Towards Reliable Bonding of Sapphire and Silicon II

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Bonding of a sapphire fiber by Melting in a Furnace / USP Laser Welding +Tensile Strength Tests on Sapphire Fibers

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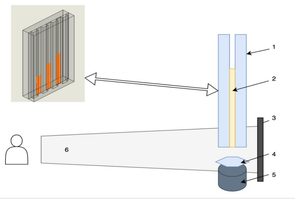
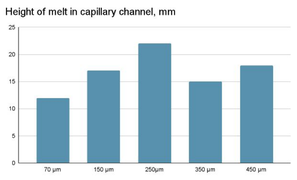
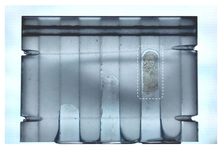
Bonding of a sapphire fiber by melting in a furnace (Inst. Of Single Crystals)

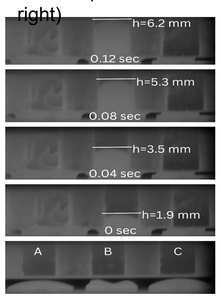


General scheme of infiltration and process observation. 1 – Plates with capillary channels, 2 – Capillary channel, 3 – Dark background for high-contrast observation, 4 – Crystal/molten droplet for infiltration, 5 – Pedestal for the molten droplet, 6 – Field of view for the observer and video camera.

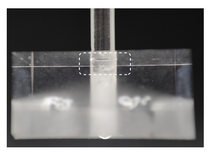


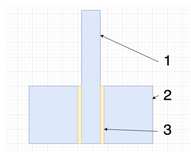


Melt rise in channels with width from 0.5 to 0.2 mm (from left to right)

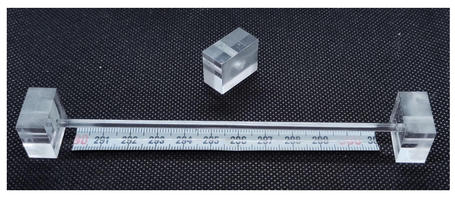


Frames of the simultaneous infiltration of three capillary channels along with a frame before contact.





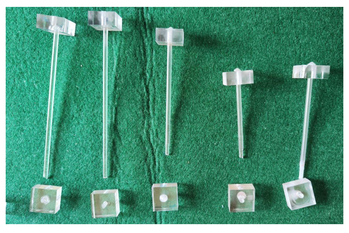
Block (2) and rod (1) fully connected by melt (3) that was pulled by capillary force in the gap between block and rod.
Thermal gradient along cylindrical capillary channel (width 0.15..0.45 mm) allows to rise melt up to 25mm.

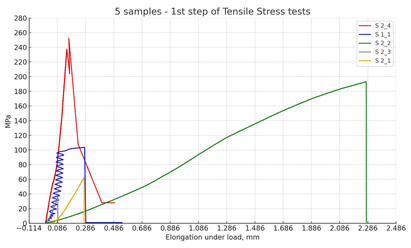


The sapphire suspension created of 3 parts : 2 blocks (20x20x10 mm^3) and rod 1.6 and 3 mm in diameter. Length up to 550 mm.

Tension stress testing for sapphire fibers

Machine for testing of tension stress INSTRON-5581, load up to 100 kN. Metal holder for cubic ends was produced. Cuprum layers were used to uniform load to the cubic surface. The cuprum parts in the metal holder for cubic ends were added to solve some misalignment between rod's axis and cubic's axis. The cuprum parts were softened by heat treatment before tests.

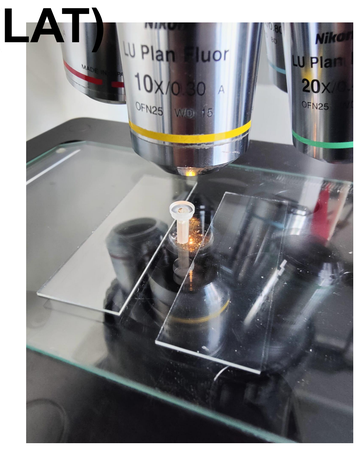


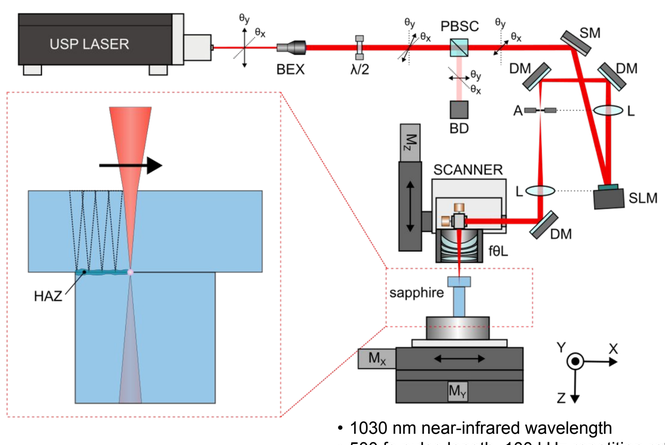


The cracks appeared at the same angle 43° +/-5° to axis to the rod. It was found by X-Ray diffraction method that mirror-like elements of surface on the crack's was R-plane

The load of failure for the samples are up to 260 MPa that shows the potential of high strength for assembled sapphire holder using sapphire melt.

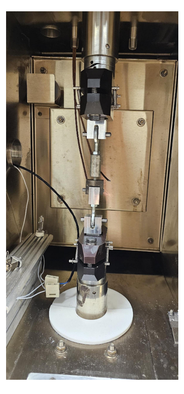
Bonding of a sapphire fiber by Ultrafast Laser Welding (LAT)

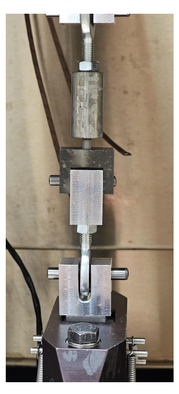


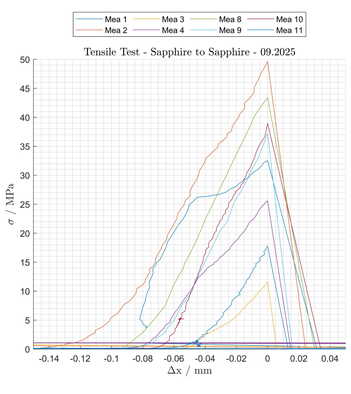


- 1030 nm near-infrared wavelength
- 500 fs pulse length, 100 kHz repetition rate
- 20 – 40 W average power
- < 15 µm focal spot size

Tension stress testing for sapphire fibers (LAT)





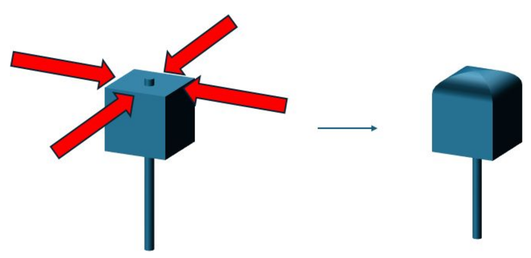


Tensile testing machine: MTS 858 Mini Bionix II , load up to 2.5 kN, Crossbar speed: 0.5 mm/min. Procedure:
- Glue the sapphire cylinder into the corresponding holder. (2-component adhesive UHU Plus Endfest)
- Curing for 24 hours
- Screw in the holder with the glued rod
- Move the crossbar and secure both holders with a dowel pin
- Start tensile test

Silicon Welding Updates:

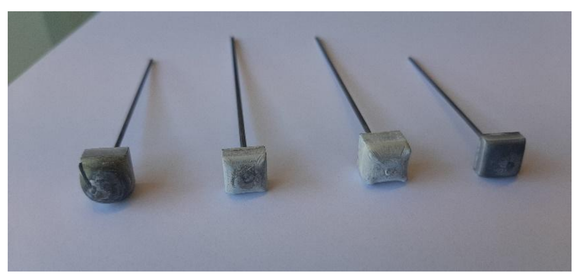
Dr. Celia Millon,
Dr. Michael Müller

Bonding of a Silicon Fiber by Float Zone (FZ) method



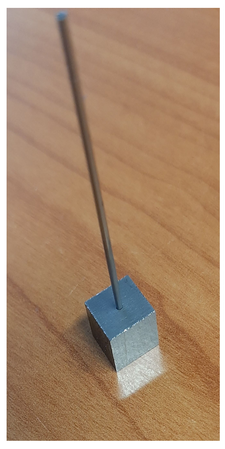
- Matching crystallographic orientations cube/rod
- Argon atmosphere
- Narrow heating zone (4 halogen lamps)
- Heat to just above the melting point (1414 °C).

Outlook:
- Capillary Gap optimization
- Thermal/Mechanical tests

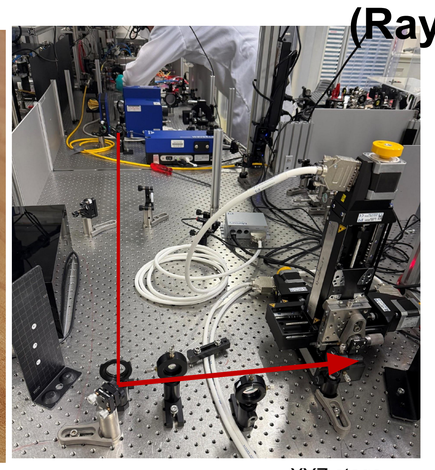


Bonded half dumbbells
(head ~ 9 x 9 x 8 mm, fiber: Ø 1.2 mm, length 60 – 80 mm)

Trials to Si-Si Welding by Ultrafast Laser 2.1µm (RayVen)

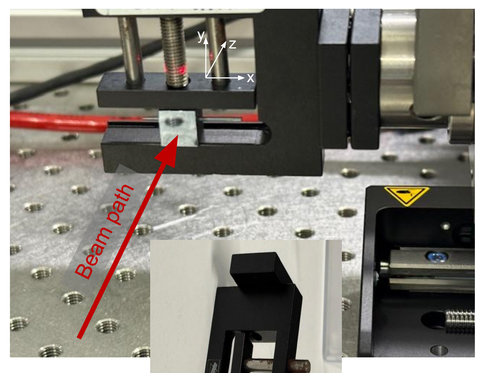


A sample to weld

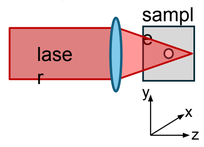


Beam path XYZ-stage

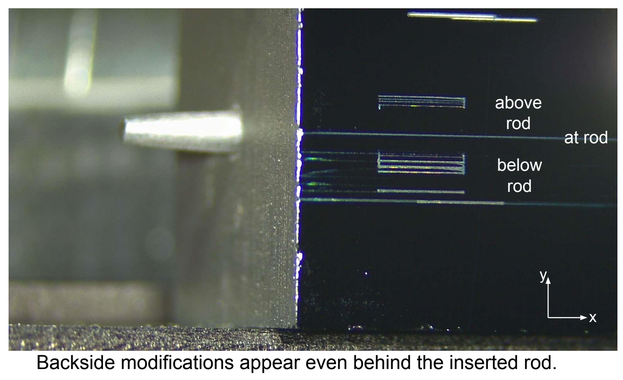
Silicon rod-in-cube mounted on stage



- Laser
  100 kHz, 3.5 W, 35 uJ, 1.5 ps
- Focusing with aspherical lens
  f = 10 mm, w_0 = 2.5 mm (radius)
- Scanning
  - Linear scans in x,y
  - Manual setting of z position
  - Velocity 2-20 mm/s

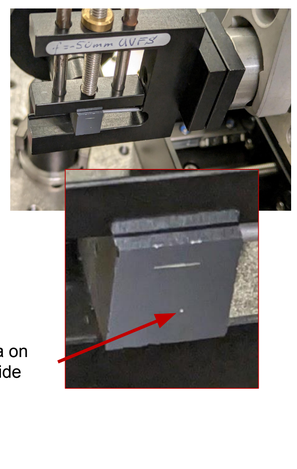


Side view



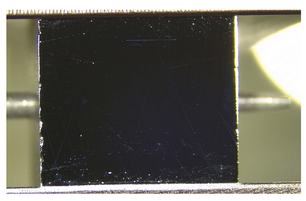
Backside modifications appear even behind the inserted rod.

Focus on the back

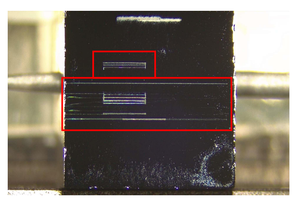


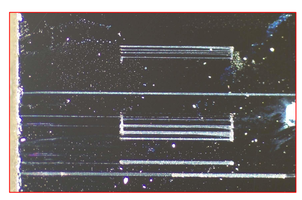
Plasma on backside

Undamaged frontside



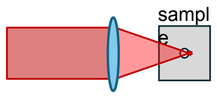
Modified backside

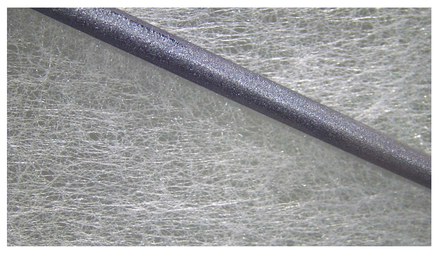




Investigation of the rod after processing

Focus on the cube/rod interface





No modifications observed

Conclusion:
Ultrafast Laser technology is not directly transferable to silicon.
Modifications required.

Outlook:
- Systematic scanning of parameters to determine the welding process.
- Increasing energy absorption by gold layers?

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