Bonding of ceramic and silicon - new options and applications

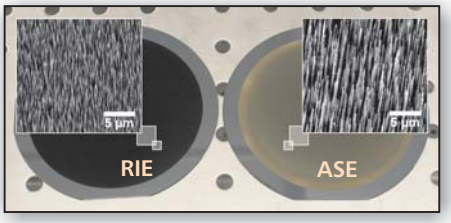
Why silicon ceramic interconnects?

The Synergy of both technological fields (Si-MEMS and LTCC) offers a great potential:

- simultaneous thin- and thick film technology
- structures from nm- to mm-scale without assembly effort
- 'high current' conductor lines and vias
- smart packaging

requirement ⇒ silicon compatible ceramic system

BGK, a silicon-compatible LTCC tape from HITK (Germany) with a TCE of 3.6 ppm/K, was investigated



Needle Properties

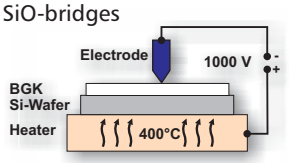
RIE		ASE®
up to 2	length [µm]	up to 25
200	diameter on top [nm]	300 ... 500
100 ... 400	diameter on bottom [nm]	700 ... 2000
10 ... 20 Mio	density [/mm²]	> 1 Mio
smooth	needle surface	ribbed

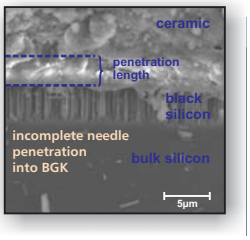
Anodic bonding of BGK with silicon

- 400°C ⇒ BGK becomes conductive due to natrium ions (4% Na_2O in the glass part of BGK)
- 700 ... 1000V ⇒ Na^+-ions migrate to the pin electrode
- formation of a space-charge region; electrostatic forces
- unsaturated oxygen bondings + Si ⇒ SiO-bridges

but:

- polishing process of the fired BGK is required (Ra = 1.2 µm to 40 nm)
- extremely time-consuming process





Parameter optimisation

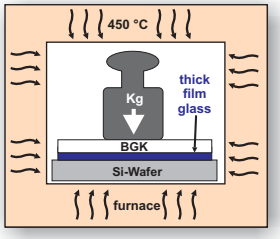
- variation of the black silicon needle length (20 µm ... 1.2 µm)
- variation of lamination parameters
  pressure: 5.3 MPa ... 15.6 MPa
  time: 10 min ... 30 min
  temperature: 70 °C ... 90 °C
- optimum ⇒ 5.3 MPa, 30 min, 90 °C

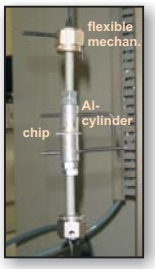
Thick Film Glass Bonding of BGK with silicon

- screen printing of Ferro FX-036 to wafer
- drying and prefiring of the thick film glass
- compressing of the bonding partners
- firing with an advised temper profile including T_{max} of 450°C

but:

- for a homogeneous bonding interface a very flat ceramic is necessary (no polishing)

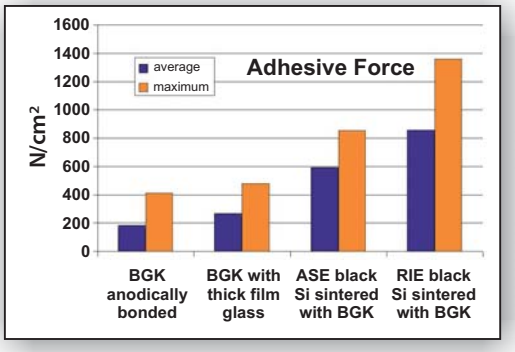




Qualifying the adhesive forces

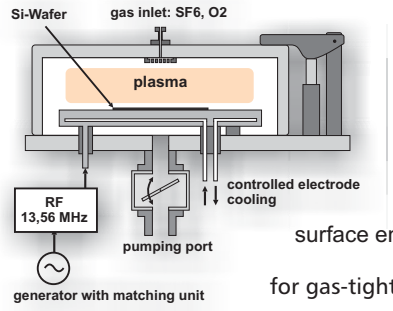
- dicing of 10 mm square pieces
- chip gluing (epoxy resin) onto Al-cylinders
- fixing the assembly with a flexible mechanism into a commercial pull tester (Zwick GmbH & Co. KG)
- tearing off the samples under controlled conditions

Properties of the bonding methods



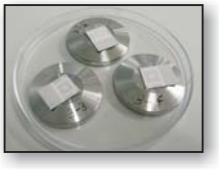
Bonding of BGK with Black Silicon

- structuring of the black silicon surface (ASE, RIE)
- plasma stripping of the residue polymer
- aligning and stacking of the bond partners
- lamination and simultaneously impressing the black silicon into BGK
- pressure assisted sintering (laterally zero shrinking, firing profile with a peak temperature of 850°C)



Black Silicon?
needle like structures with micro- and nanometer dimensions, fabricated by lithography-free, self-organised etching processes on standard silicon etching machines (ICP, RIE)
Not only an unwanted side effect of anisotropic silicon etching!

- surface enlargement by using black silicon leads to a significant increase of the adhesive forces
- for gas-tightness a total needle penetration into BGK is necessary



bonding method	Temp. [°C]	max. adh. Force [N/cm²]	operating expense
anodic bonding	400	413	high
thick film glass bond.	450	479	medium
bond. with ASE bl. Si	850	852	low*
bond. with RIE bl. Si	850	1360	low*

)* assuming plasma structuring for silicon during processing

CONTACT | INFO

Technische Universität Ilmenau, IMN, Functionalised Peripherics
M. Fischer, Dr. J. Müller
98693 Ilmenau (Germany), Phone: +49 3677 69-3413
E-mail: michael.fischer@tu-ilmenau.de

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