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Application News

Servopulser™ EHF-L Series Tabletop Dynamic and Fatigue Testing System
inspeXio™ SMX™-225CT FPD HR Plus Microfocus X-Ray CT System

Durability Evaluation of Bond Between SiC Chip and Copper Substrate Joined with Silver Sintering Die Attach Material

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User Benefits

- Shear fatigue testing of SiC chips mounted by silver sintering is possible by using a SiC chip fixture with a fine-adjustment stage.
- High-accuracy dynamic control can be achieved by using the Servo Controller 4830.
- X-ray CT allows nondestructive observation of the internal condition of SiC chips and Ag sintered bonds.

■ Introduction

Silver (Ag) sinter joining is a technique in which particles are bonded together by heating/compression of a paste containing silver particles. In recent years, attention has focused on EVs (electric vehicles) as a key technology for realizing a decarbonized society, and wide bandgap power semiconductors such as SiC, which are expected to reduce energy loss and provide excellent heat conduction/heat resistance, have become indispensable for improving EV performance. In particular, with the use of large current/high density power semiconductors, performance under high temperature environments is now required. To achieve this, Ag sinter joining has attracted interest, as Ag sintered bonds can maintain good mechanical properties under higher temperature environments than conventional solder bonds.

In this article, a shear fatigue test of the bond between a SiC chip and a copper substrate formed by silver sinter joining was conducted using a Servopulser dynamic and fatigue testing system, and the fracture mode of the SiC chip after an endurance test was observed using X-ray CT.

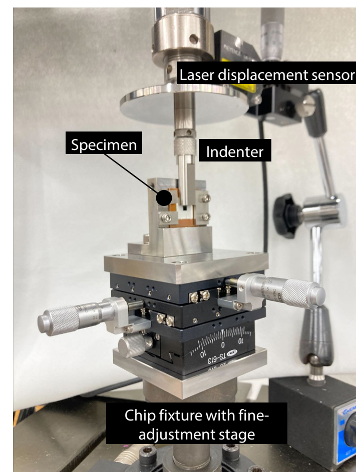


Fig. 2 Test Fixture

■ Specimen Information and Measurement System

Fig. 1 shows a schematic diagram of the test specimen. A SiC chip with a one-side length of 3 mm and thickness of approximately 0.35 mm was bonded to the center of a copper substrate with a one-side length of 24 mm. Fig. 2 shows the test fixture. Since the deformation of the bond during the test is extremely small, in addition to the stroke of the testing machine, displacement was also measured using a laser displacement sensor. The target SiC chip is also very brittle, and cracking will occur, originating from the loading point, if the load is concentrated on one point. Since this would make it impossible to evaluate the bond surface, the fixture was equipped with a fine-adjustment stage so that compression could be applied uniformly to the entire surface on the SiC chip, and the indenter contact angle and test position were adjusted while observing the specimen on a monitor. Fig. 3 shows the condition of specimen position adjustment, and Table 1 shows the instrument configuration. After the endurance test, the specimen was observed by X-ray CT.

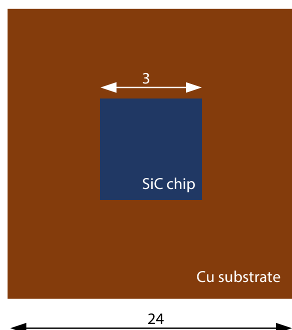


Fig. 1 Dimensions of Test Specimen (SiC Chip Thickness: 0.35 mm)

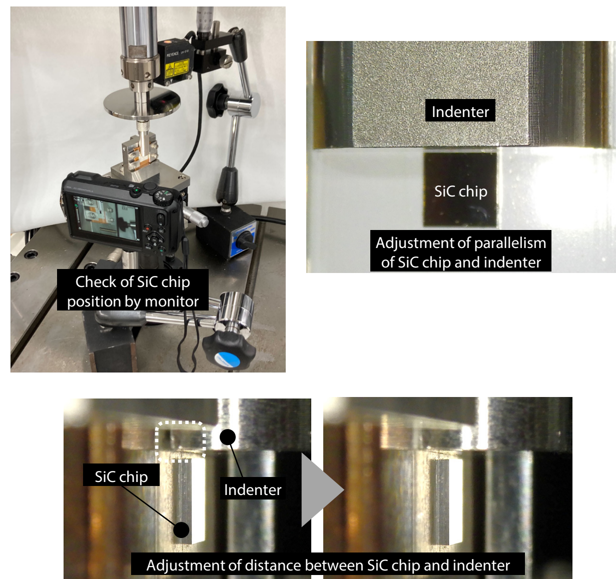


Fig. 3 Condition of Specimen Position Adjustment

Table 1 Instrument Configuration

Fatigue testing machine	: EHF-LV
Load cell	: 5 kN
Test fixture	: SiC chip fixture with fine-adjustment stage (prototype)
Controller	: Servo Controller 4830
Software	: Windows software for 4830
X-ray CT instrument	: inspeXio SMX-225CT FPD HR Plus

■ Static Shear Test

To set the conditions for the fatigue test, first, a static shear test was carried out. Table 2 shows the test conditions of the static shear test, Fig. 4 shows the test force-displacement diagram of respective test specimens, and Fig. 5 shows examples of the test specimens after the test. In Fig. 5 (a), the SiC chip has fractured, and in Fig. 5 (b), shear fracture has occurred. Table 3 summarizes the test results. The results in Table 3 are the results excluding fracture of the SiC chip.

Table 2 Test Conditions

Test speed	: 0.1 mm/min
Origin point of elongation	: 5 N
Number of tests	: n = 3

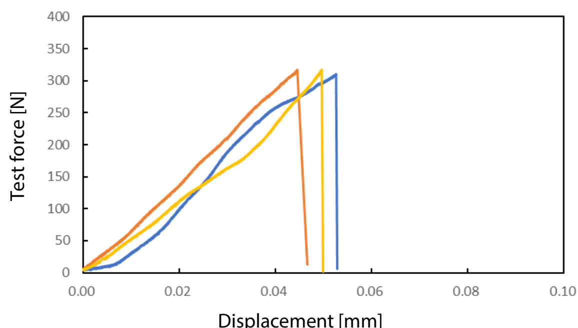


Fig. 4 Test Force-Displacement Diagram

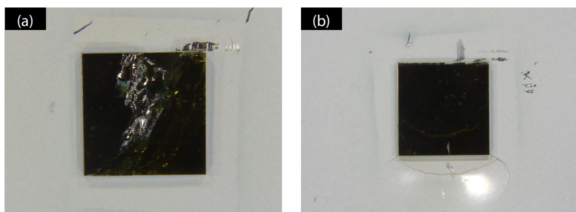


Fig. 5 Examples of Test Specimens after Test
(a) Fracture of SiC chip (b) Shear fracture

Table 3 Instrument Configuration

Test No.	Max. test force [N]	Max. stroke [mm]	Max. displacement [mm]
1	310.39	0.0569	0.0527
2	316.98	0.0477	0.0446
43	317.97	0.0510	0.0496
Average	315.11	0.0519	0.0489
Standard deviation	4.12	0.0047	0.0041
Coefficient of variation	1.31	8.99	8.36

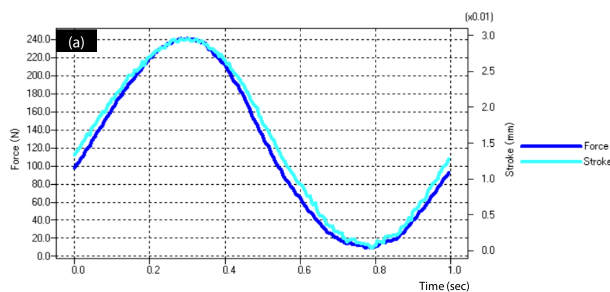
■ Endurance Test

An endurance test was conducted with specimens A and B. The condition of the endurance test was set to a displacement-control maximum stroke of 0.03 mm for the average maximum stroke of 0.0519 mm in the static shear test. Table 4 summarizes the conditions of the endurance test. Fig. 6 shows the waveform at 10000 cycles for specimen A. From Fig. 6 (a), it can be understood that the stroke could be controlled to approximately a sine wave, as targeted. Fig. 6 (b) shows the test force-stroke diagram. As the results of the endurance test, Fig. 7 shows graphs of the characteristic values of the peak values of specimens A and B.

From Fig. 7, the peak values of the test force during the test show approximately constant values, and brittle fracture occurred instantaneously on reaching the number of cycles to fracture. The number of cycles to fracture was 17988 for specimen A and 19262 for specimen B.

Table 4 Conditions of Endurance Test

Control method	: Stroke control
Maximum stroke	: 0.03 mm
Frequency	: 1 Hz
Number of tests	: 2 (specimen A, specimen B)



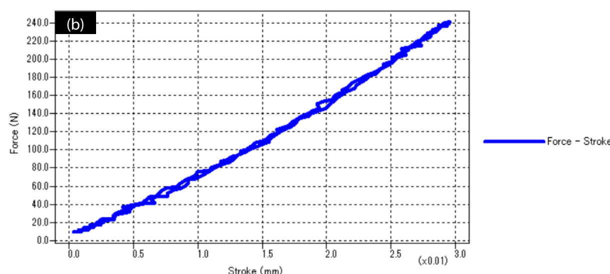
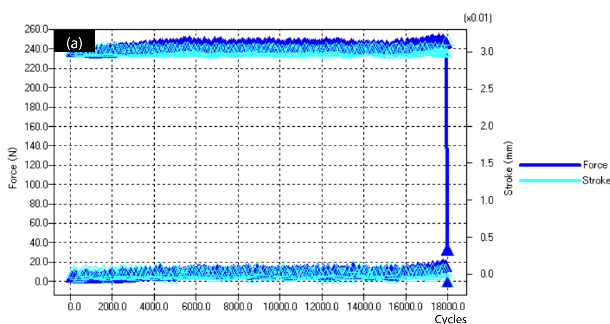


Fig. 6 Waveform of Specimen A at 10000 Cycles
(a) Time-Test Force-Stroke Diagram, (b) Test Force-Stroke Diagram



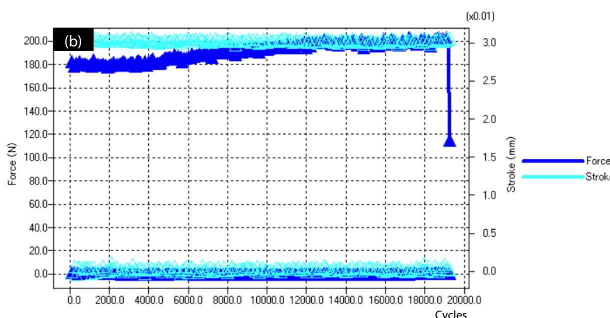


Fig. 7 Results of Endurance Test
(a) Graph of Characteristic Values of Peak Values for Specimen A
(b) Graph of Characteristic Values of Peak Values for Specimen B

■ Fracture Observation by X-Ray CT

Fig. 8 shows photographs of the specimens after the endurance test. In specimen A, a crack has occurred in part of the upper right area of the chip, and some of the sintered die attach material on the underside of the chip has delaminated. In specimen B, the entire chip is heavily damaged. Nondestructive observation of the respective specimens was carried out by X-ray CT. Fig. 9 shows X-ray CT images of specimen A. From Fig. 9 (a), it was found that damage had occurred in the Ag sintered bond layer directly under the damage of the SiC chip observed by visual inspection. From Fig. 9 (b), it can be understood that the crack in the Ag sintered bond layer reached the Cu substrate. In Fig. 9 (c), although the Ag sintered bond layer is damaged, the SiC chip itself is almost undamaged, but delamination of the Ag sintered bond layer under the SiC chip was observed.

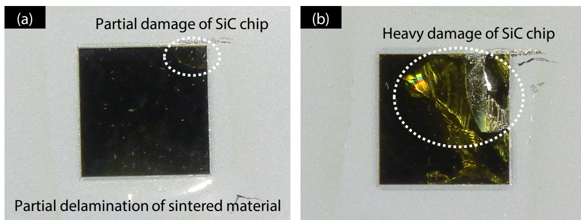


Fig. 8 Appearance of Specimens after Endurance Test
(a) Specimen A (b) Specimen B

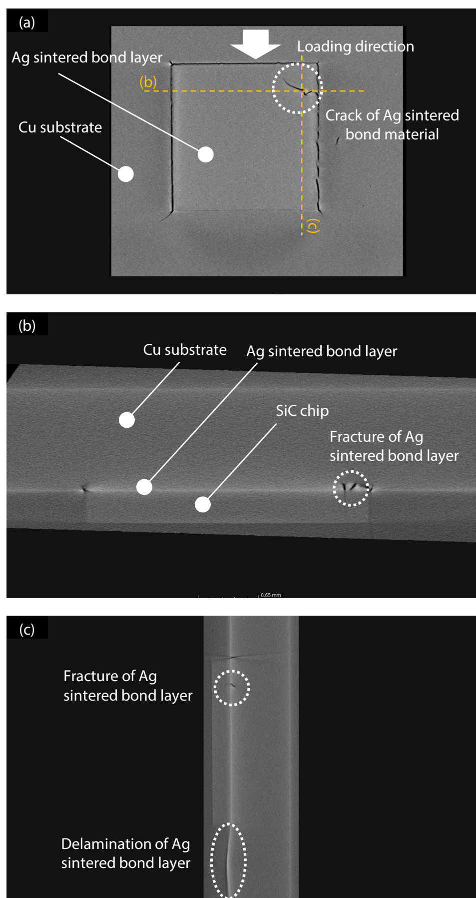


Fig. 9 X-Ray CT Images of Specimen A
(a) Cross-Sectional Image of Ag Sintered Bond Layer from Above SiC Chip Surface
(b) Cross-Sectional Image from Side of SiC Chip (Horizontal)
(c) Cross-Sectional Image from Side of SiC Chip (Vertical)

Fig. 10 shows X-ray CT images of specimen B. In Fig. 10 (a), a crack was observed in the lower left part of the Ag sintered bond layer. In Fig. 10 (b) and (c), fracture was observed in the Ag sintered bond layer, but delamination was not observed under the SiC chip. It is thought that delamination did not occur in specimen B because the SiC chip fractured over a wide range.

Fig. 11 (a) shows an X-ray CT image of the crack in the SiC chip of specimen B. In this image, part of the crack in Fig. 8 (b) was observed. From Fig. 11 (b) and (c), it was found that this crack in the SiC chip did not reach the Ag sintered bond layer.

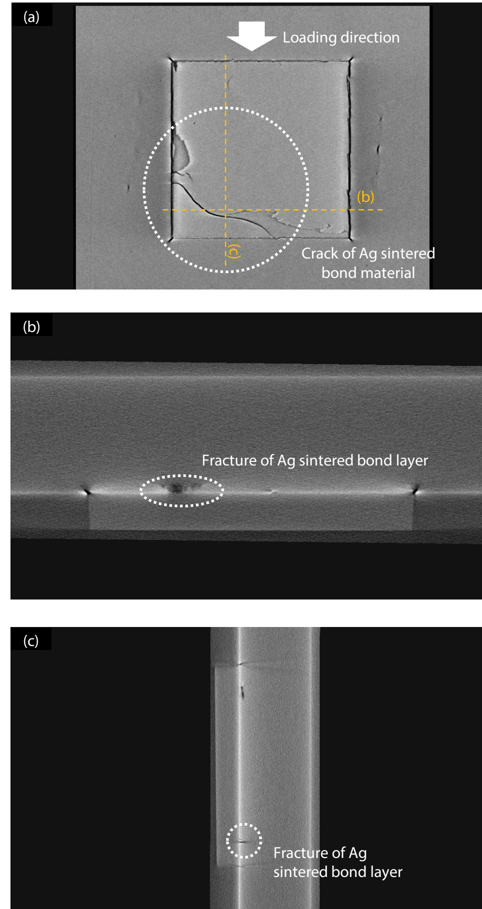


Fig. 10 X-Ray CT Images of Specimen B
(a) Cross-Sectional Image of Ag Sintered Bond Layer from Above SiC Chip Surface
(b) Cross-Sectional Image from Side of SiC Chip (Horizontal)
(c) Cross-Sectional Image from Side of SiC Chip (Vertical)

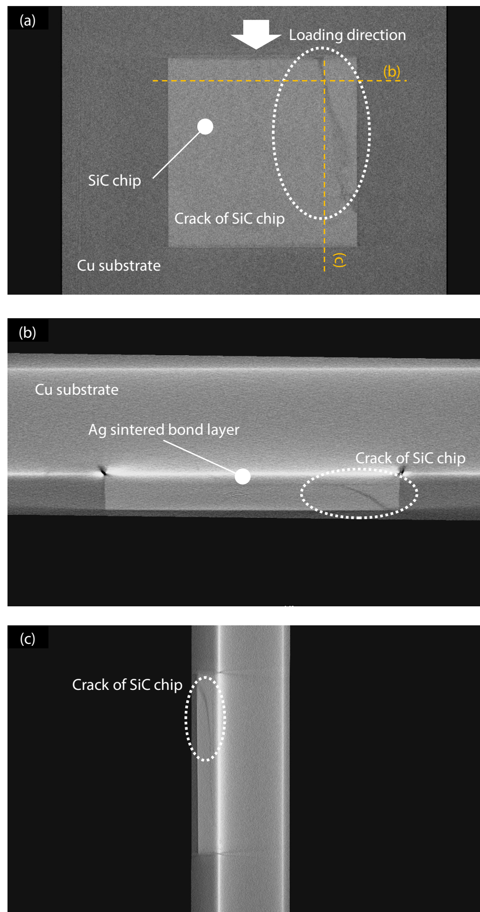


Fig. 11 X-Ray CT Images of Specimen B
(a) Cross-Sectional Image of SiC Chip from Above SiC Chip Surface
(b) Cross-Sectional Image from Side of SiC Chip (Horizontal)
(c) Cross-Sectional Image from Side of SiC Chip (Vertical)

■ Conclusion

An endurance test of SiC chips was conducted using the Servopulser dynamic and fatigue testing system. Satisfactory testing was possible by using a SiC chip fixture with a fine-adjustment mechanism. Use of X-ray CT allowed detailed observation of the fracture of SiC chips.

<Related Applications>

1. Cross-Sectional Analysis of Power Semiconductor and Silver Sintering Die Attach Material, Application News No. 01-00989

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01-01049-EN First Edition: Dec. 2025

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