"St Peterburg updates on studies of thermomechanical compatibility of CF and Si plates with different CTEs"

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Reported by G.Feofilov
ITS-upgrade WP5 meeting, 10 October 2023, 16300 → 17:00 Europe/Zurich
https://indico.cern.ch/event/1334873/

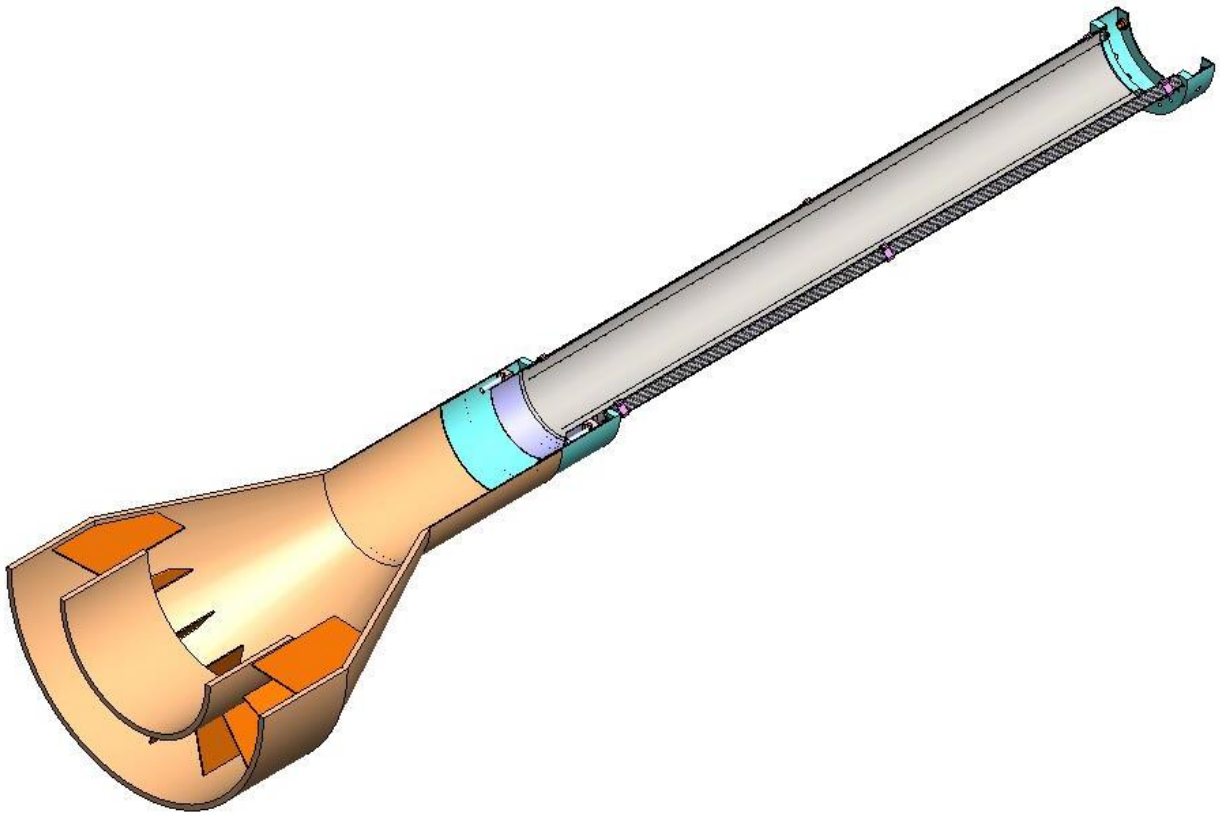
Layout

Introduction

1) Conceptual design of self-supported module
2) Ultraligthweight self-supported mechanics
3) Prototyping and CTE tets

Conclusion

Conceptual design of self-supported module



Conceptual design of self-supported module

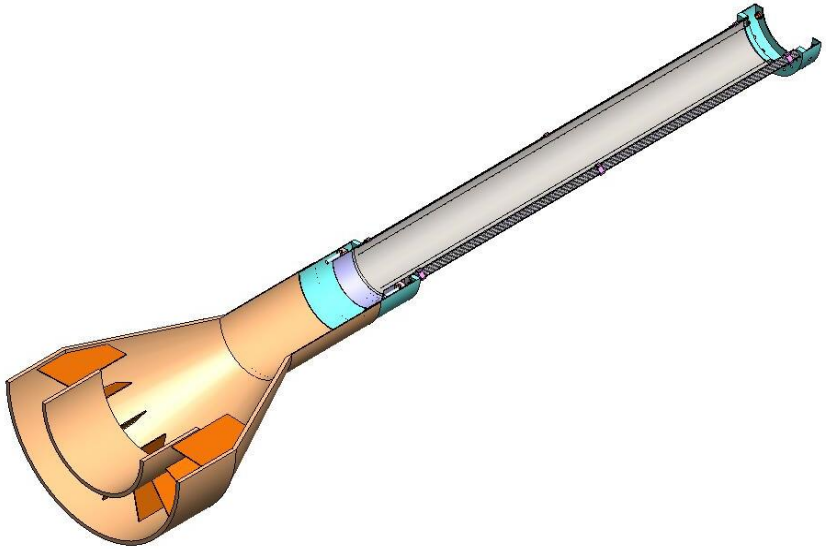
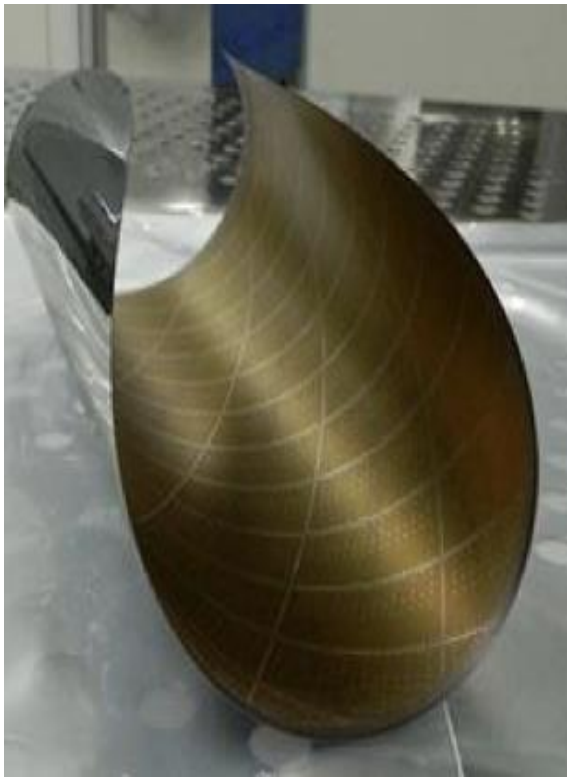


Photo of self-supported module with dummy bent Si

CTE compatibility for Si and CF -?



Bent Si-plate

(A)

(B)

(B

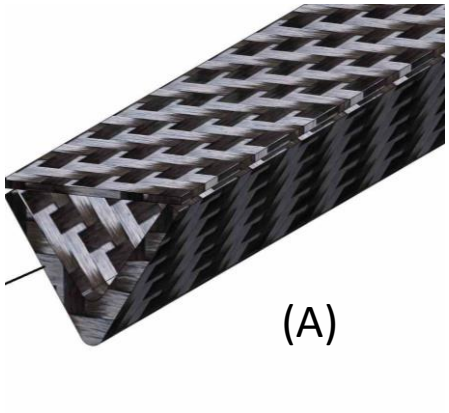
Photos of end-view (A) and side views (B)of extra-lightweight trihedral CF longerons produced with NIICAM prepreg

CTE Si =
Si sensor (CTE = (2.6–3.3) x $10^{-6}/K^{-1}$
And up to 5.1 x $10^{-6}/K^{-}$

CF composite *CTE* =f rom ~ 0 to $-0.64 \times 10^{-6}/°K$

CTE compatibility for Si and CF -?

(B)



(A)

Photos of end-view (A) and side views (B) of extra-lightweight trihedral CF longerons produced with NIICAM prepreg

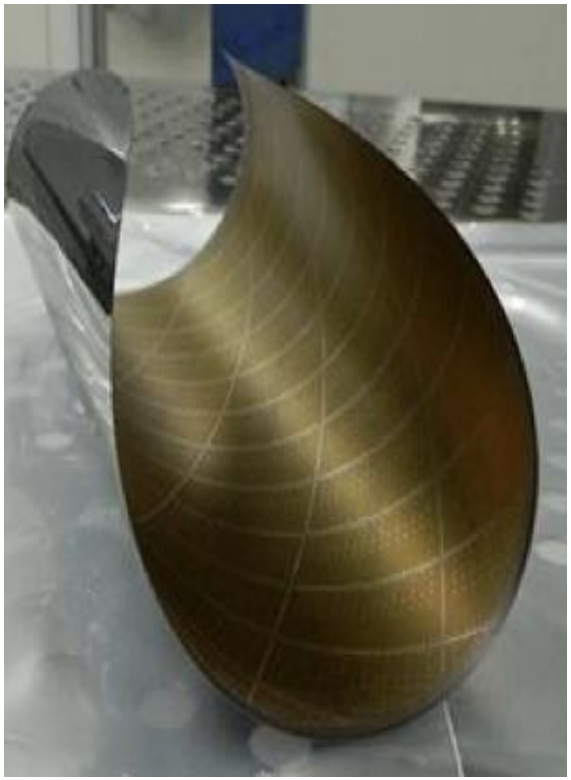
Longeron No.	Side edge, mm	Profile side hight,mm	Weight of Longeron, g	Weight of Longeron +CF plate, g
SPBU-ITS3-CF4	4,11….4,40	3,43…3,60	1,68г	1,85г
SPBU-ITS3-CF5	3,97….4,12	3,44…3,62	1,74г	1,89г
SPBU-ITS3-CF6	4,08….4,44	3,85…3,59	1,73г	1,89г

CF Longeron length - 287 mm

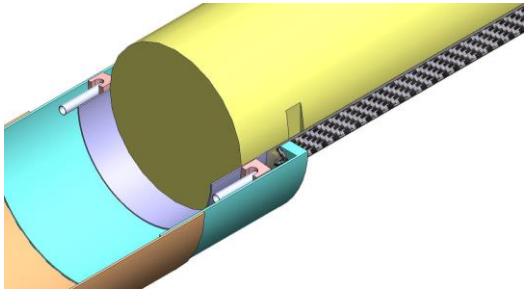
CF composite *CTE* =f rom ~ 0 to -0.64×10^{-6}/°K

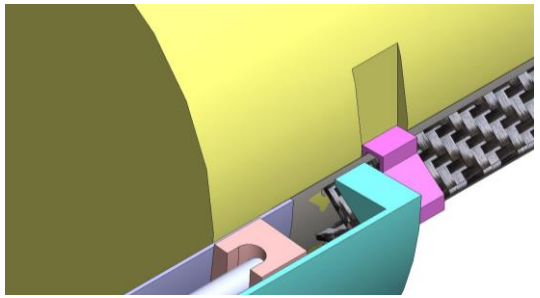
CTE compatibility for Si and CF -?

Proposed earlier:



Bent Si-plate





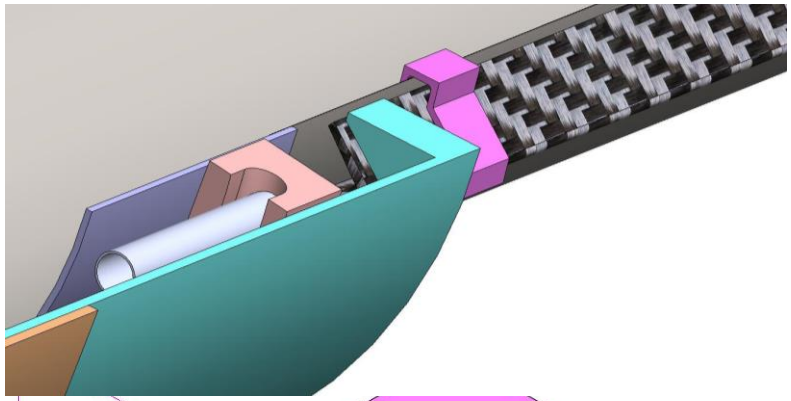
The application of mechanical clips during assembly could allow to disentangle the materials with different CTEs , namely, Si sensor (CTE = (2.6–3.3) x $10^{-6}K^{-1}$.) and carbon fiber composite (CTE~ *CTE* =from ~ 0 to −0.64 × 10^{-6}/°K).

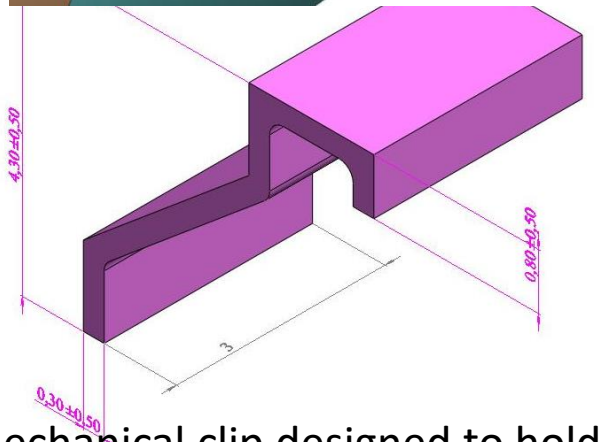
CF composite *CTE* = from ~ 0 to −0.64 × 10^{-6}/°K

The linear CTE of pure silicon
CTE = (2.6–3.3) x 10^{-6} /K^{-1}

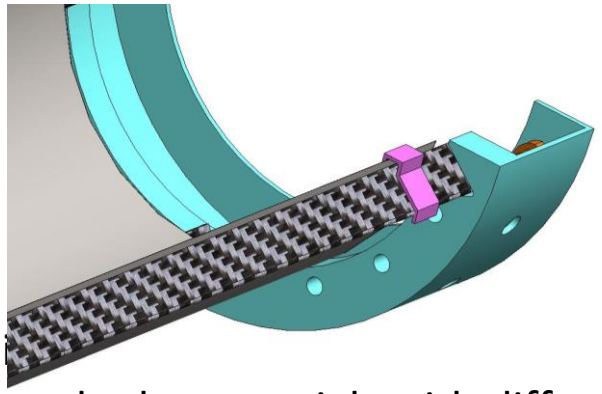
https://resources.system-analysis.cadence.com/blog/msa2021-the-importance-of-matching-the-cte-of-silicon

CTE compatibility for Si and CF -?





The mechanical clip designed to hold the bent sensor inside the CF support structure and to avoid, at the same time, mechanical stress on thin large area Si sensor, due to CTE mismatch with CF composite structures.



The appli
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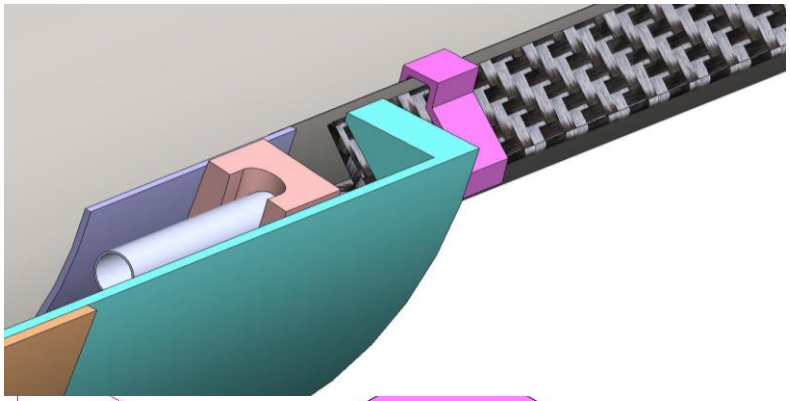
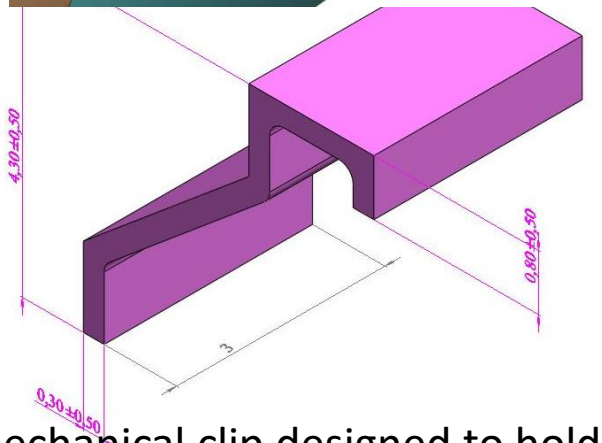
CTE compatibility for Si and CF -?





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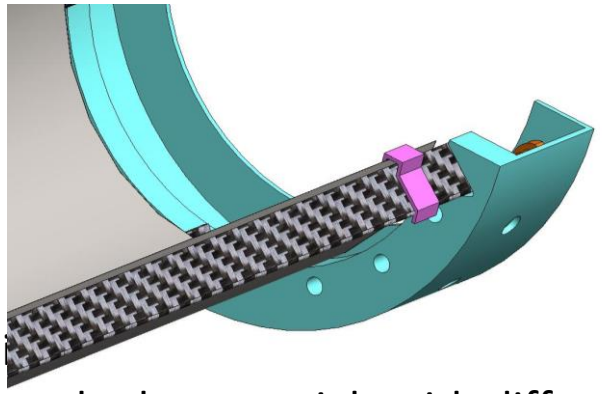

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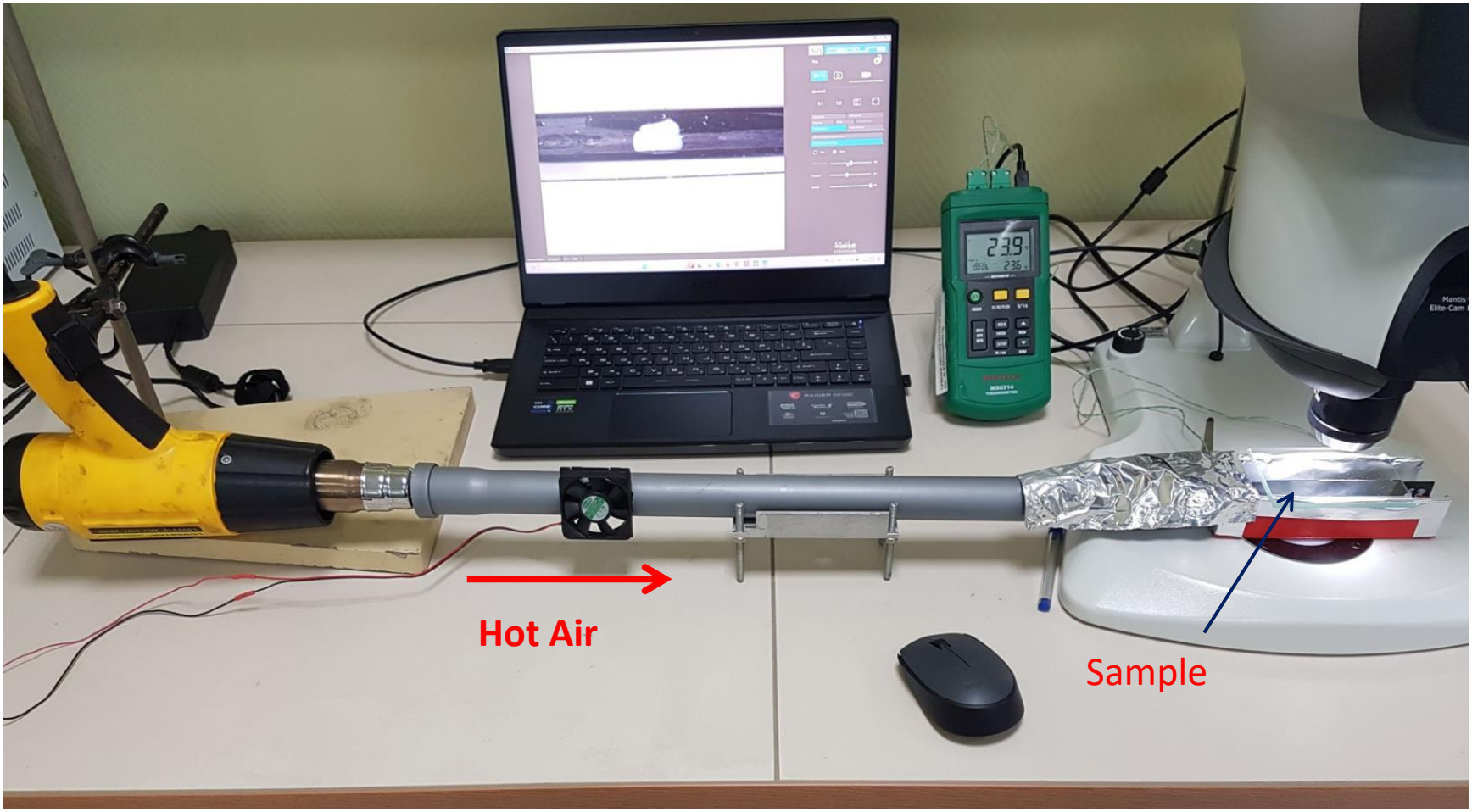
- **Could be nice, but….**
- **The problem in application of mechanical clips:**

It is the high fragility of thin ~40µ Si –sensors…

- **To glue? Where? Continuous line of glue? Or Dots?**

Test station

Thermal measurements



Thermal measurements of the deflection of a 40 μm thick silicon wafer glued at the ends to a carbon wafer

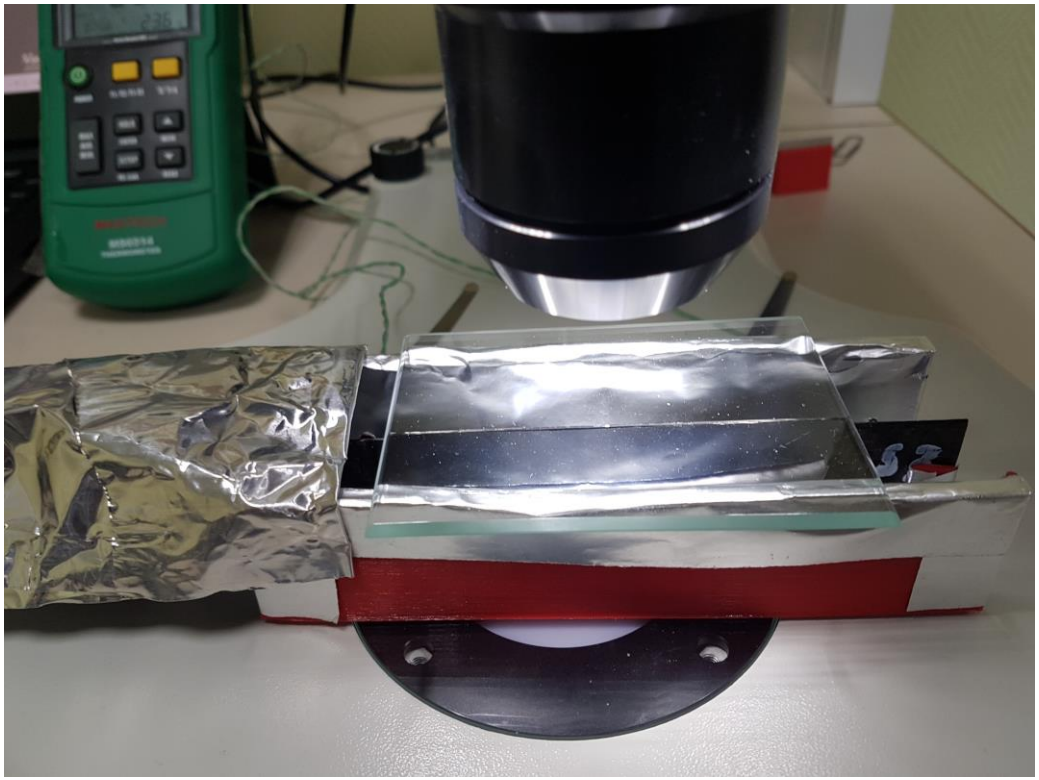
1) Microscope

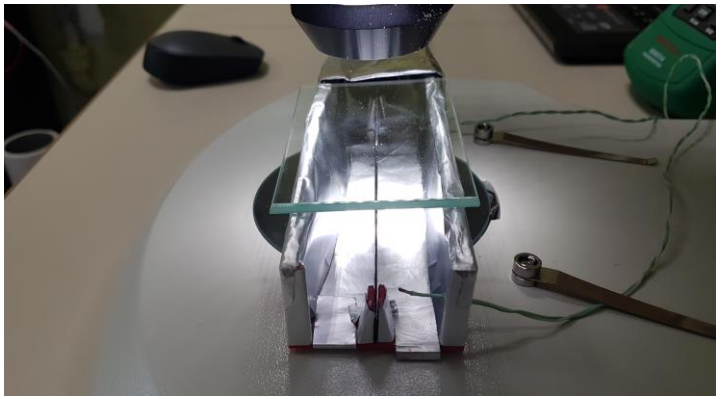
2) Holder with fixed sample

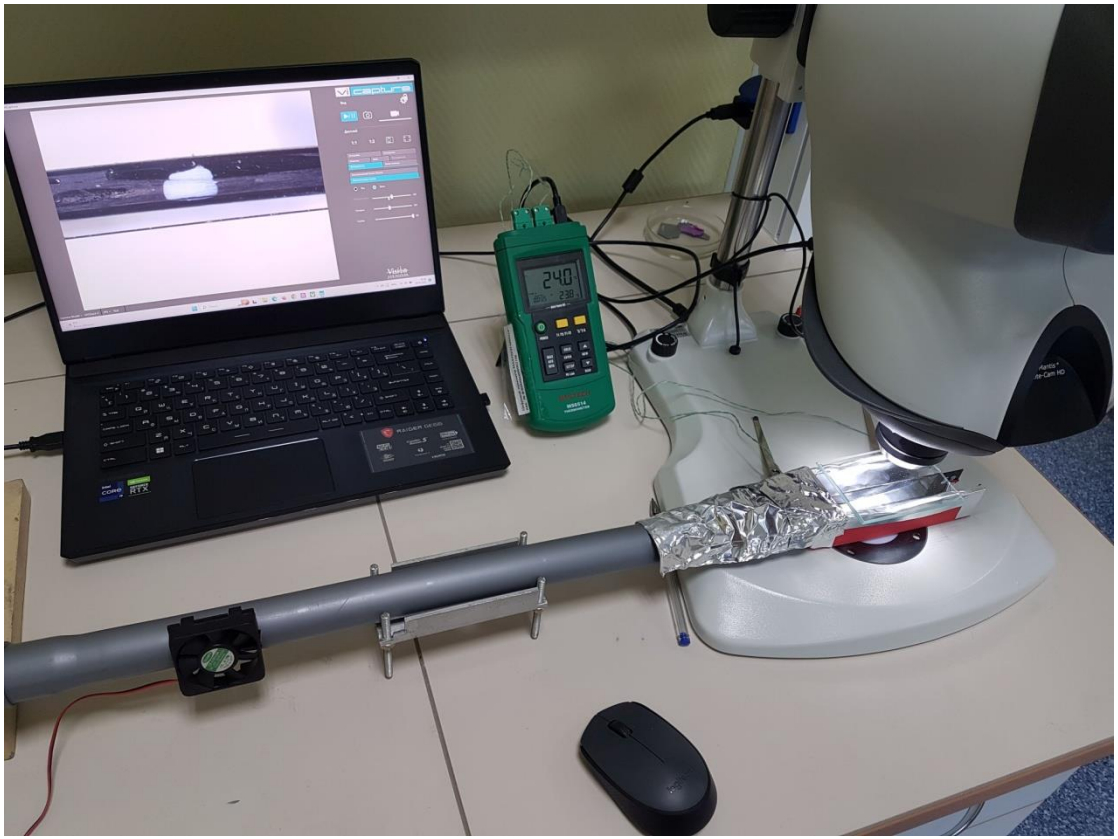
3) Adjustable hot air flow is created by a special wind tunnel (industrial hair dryer, pipes, flow control system), two thermocouples located at the ends of the test sample (input and output of heat flow into the installation): T1 and T2.

- SAMPLE (Si_CF plate):

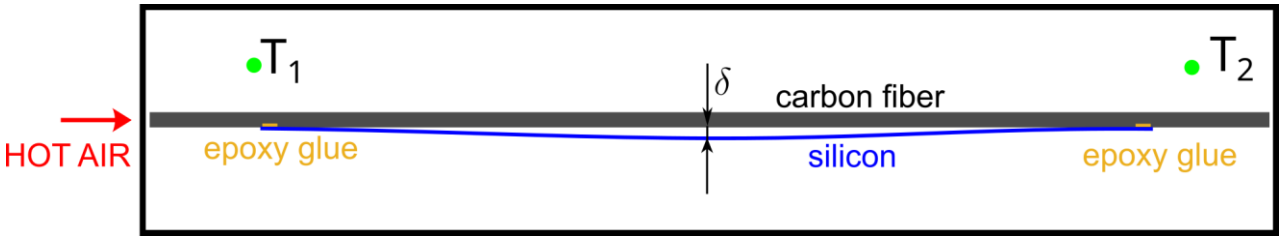
Sample holder





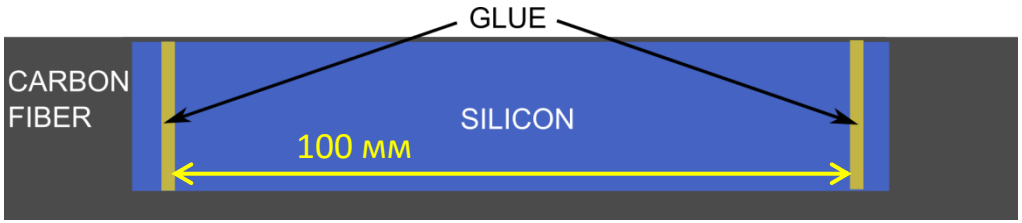


Measurement diagram (top view)



Distance between T1 and T2: 125 mm
T1 from the left edge 25 mm, T2 from the right 10 mm
Sample mounting fixture length 150 mm

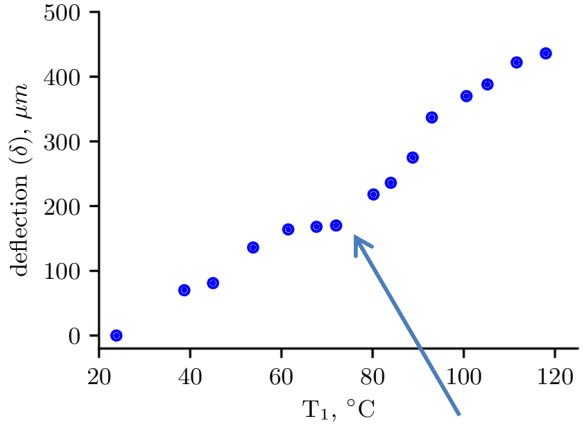
Sample No. 1

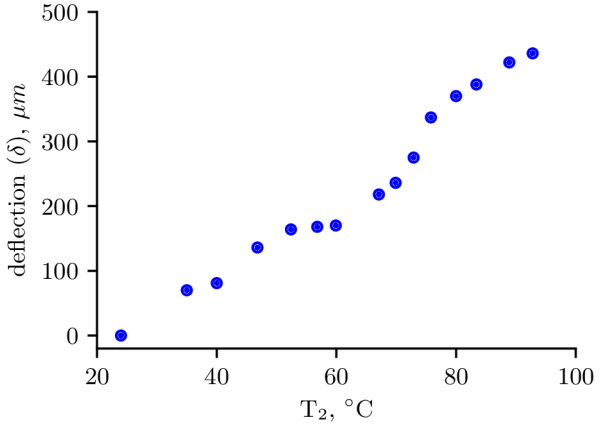


Gluing scheme

Silicon 22 mm wide, glued to a carbon fiber substrate 150 mm long, 27 mm wide and 0.8 mm thick. Epoxy adhesive ED-20 with hardener Etal-45M is applied in the form of strips 2 mm wide, the distance between the glues is 100 mm.

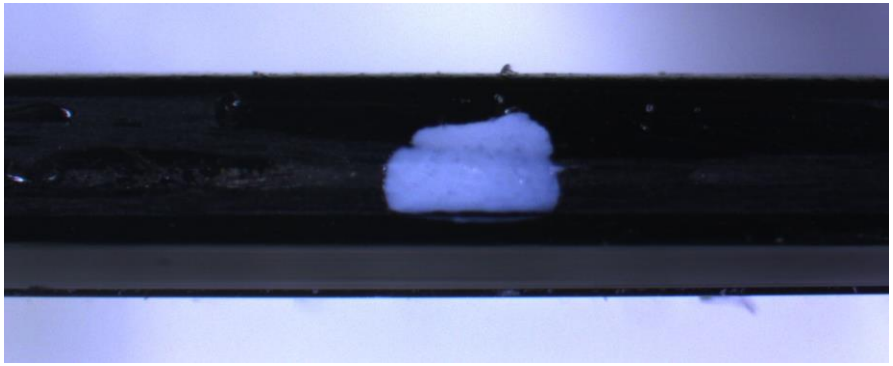
Results of measurements of the bending of a silicon wafer depending on temperature on thermocouples T1 and T2



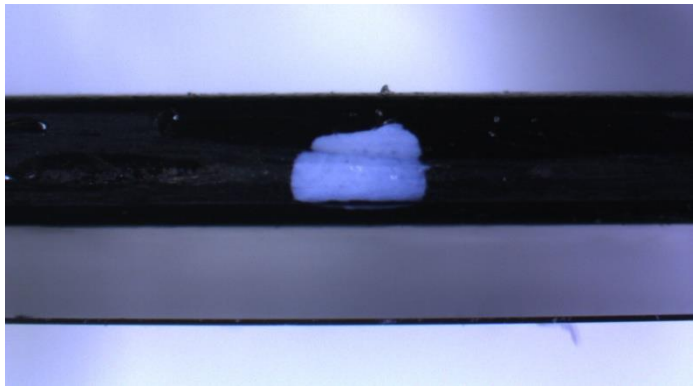


An abrupt change in the position of the maximum plate deflection is observed on the sample, at a temperature in the region of T1 ≈ 75 °C (right edge of the plateau)

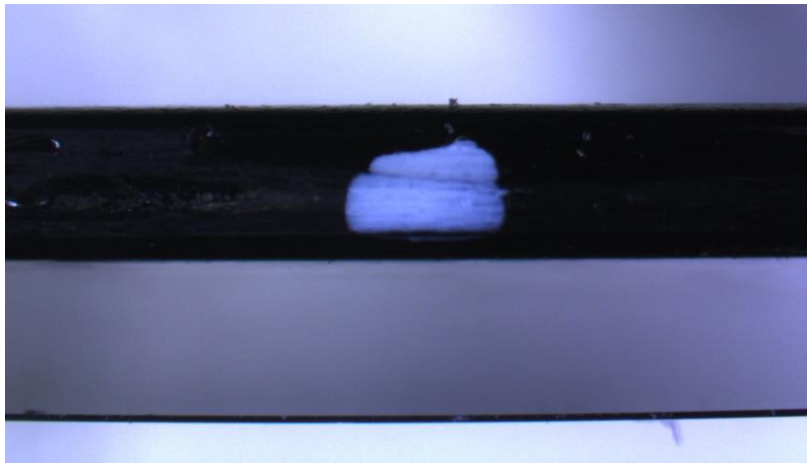
An example of silicon plate deflection, sample No. 1 (photos from a microscope



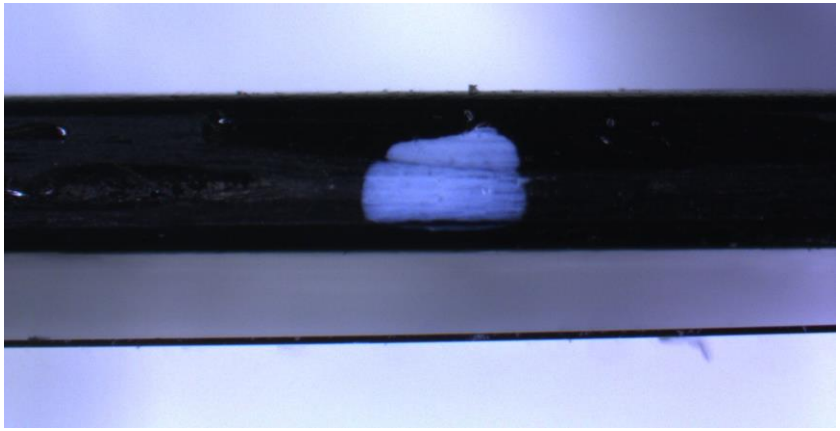
T_1=33 °C, T_2=31 °C (начало, до нагрева)



T_1=76 °C, T_2=68 °C

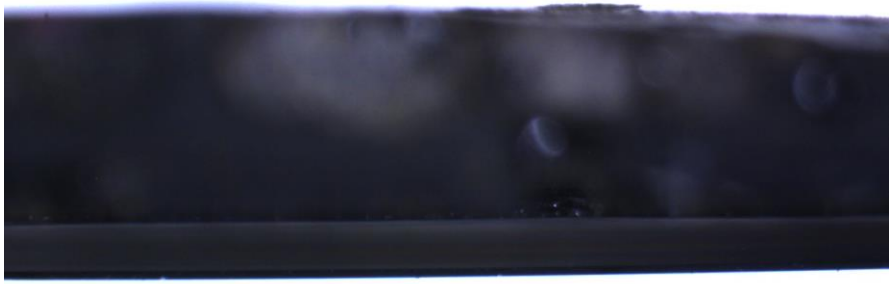


T_1=124 °C, T_2=109 °C

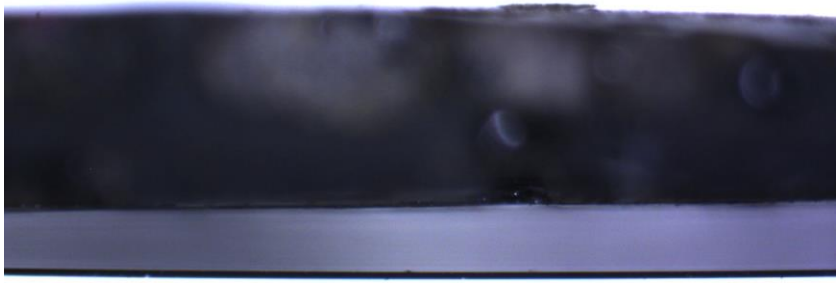


T_1=30 °C, T_2=31 °C (после охлаждения)

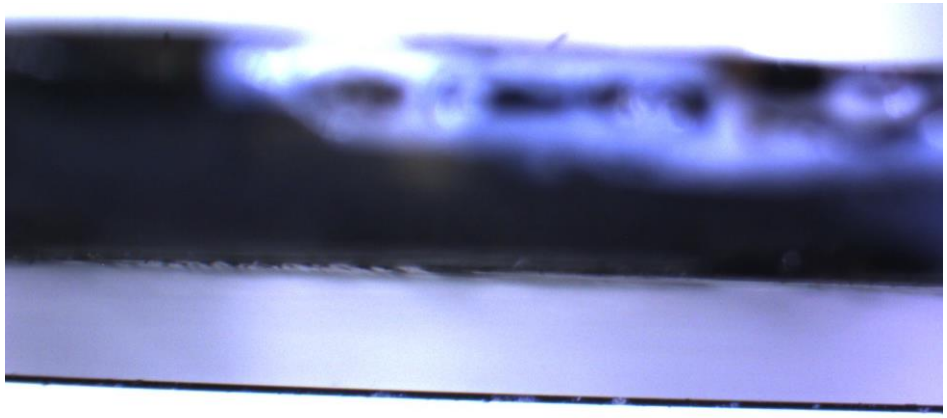
An example of silicon plate deflection, sample No. 1 (photos from a microscope)



T_1=45 °C, T_2=40 °C

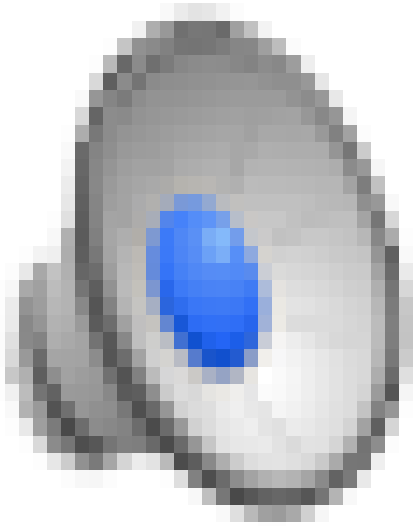


T_1=80 °C, T_2=67 °C

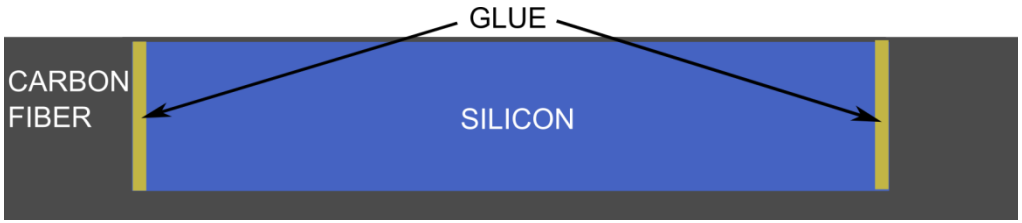


T_1=118 °C, T_2=93 °C

Sagging of Si with temperature



SAMPLE № 3



Gluing scheme

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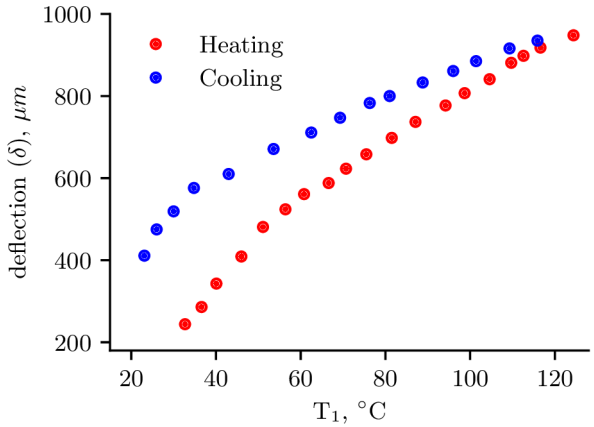
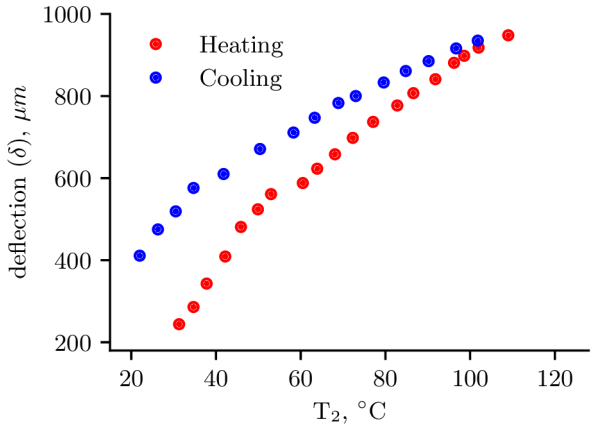
Results of measurements of the bending of a silicon wafer depending on temperature on thermocouples T1 and T2

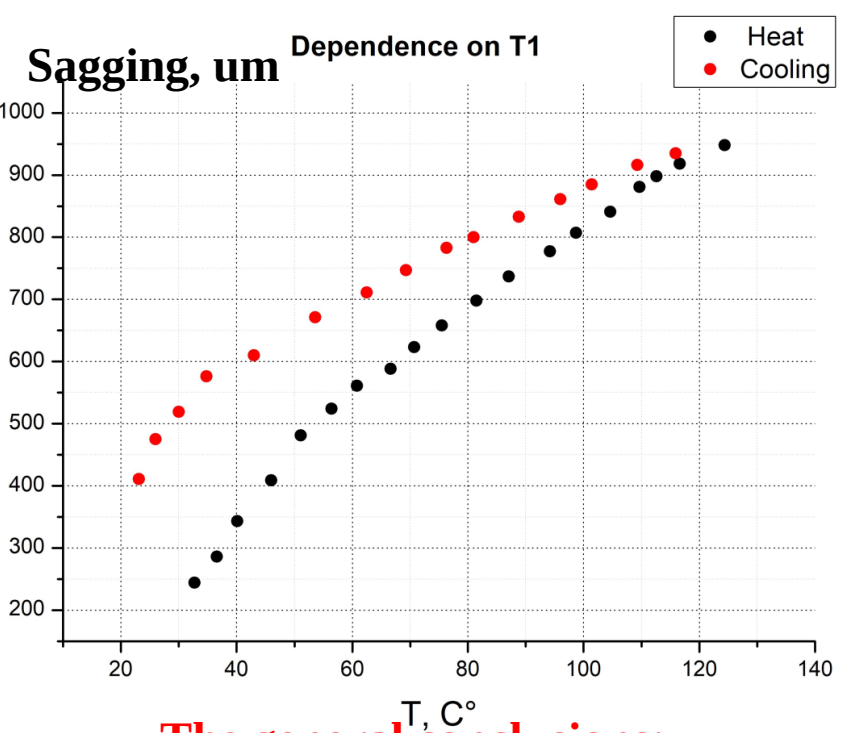


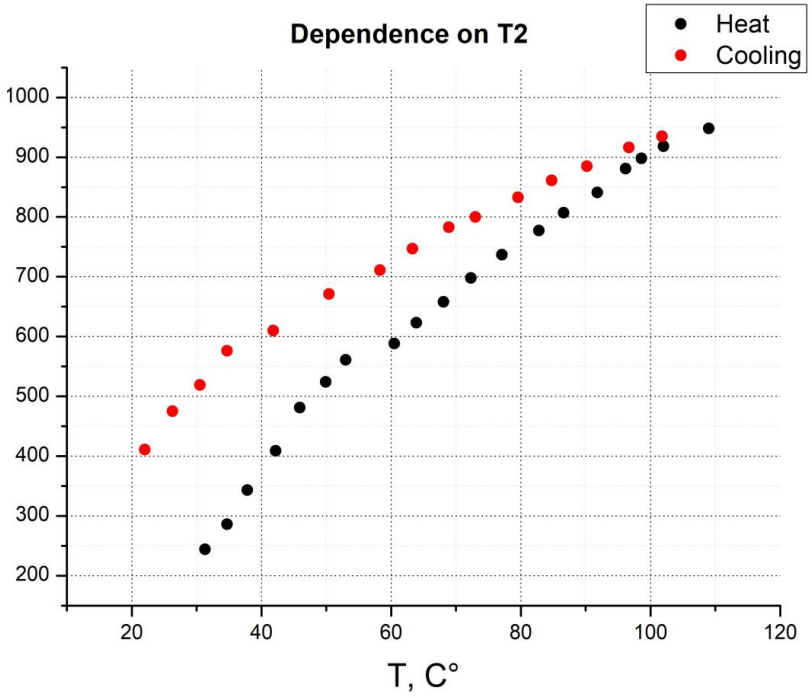


Hysteresis is observed

Thermal measurements

The distributions along the Y axis show the deflection of the silicon wafer when it is heated. Along the X axis is the temperature at the entrance to the installation - thermocouple T1 and the temperature at the outlet of the experimental installation. The measurements were carried out when heated to 120-130 °C (black circles - Heat), and then immediately when the sample cooled (red circles - Cooling)

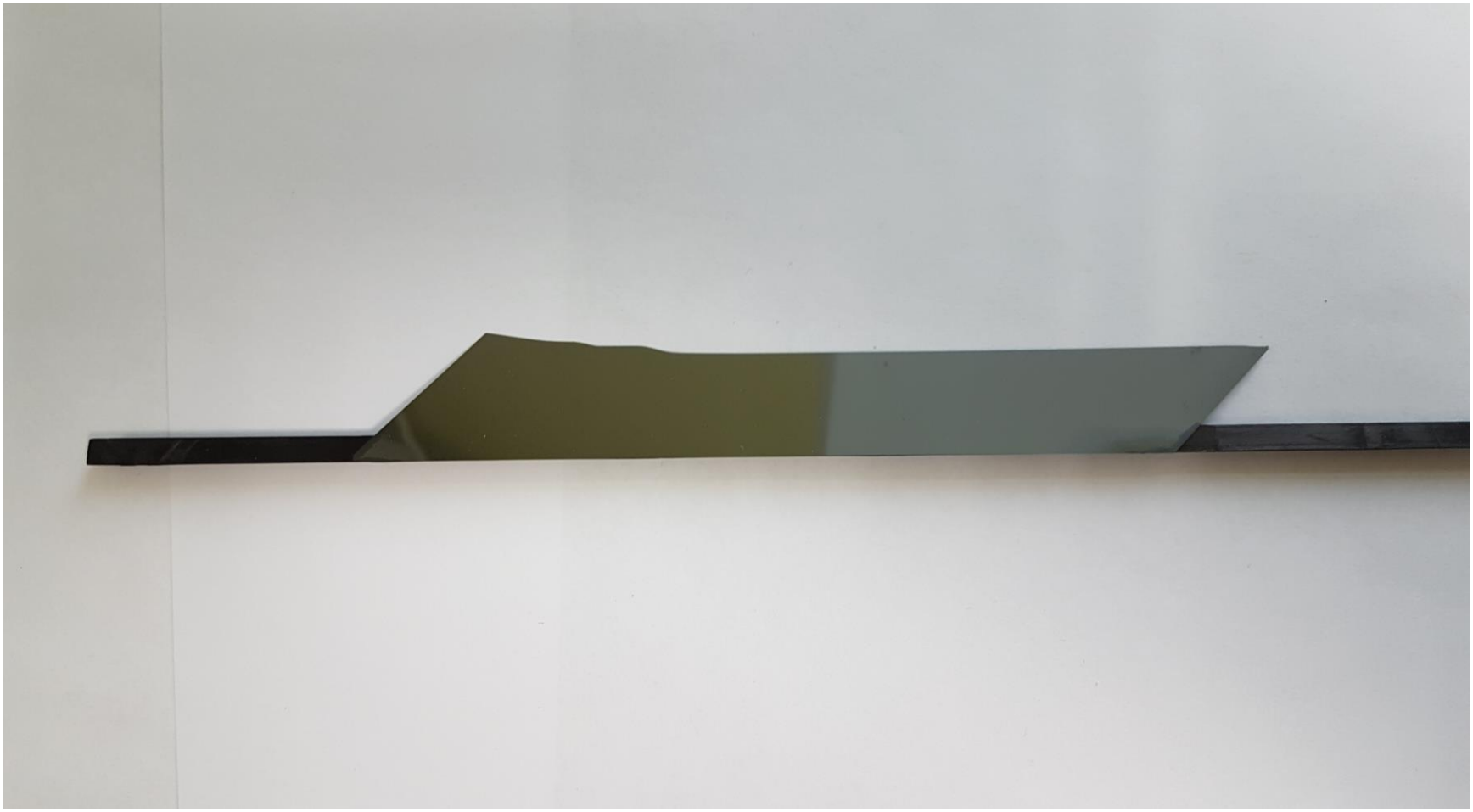




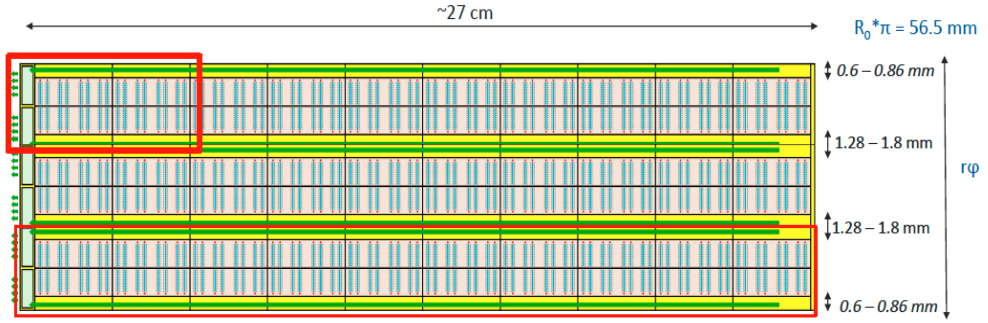
The general conclusions:

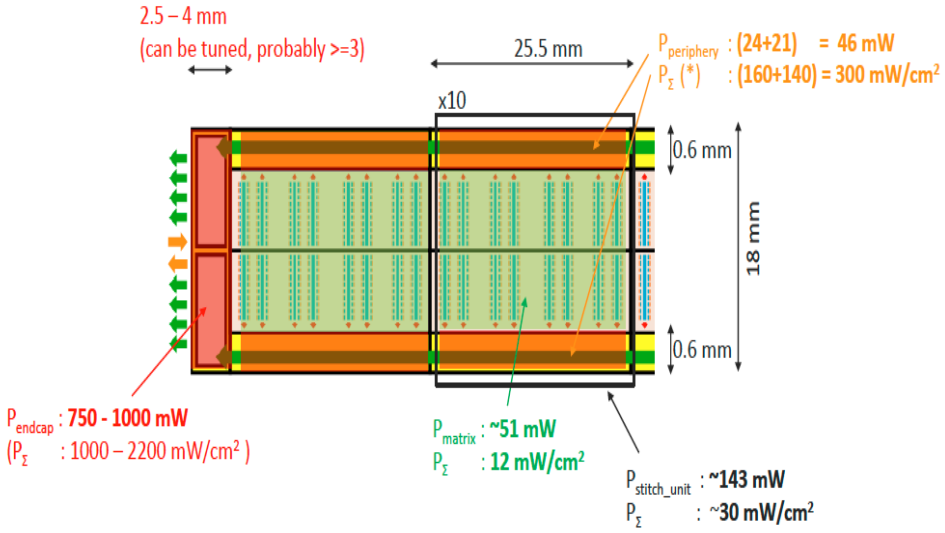
- **When heated, flat silicon plate bends almost linearly**
- **Cooling process indicates Hysteresis.**
- **Important: Si plate does not break in these temperature variations with 8 cm distance between gluing point!**

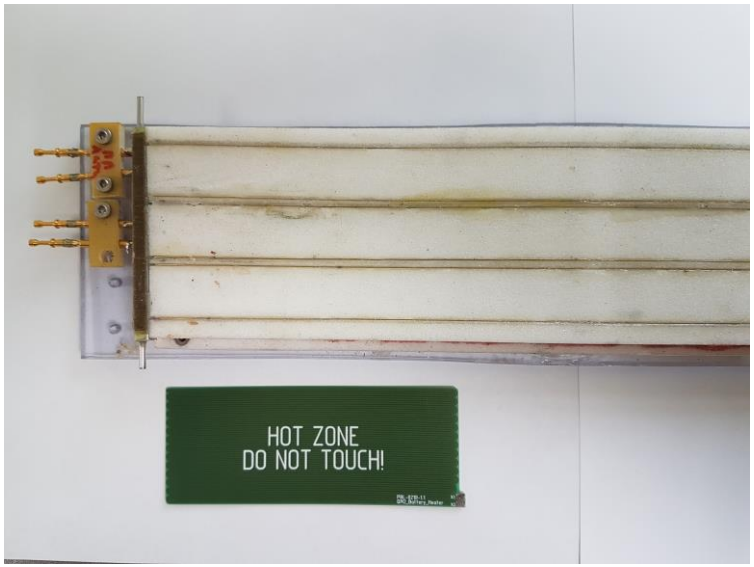
Future near tests: Si+CF rib CTE compatibility test



Near future plans: cold gas cooling tests for non-uniform + uniform power generation (using current ALICE specifications)







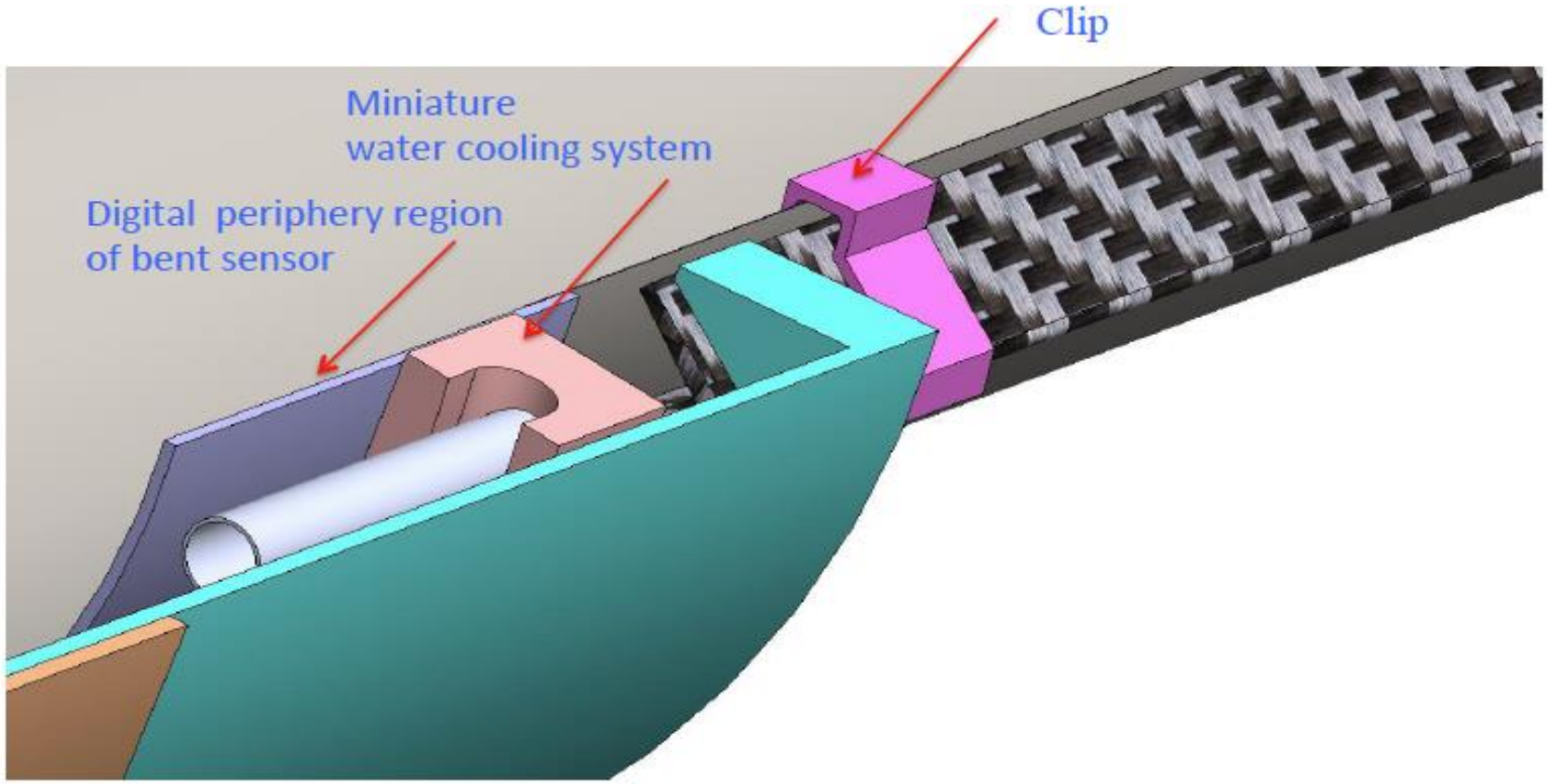
- Test sample is prepared
- Temperature maps registration
- …

Conclusions

- We started in SPb the thermomechanical tests of CTE compatibilty for available CF composite structures and Si plates.
- When heated, flat silicon plate bends almost linearly
- Cooling process indicates some Hysteresis.
- Important: Si plate does not break in these temperature variations with 8 cm distance between gluing point!
- Near future plans include:
  - ✓ Si+CF rib CTE compatibility test
  - ✓ cold gas cooling tests for non-uniform + uniform power generation (using current ALICE specifications)

Thank you for your attention!

CTE compatibility for Si and CF -?



Schematic of the liquid cooling tube embedded into **Pyrolytic Graphite** elements inside the SHC at the end-cup high density power region.