to produce a signal. We have repeated this process by changing the propagation direction and the distance between the transducer and the sample. These automatic processes are operated by a serve-motorized linear stage and a motor controller with Labview program.

The key step of our signal processing is FFT analysis. We could get reflected signal waveforms at each z value from above process. These waveforms can be converted into frequency spectrum at each defocus by FFT analysis. Let V(f,z) be the magnitude of the data of the waveform at frequency f and defocus z. By changing the axis of the graphs, we can eventually get the graph below.

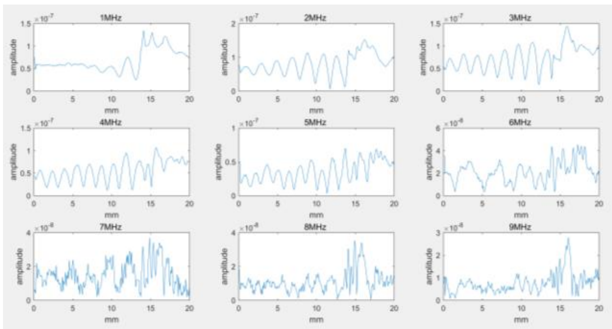

Fig. 2. V(f, z) curves of a 0.26-mm-thick [100] silicon wafer

3. Result and discussion

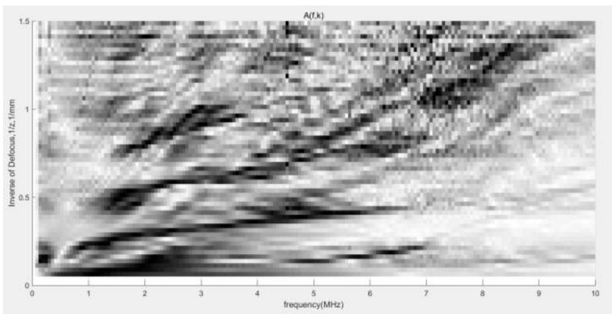

Fig. 3. Image of A(f, k)

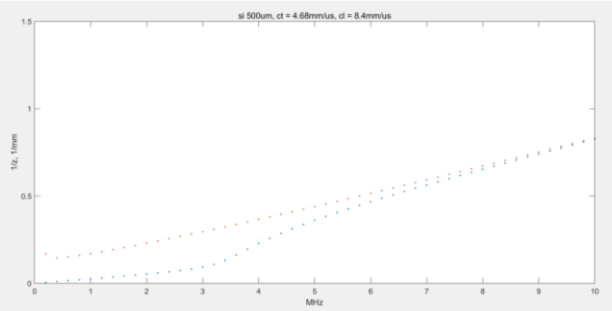

Fig. 4. Theoretical expectation of f, 1/z graph

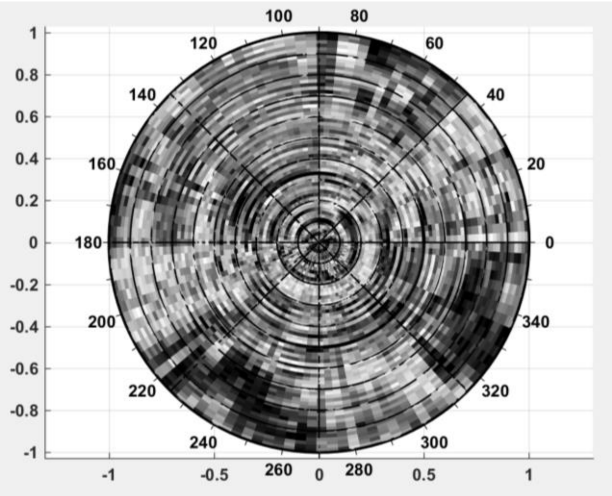

Fig.5. A(f, k) graph according to direction at f=3MHz

To precisely determine the oscillation period of the V(f, z) curve, the curve was Fourier transformed with respect to z to get an A(f, k) graph where k is the inverse of z[3]. To visually determine the peak values, we plotted the A(f, k) data with a gray scale image of a 270um-thick-[100] silicon wafer. Peak values of the graph followed the curve as shown in the Fig.3. The k-f relation of the peak values corresponds to the specific mode of dispersion curve that shows the relation between phase velocity and multiple of frequency and thickness. A curve with respect to f and 1/z was obtained from the theoretical dispersion curve, and it showed the similar tendency with our experimental data (Fig.3). In addition, by comparing the actual phase velocity with the theoretical values, we could confirm that the upper curve of Fig.3 corresponds to the A0 mode and the lower one corresponds to the S0 mode. To check out the tendency of the A0 and S0 mode according to direction, we got a graph from 0° to 360° in 3-degree intervals at 5 MHz (Fig.5). Then, we eventually plotted a polar graph of the phase velocity along the direction based on Fig. 4.

It indicates that the A0 mode is isotropic and the S0 mode is anisotropic.

In the case of A0 mode, the oscillation of material is perpendicular to the traveling direction of the wave, which is also perpendicular to the plane, that is, [100] direction. So the A0 mode becomes isotropic. For the S0 mode, the traveling and the vibration direction is parallel, and the wave propagates while the horizontal vibration generates the vertical vibration. Therefore, the crystal structure oscillates in different directions, and the phase velocity changes. Since the [110] and [111] directions repeat at the intervals of 45 degrees in the crystal structure, the S0 mode becomes symmetrical.

4. Conclusion

The dispersion curve at a certain angle was determined by using the V(f, z) method[1], [3]. The samples were rotated in 3 degrees interval. The dispersion curve obtained by the experiment indicates that the A0 mode is isotropic and the S0 mode is symmetrical. The change of dispersion curve according to propagation angle could be explained by examining the crystal structure and the oscillation direction of the material.

By examining the gray color-coded graph, the axisymmetric pattern had a relationship with the crystal structure. For [100] sample, dark areas were observed in every 90 degrees. Thus, we conclude that the characteristic of elastic wave propagation is related to the crystal structure.

For further researches, the remaining problem is to investigate the propagation of group velocity. We will also conduct experiments on different types of anisotropic materials such as sapphire. In addition, the direction that cannot be expressed by Miller index could be studied more.

Acknowledgment

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References

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