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Ultrashort pulse laser slicing of wide bandgap 4H-SiC crystal

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1. Introduction

Silicon carbide (SiC) is one of the key materials for electric power devices, because it has excellent characteristics of wide band gap semiconductors. Because the production cost of crystalline SiC of high quality is very high, it is desirable to slice a large SiC ingot into as many thin SiC substrates as possible. It is difficult to slice SiC crystals without wire kerf-loss by a conventional method using a wire-saw. The loss of the SiC crystal is typically over 70 %. In this study, we applied ultrafast laser processing to slicing of SiC single crysal with lower loss instead of *smart-cut* process[1], We have succeeded to achieve exfoliation of 4H-SiC single crystal with a loss of less than 30 μm thickness.

2. Experiment

The sample was commercially available highly n-doped 4H-SiC (0001) plate with a bandgap of 3.26 eV, thickness of 420 μm. Before laser irradiation, the sample was cut to smaller plates of 5 mm^2 square. Figure 1 illustrates the process of wafer depth-slicing of a SiC plate using ultrafast pulsed laser. The femtosecond laser pulses were focused inside a SiC plate with a 50× objective lens (NA=0.80). The laser-induced damage lines were written by scanning the sample at 100 μm/s. The central wavelength of the laser pulse was 800 nm, the repetition rate was 1 kHz, and the pulse duration was changed from 220 fs to 2 ps. Double pulse trains was made by a Mach-Zehnder type optical setup to enhance the light absorption. The spherical aberration due to the high refractive index of SiC was compensated using a spatial light modulator (Hamamatsu Photonics; X10483). After the damage lines written in the whole area of the SiC plate, the both surfaces of the SiC plate were glued to two metal plates, and a tensile stress was loaded normal to the surface of the plate by a universal testing machine (Instron; 1122) [Fig. 1(b)]. After the exfoliation test, two separated SiC pieces [Fig. 1(c)]

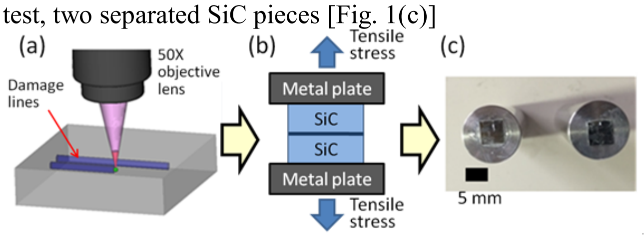

Figure 1. Schematic illustration of wafer depth-slicing using an ultrafast pulsed laser.

3. Results and discussion

Before SiC exfoliation, we investigated the damage threshold and optimized laser irradiation condition. Figure 2 (a) shows the width and depth of the laser induced damage line as a function of pulse energy. The damage threshold inside SiC was about 4 μJ, but damage appeared on the surface when the pulse energy exceeds 12 μJ by both single and double pulse trains. It was found that damage lines of nearly constant volume could be written at 8-10 μJ. Therefore, damage lines were written inside a SiC plate for exfoliation. Figure 2 (b) shows the 1D height profile of the separated surface of a SiC plate after exfoliation. The maximum different height was not more than 30 μm. This value is quite smaller than the kerf-loss (~ 100 μm) produced by the conventional wire-saw slicing.

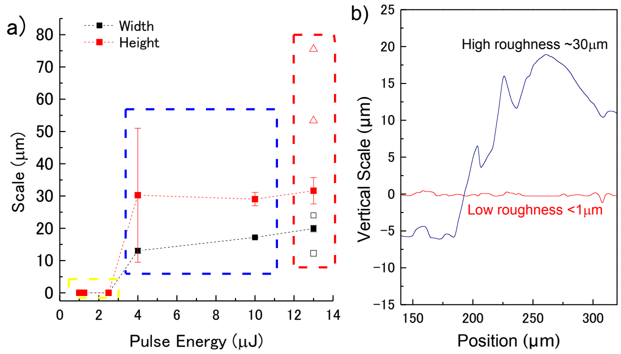

Figure 2. (a) The width and height of the induced damagearea as a function of the each pulse energy of 220 fs laser double pulse train. (b) The height profiles of the exfoliated SiC plates on the highest-roughness region (black) and the lowest-roughness region (red).

4. Conclusions

We have demonstrated that the thin SiC could be successfully sliced off from a wafer by focusing an ultrafast pulse laser with double pulse configuration. It was shown that the loss produced by the femtosecond laser slicing method was more than 4 times less than that by the conventional wire-saw method.

Acknowledgements

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References

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