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Multilayer scanning of RF BAW device for focus adjustment by laser probe system

レーザプローブによる RF BAW 素子における焦点補正ための多層走査

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1. Introduction

A variety of laser probes have been applied to the visualizaion of propagating surface and bulk acoustic waves (SAW/BAW)[1-2]. The authors have recently developed a phase-sensitive laser probe system based on Sagnac interferometer for the diagnosis of RF SAW/BAW devices[3].

High lateral resolution is achieved by an objective lens with large magnifying power. Since it also results in a shallow focal depth, the out-of-focus problem may occur partly in the captured image field when the device surface is uneven.

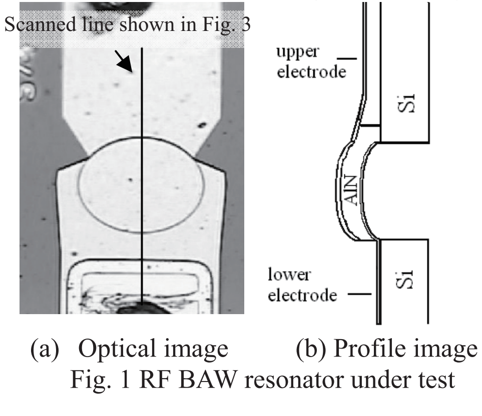
For example, even if the change in the surface height is only about 2 μm in 2 GHz RF BAW devices, this would badly affect the captured image quality when a 100x objective lens is employed.

This paper describes a scanning method to make the whole image in focus, with which the wave field can be better analysed.

2. Influence of Defocus

Use an RF BAW resonator[4] as a DUT shown in **Fig. 1(a)**, a piezoelectric AlN thin film is sandwiched in between two Ru electrodes, and the structure is floating on a Si substrate through an air cavity. **Fig. 1(b)** shows profile of the DUT, the structure and the deformation due to residual stress from backside leads to an altitude difference about 2 μm between the resonator part and the lower electrode. The line in the middle of the device represents one scanning route. The detail of the data acquired along this line will be discussed in Fig. 3.

The confocal optical system [5] and 100x objective lens used for high resolution make small spot size of about 1 μm. Meanwhile, the focal depth is shallow. **Fig. 2** shows the signal intensity changes with the relative height from the optical lens to the DUT. When the relative height deviates for 2 μm from the best-focus point, signal intensity decreases by about 30%.



(a) Optical image (b) Profile image

Fig. 1 RF BAW resonator under test

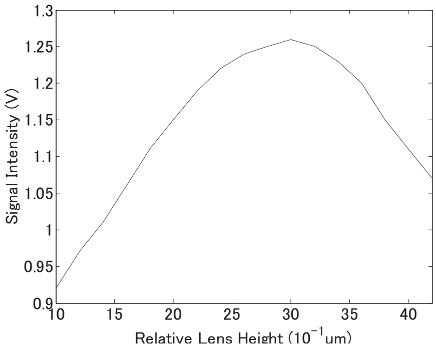


Fig.2 Signal intensity changes with lens height: using 100x objective lens

Fig. 3 shows the vibration amplitude of the middle line on DUT (see Fig.1 (a)) by the laser probe system. The measurement was performed for two cases: the objective lens was adjusted into focus on either lower or upper electrode (particular the parts indicated by arrows in Fig. 1 (b)). It is clear that the vibration is well confined in the floating region. The variation in the region is due to lateral propagation of plate modes call the transverse mode resonance.

It is interesting to note that the position dependence of acquired data changes with the lens height. On the other hand, provided that we have measured data properly representing the wave field, it will be possible to evaluate the wave field quantitatively [6]. So it is important to scan the DUT all in focus even when the surface is uneven.

At this point of view, we proposed this

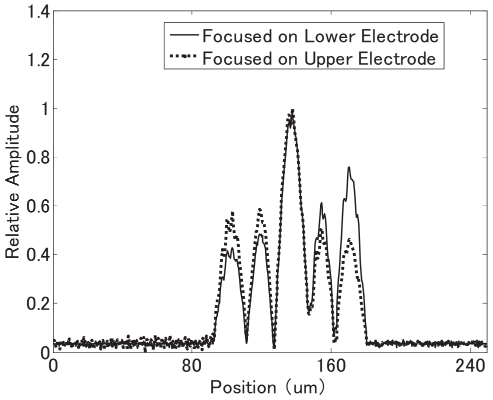


Fig. 3 Data of middle line on DUT

multilayer scanning method and demonstrated its efficiency and effectiveness.

3. Result of Multilayer Scanning

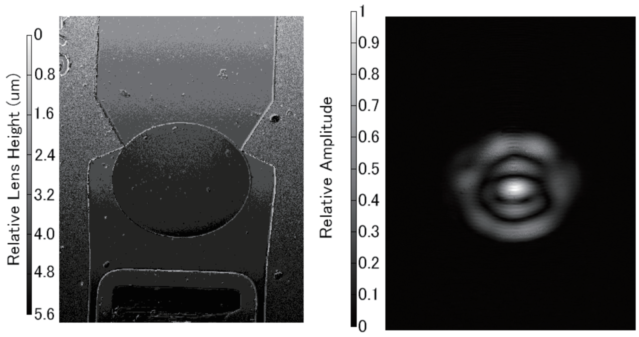
The multilayer scanning method is applied to overcome the influence of uneven surface. It is accomplished in the following procedures. First, scanning of a device surface is repeated for multiple times setting an objective lens at a different height, and both the interferometeric (RF) and monitor (DC) outputs of a photo detector are recorded. Then, the lens height giving the best focus at each sampling point is determined from the DC output. Finally, the RF output data with the best focus height at each sampling point is extracted to compose a whole image.

A 100x objective lens (LMPLFLN100×, Olympus, Japan) is used, we scanned the DUT 8 times with lens height of 0.8 μm intervals, and processed the data. **Fig. 4(a)** shows variation of the lens height giving the maximum DC output. **Fig. 4(b)** shows the amplitude image composed of the RF output with the best focus at each sampling point.

3. Analyses

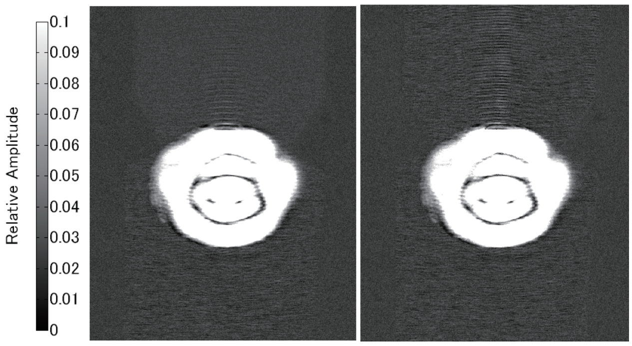
Fig. 4(a) clearly shows the change in the surface height within the device as well as surface inclination.

The brightness at the Si substrate surface changes smoothly. This is due to the inclination of the device. Meanwhile, it can be clearly seen that the brightness of upper electrode is different from the substrate. This represents the height difference of the uneven surface. Similarly, the brightness of the floating area is the dakest because of the highest altitude. These results indicate that variation of the surface height can be reproduced by the simple method employed in this paper.



(a)Change in lens height (b) Composed image

Fig. 4 Images with the best focus



(a) Conventional image (b)Composed image

Fig.5 RF output with modulated brightness bar

To show the impact of the present technique, the conventional one layer image and composed image (Fig.4 (b)) are compared as in **Fig. 5** with brightness map modified into saturation. Thanks to the proposed technique, the leakage can clearly be seen; one can recognize the energy flow with small decay.

In Fig.5(a) without the proposed technique, it seems that the leakage propagating out of the floating region is weak, and decays very quickly. However, in Fig.5(b), the composed data, we can see that the leakage is not so weak, and propagate through the upper electrode till the edge of the device with little decay.

4. Conclusion

To solve the out-of-focus problem which may occur partly in the captured image field when the device surface is uneven, the paper discussed one useful multilayer scanning method for the fast-scanning laser probe system.

It was suggested with this proposed technique, even for a DUT with uneven shape or surface, the whole area of the surface can be adjusted in-focus properly. In this way, the leakage can be seen more clearly and vividly, and the wave propagation on the surface can be measured more precisely.

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