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Harmonic Imaging of Thermal Fatigue Cracks of Several Tens nm Gap in Glass Plates

ガラス板内の隙間幅数十 nm の熱疲労き裂の高調波可視化

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1. Introduction

Bonded wafers are developed for 3D integrated semiconductor devices. If disbond or weakly bonded spots are included in the bonded interface, IC tips could be damaged by dicing. Therefore, nondestructive evaluation of the disbond in wafers is required. However, the conventional ultrasonic technique has low sensitivity for small defects of kissing bond type or weak bond within the interface of dissimilar materials due to small difference in acoustic impedance, ΔZ, in the former or large difference in ΔZ in the latter.

Higher harmonic technique which detects the waveform distortion of the wave scattered at the defects from the incident sinusoidal wave has high sensitivity for the defects just mentioned. With this technique, nonmetallic inclusions [1] in continuously cast steel slab and local plastic deformation around a circular hole [2] are imaged.

In this study, we apply the technique for imaging a thermal fatigue crack, which has gap distance of several tens nm, in a glass plate.

2. Experimental

As shown in **Fig. 1**, the incident sinusoidal tone-burst wave is severely modified at the closed crack of sub-micron gap [3]. This waveform distortion is expressed by higher harmonics in frequency domain. By using selectable analog high-pass filters, we capture the higher harmonic of any order of interest. To visualize the small defects of several microns, we used an immersion higher harmonic imaging systems shown in **Fig. 2.**

A thermal fatigue crack was generated in a glass plate of thickness, width and length of 15mm, 100mm and 150mm, respectively. Through thickness crack is extended by cyclic heating and cooling. The typical temperature range T and cycle numbers N are $453 \leqq T \leqq 593K$ and $2 \leqq N \leqq 10$, respectively.

The SEM image of the edge of a thermal fatigue crack is shown in **Fig. 3.** The gap distance is in 10 to 30 nm.

A sinusoidal tone-burst wave pulser, RITEC RPR-4000, was used for transmission and reception of ultrasonic waves. A focused transducer with a diameter, central frequency and focal length of 9.6 mm, 5MHz, 51 mm, respectively, was used. Sinusoidal burst wave of 3.5 MHz was transmitted and higher harmonics were extracted by a high-pass filter of 6 MHz.

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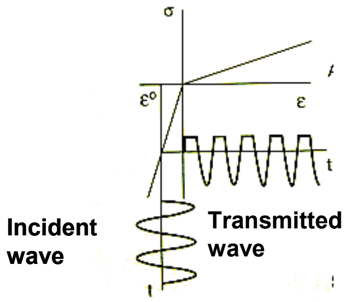

Fig. 1 Waveform distortion at a closed crack [3].

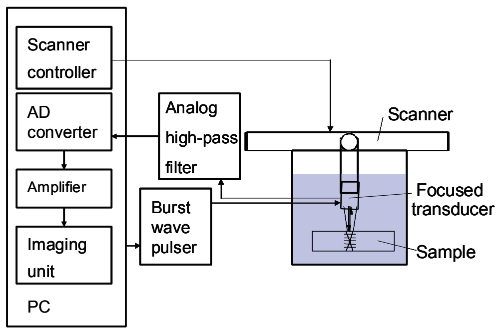

Fig. 2 An immersion harmonic imaging system.

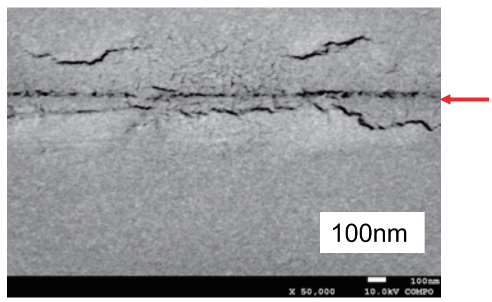

Fig. 3 SEM surface image of thermal fatigue crack.

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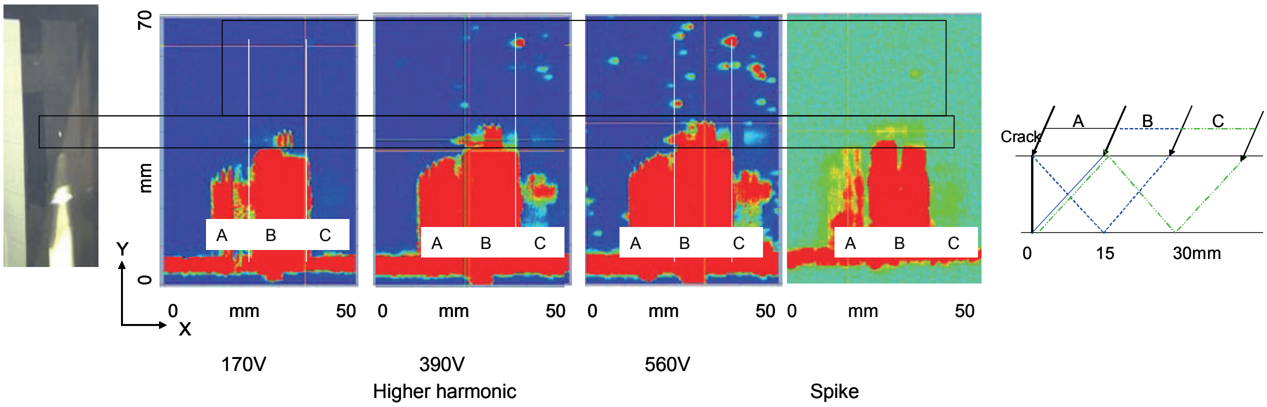


(a) (b) (c) (d)

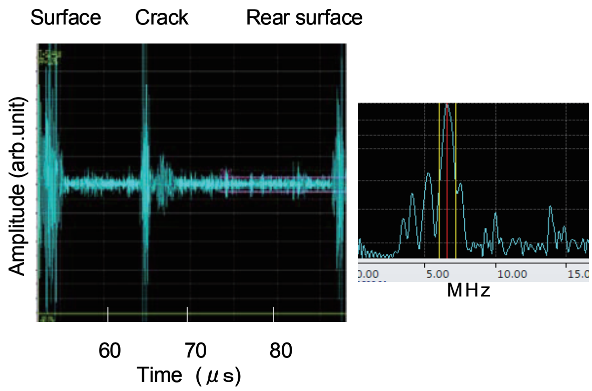
Fig. 4 Images of cracked face: (a) optical, (b) higher harmonic, (c) spike wave, (d) ultrasonic beam paths

3. Harmonic images

The second harmonic images of the thermal farigue crack are shown in **Fig. 4** (b) with the optical image (a) and the convential ultrasonic image (c). These images are obtained by angle incidence of 18 degree as shown in Fig. 4 (d), where A, B and C are scan positions. In the higher harmonic images, the scattered points and area increases with an increase in voltage applied. At 560V, cracked area extends to the small white spot shown in (a). The crack length is approximately 70mm, however, only scattered points are shown in the upper area of the harmonic image. The reason is that strong residual compressive stress near the crack tip constraints the clapping of the cracked faces. Only at the near surfaces of weak residual stress, partial cracks shown in Fig. 1 are visualized. **Fig. 5** shows the received the waveform and the frequency spectra.

The crack image shown in Fig. 4 (c) by use of a spike wave pulser, Panametrics 5900 PR, can't show clearly even the white spot shown in Fig. 4 (a) due to weak transmission power.

Fig. 6 shows the striation and inclusions on the cracked face. The inclusions are about 0.1 mm in diameter.



(a) (b)

Fig. 5 Received wave (a) and spectra (b).

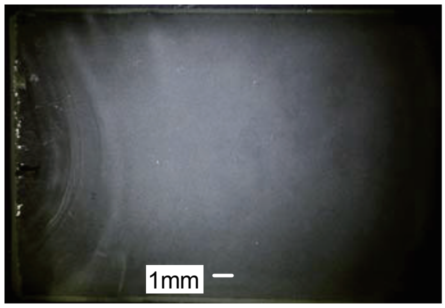


Fig. 6 Striation and inclusions on the cracked face.

4. Conclusion

Some parts of the thermal fatigue crack of some tens nm gap in a glass plate is clearly images by the immersion higher harmonic imaging technique. Cracked face near the crack tip is not imaged by high compressive residual stress.

If spatial resolution will reach to a few micron meter, the technique could be applied for detection of disband in bonded wafers.

Acknowledgment

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References

1. K. Kawashima, et al.: Jpn. J. Appl. Phys. **49** (2010) 07HC11.
2. K. Kawashima: Jpn. J. Appl. Phys. **50** (2011) 07HC14.
3. C. Pecorari and I. Solodov: in P. P. Delsanto Edt., Universality of Non-Classical Nonlinearity. Applications to Non-Destructive Evaluation and Ultrasonics, 309, Springer, 2007.