Preliminary Die Shear Results of SiC Die with Patterned Pt Metallization Attached to (Au)Pt/HTCC Alumina

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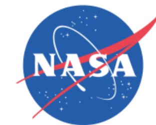

Background

- Pt/HTCC alumina packaging system
  - Pt/HTCC chip-level packages: 32, 16, 24, and 44-pins
    - Compatible to current HTCC industrial process
    - Electrically characterized at temperatures up to 5500 °C
    - Long term tested with SiC ICs at temperatures at 500 °C
    - Au plated
    - Au thick-film paste based conductive attachment developed
      - Tested with NASA GRC SiC ICs with $TaSi_2$/Pt/Ir/Pt backside metallization
      - Long term electrically tested at 500 °C
      - Reasonable mechanical strength, quantitative die shear data needed
  - Pt/HTCC circuit boards
    - HTCC packaging industrial process
    - Compatible to Au/Pt/HTCC chip-level packages
    - Multilayer capability
    - Pt pads for both mechanical attachment and electrical connection
    - Au plating applicable
    - Chip level packages attached to the board at 850 °C
      - Package attachment at lower temperature preferred to avoid SiC IC exposure to extreme temperature (850 °C)

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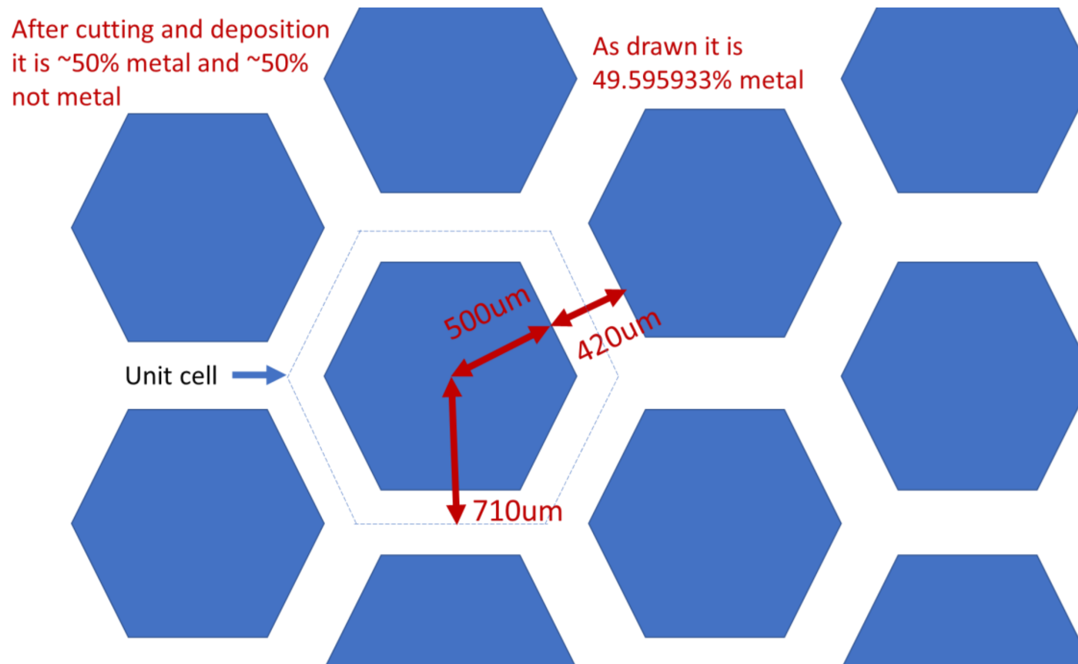
SiC Die Metallization Pattern



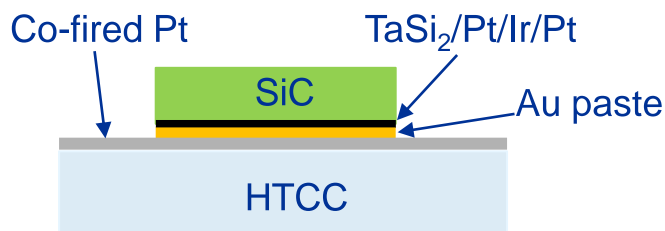
Hexagon TaSi2/Pt/Ir/Pt metallization pads

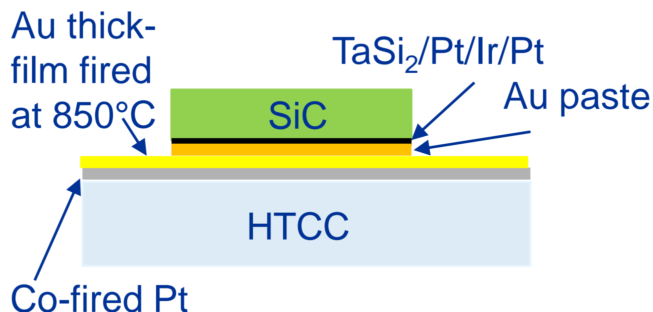
Metallized area 50%, hexagon pad 0.866 mm^2, top metal Pt

P-clean followed by 60 s standard buffered oxide etching (BOE)

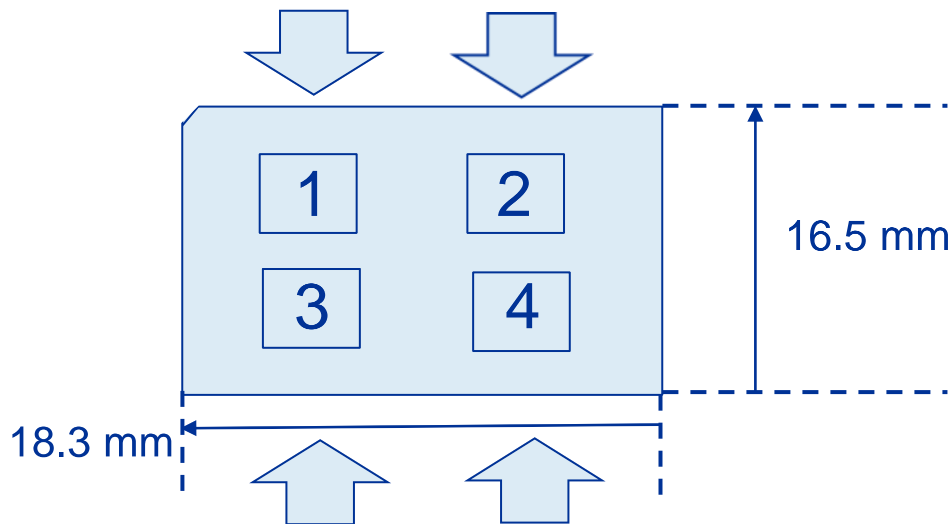
Die Shear Test Assemblies and Shear Directions

Die-shear Samples





Shear direction for Die 1 and 2



Shear direction for Die 3 and 4

SiC die: 5 mm x 5 mm x 300 μm

Pt/HTCC or Au/Pt/HTCC alumina substrate: 18.3 mm x 16.5 mm x 0.4 mm thick

Attached with DuPont 5063D paste, 600°C for 3 hrs, ramp rates at 3°C/m

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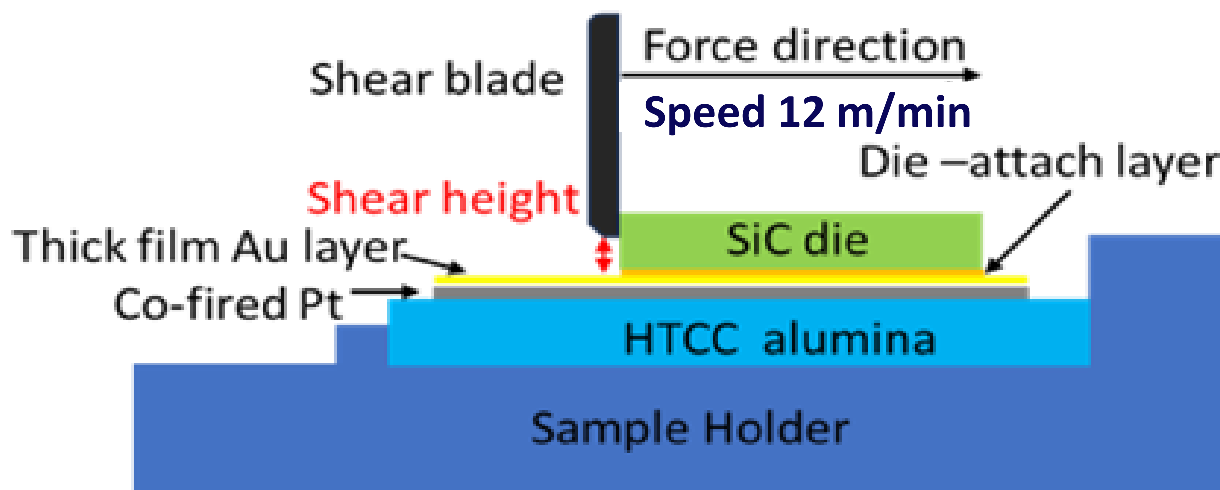
Die Shear Test



- Pt/HTCC and Au/Pt/HTCC substrates
- Typical shear speed: 12 m/min
- Shear height setting: 95 µm

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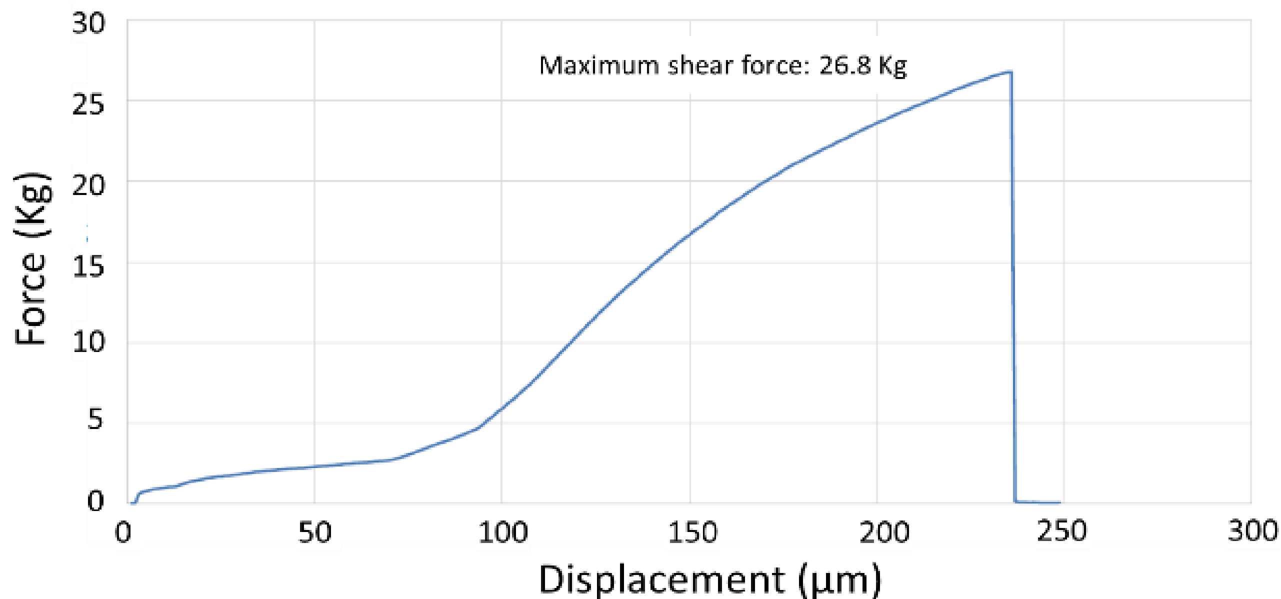
Die Shear Test Data



- Shear force (kg) vs. shear tool displacement (µm)
- Typical shear tool speed: 12 m/min
- Sharp drop at breaking / failure point – die shear strength
- Maximum shear stress: die shear strength / effective attach area

Die Shear Results Par I - Pt/HTCC Alumina substrate

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Pt/HTCC Substrate Shear Results

Sample	Die shear (kg)	Number of Hexagon pads	Max.-shear stress (kg/mm^2)
P1	9.03	13	0.80
P2	11.84	12.5	1.09
P3	11.02	13	0.98
P4	17.22	13	1.53
P5	9.61	13	0.85
P6	11.91	13	1.06
P7	16.92	13	1.50
P8	13.38	11.5	1.34
P9	15.7	11.5	1.58
P10	14.31	12.5	1.32
P11	18.56	13.5	1.59
P12	14.2	14.0	1.17

Shear speed: 12 m/min, shear height 95 µm, lowest die shear > 9 kg

Die Shear Results Par I - Pt/HTCC Alumina

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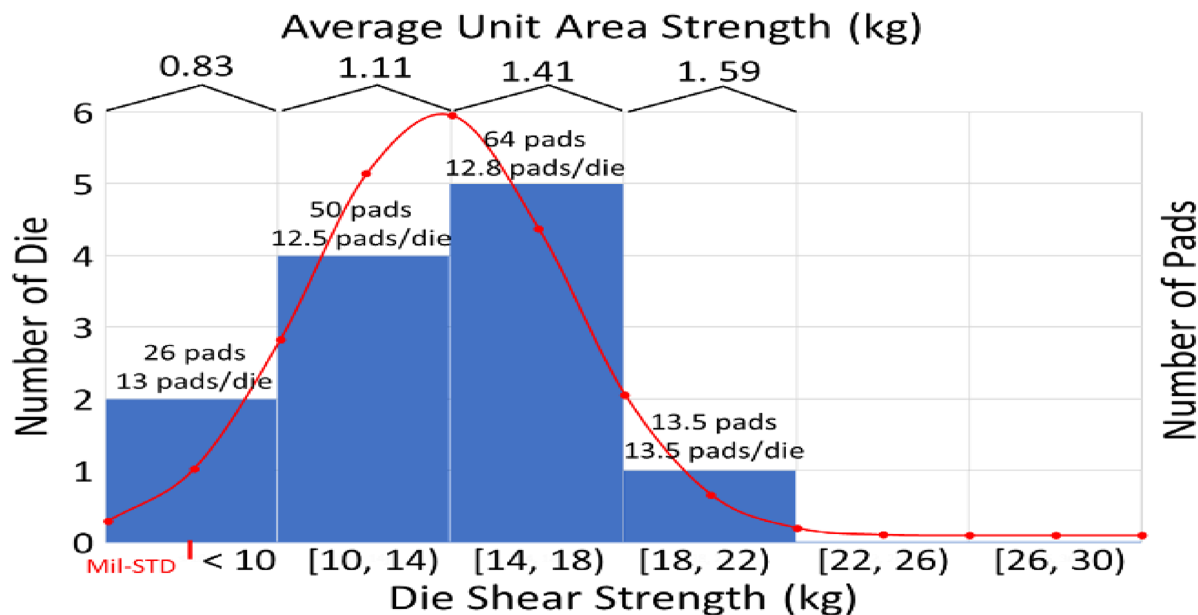
Pt/HTCC Substrate Shear Results



- Averaged die shear strength: 13.64 kg
- Standard deviation: 2.94 kg
- The lowest shear strength measured > 9 kg
- 2.0 x die shear strength of MIL-STD 833 for 5 mm x 5 mm die is 5.0 kg
- More data needed to better fit the normal distribution curve

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Die Shear Results Par I - Pt/HTCC Alumina

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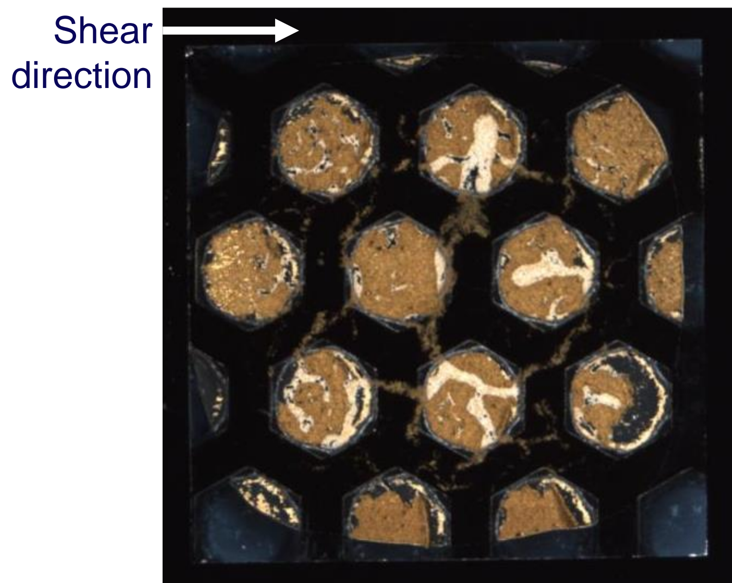
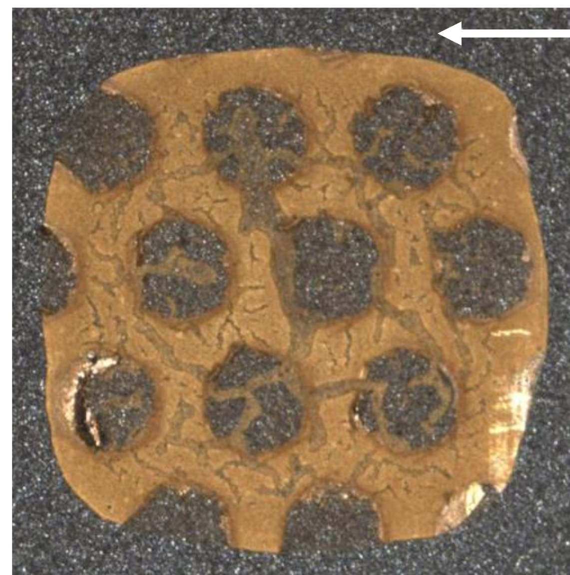
Pt/HTCC Substrate Shear Results – Failure Mechanism

Shear direction



SiC die



Shear direction

Pt/HTCC substrate

Dominant failure at Au attach layer / Pt (substrate) interface

- Adding an Au thick-film layer on Pt/HTCC substrate for improvement?

No major void in area of Pt bond pads

Die Shear Results Par II – Au/Pt/HTCC Alumina

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Au/Pt/HTCC Substrate Shear Results

Sample	Die shear (kg)	Number of hexagon pads	Max.-shear stress (kg/mm^2)
A1	16.0	12.5	1.48
A2	18.0	11	1.89
A3	14.22	12	1.37
A4	18.42	12	1.77
A5	14.10	10.5	1.55
A6	25.28	13.5	2.16
A7	21.11	13.5	1.81
A8	19.24	12	1.85
A9	26.80	13	2.38
A10	20.45	12	1.97
A11	19.37	12	1.86
A12	14.92	12	1.44

Shear speed: 12 m/min, shear height 95 µm

Au thick-film on Pt/HTCC substrate fired at 850 °C for 15min

39% improvement, lowest die shear > 14 kg

Die Shear Results Par II – Au/Pt/HTCC Alumina

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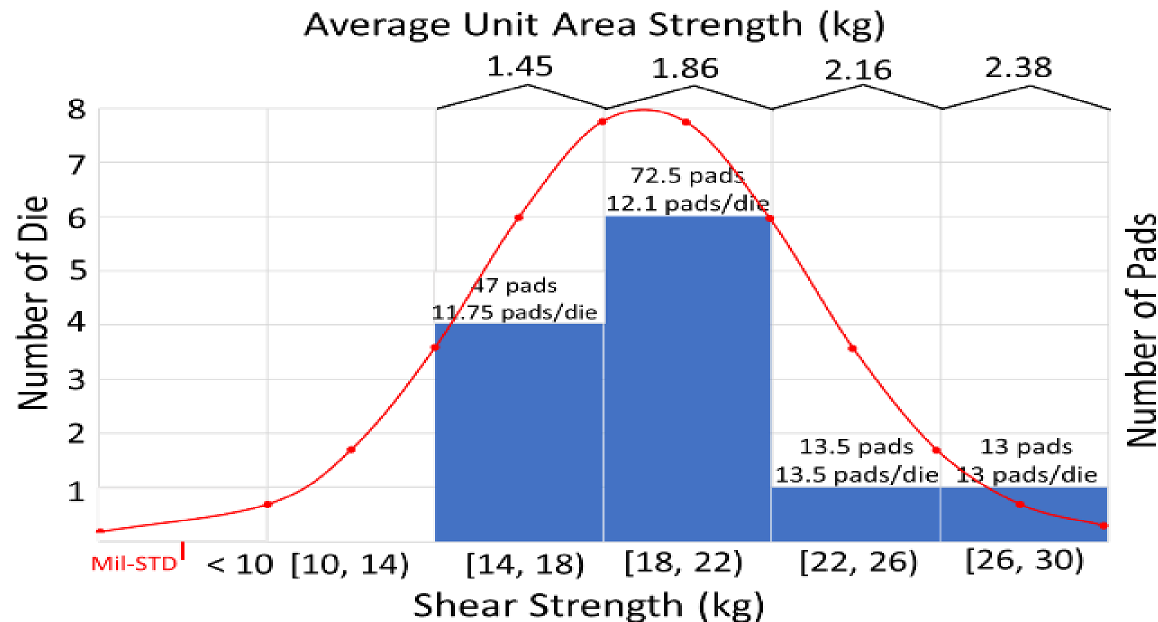
Au/Pt/HTCC Substrate Shear Results



- Averaged die shear strength: 18.99 kg
  - 39% improvement compared with Pt/HTCC substrates
- Standard deviation: 3.88 kg
- The lowest shear strength measured >14 kg
- 2.0 x die shear strength of MIL-STD 833 for 5 mm x 5 mm die is 5.0 kg
- Die shear strengths of 1 mm^2 (small area) > 2.0 x MIL-STD 833
- More data needed to better fit the normal distribution curve

Die Shear Results Par II - (Au)Pt/HTCC Alumina

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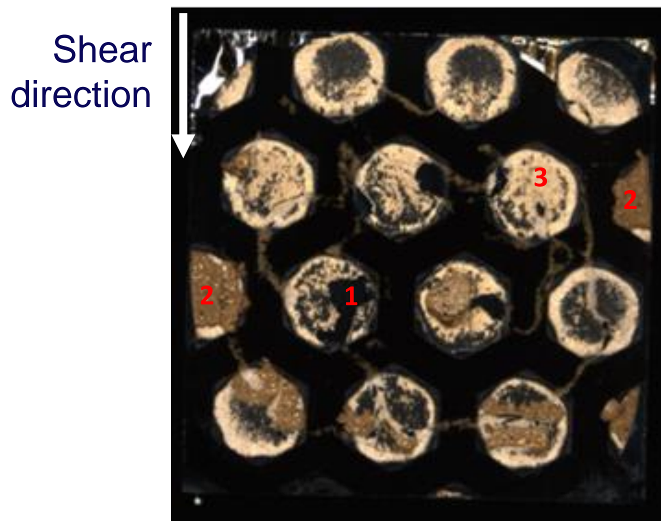
Au/Pt/HTCC Substrate Shear Results – Failure Mechanisms



SiC die

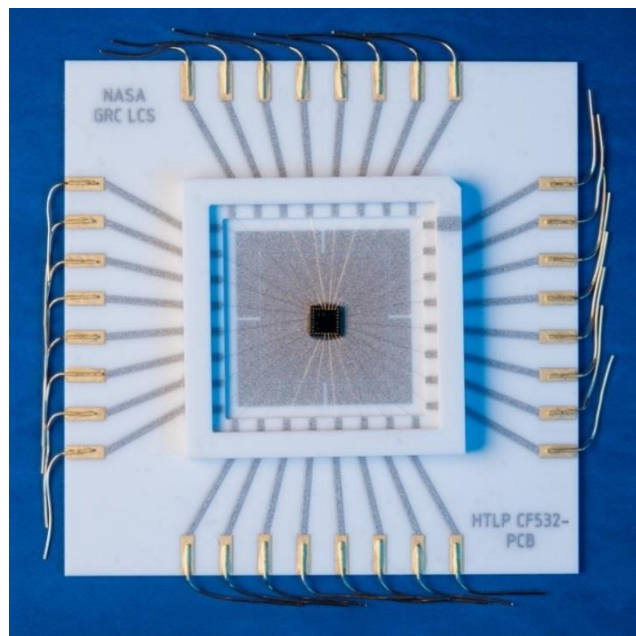
Au/Pt/HTCC substrate

Failures: 1. SiC / metallization pad interface 2. Au thick film attach layer 3. Au thick-film/Pt (HTCC substrate) interface

- No weakest link
- Substrate buckled under shear stress

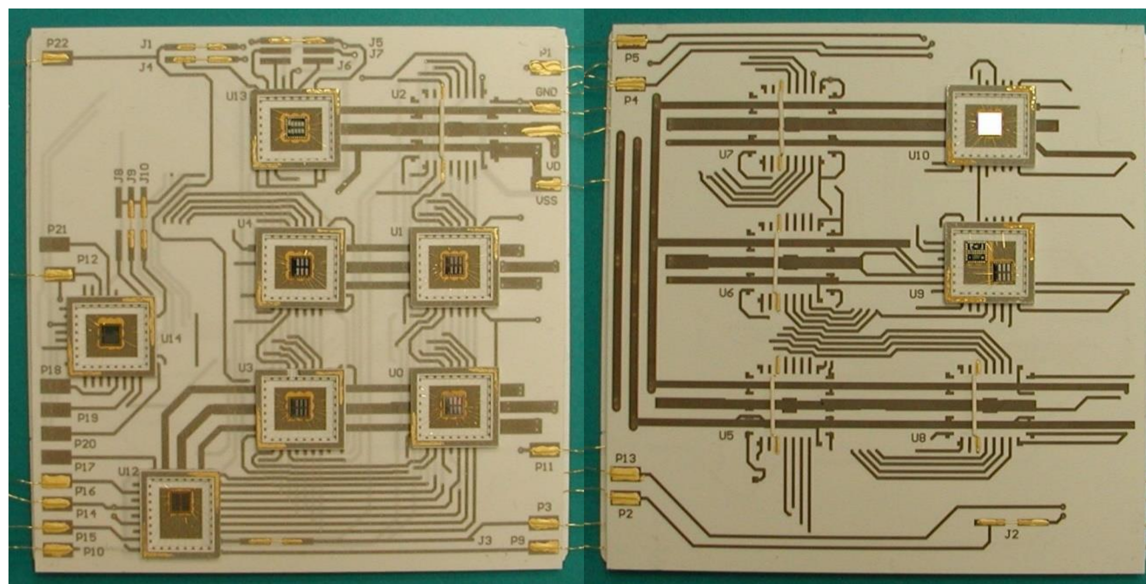
No major void observed, not in areas of hexagon bond pads

Test Assembly of a SiC IC with HTCC Alumina Packaging System



- PCB measures 50.8 mm x 50.8 mm, Pt traces co-fired with alumina
- Packaged SiC chip with a 32 I/Os Pt/HTCC alumina package and PCB
- Package attached to board with Au paste at 850°C first
- 1 mil Au alloy wire thermo-sonically bonded
- Facilitated long term test of SiC ICs at 500 °C

Double-sided Multilayers HTCC Circuit Board



- 11.43 cm x 11.18 cm HTCC alumina circuit board with four layers of Pt conductor
- Pt surface metallization, and hermetic Pt via
- Nine packages with total of ten SiC IC chips integrated on the board
- Smaller version of 32-I/O packages, I/O wires and jumpers attached
- Packages attached to board with Au paste at 850°C first

Discussion

Shear data validate room temperature mechanical strength of SiC die attach to Au/Pt/HTCC alumina substrate with Au paste at 600°C

- More shear tests including thermal durability and in situ high temperature tests needed
- Shear strength of Au paste /Au/Pt/HTCC fired at 600°C can apply to HTCC/Pt/Au/ Au paste /Au/Pt/HTCC

Bonding strength of Au paste on Au/Pt/HTCC fired at 600°C

- Shear strength: 1.8 kg/mm^2
- Au/Pt bond pads area for a 16-pad HTCC package: 79 mm^2
- Shear strength: 70 kg considering 50% effective bonding area (40 mm^2)
- Attach Au/Pt/HTCC packages to (Au)Pt/HTCC circuit boards at 600°C feasible
- Acceptable temperature to SiC ICs and Au bonding wires
- Enable packaged ICs tested and selected for subsequent board integration

Summary

- 5 mm x 5 mm SiC with 50% patterned TaSi2/Pt/Ir/Pt metallization attached to Pt/HTCC substrate with DuPont 5036D paste fired at 600 °C
- average die-shear strength 13.6 kg (> $6x10^5$g)
- Au thick-film layer on Pt/HTCC showed ~ 39% shear strength improvement
- Exceeding 2.0 x MIL-STD 833 requirements for large die
- Shear tests after long term exposure to high temperature as well as high temperature in situ shear tests needed

- Sufficient bonding strength of Au paste on Au/Pt/HTCC fired at 600°C
  - Au/Pt/HTCC packages attached to (Au)Pt/HTCC circuit boards at 600°C
  - Enable individually packaged high-temperature IC units before integration onto circuit boards
  - Allows user to test and select individually packaged ICs

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Thank You Very Much for Your Attention!

Acknowledgements

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