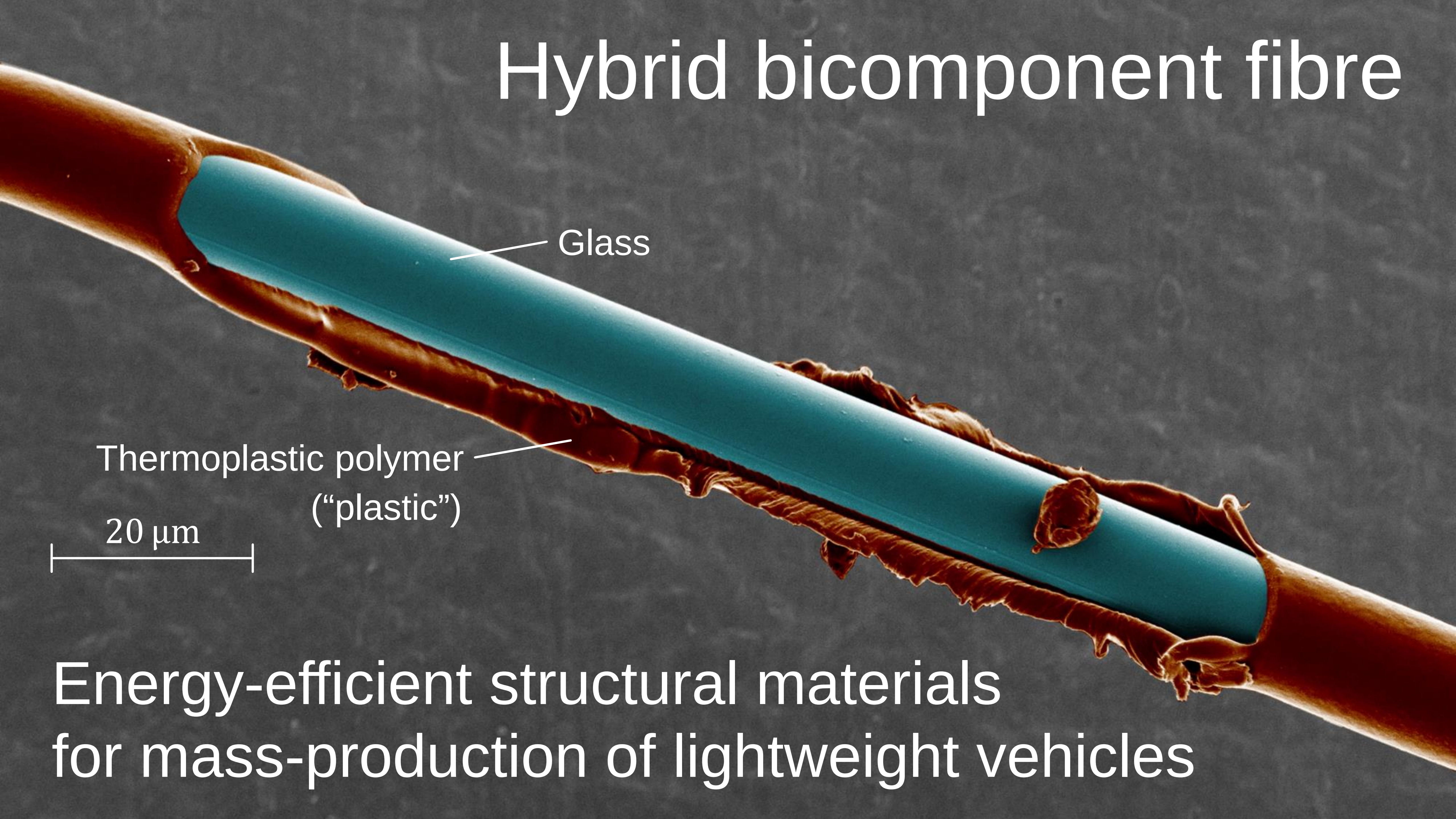

Hybrid bicomponent fibre
Glass
Thermoplastic polymer
(“plastic”)
20 μm
Energy-efficient structural materials
for mass-production of lightweight vehicles

Christoph Schneeberger

Doctoral candidate at ETH Zurich
└ 2015 to 2020

MSc & BSc ETH
in Mechanical Engineering

SCCER Mobility Capacity Area A3
"Minimization of Vehicular Energy Demand"
└ Direct consolidation via hybrid yarn route

Laboratory of Composite Materials and Adaptive Structures

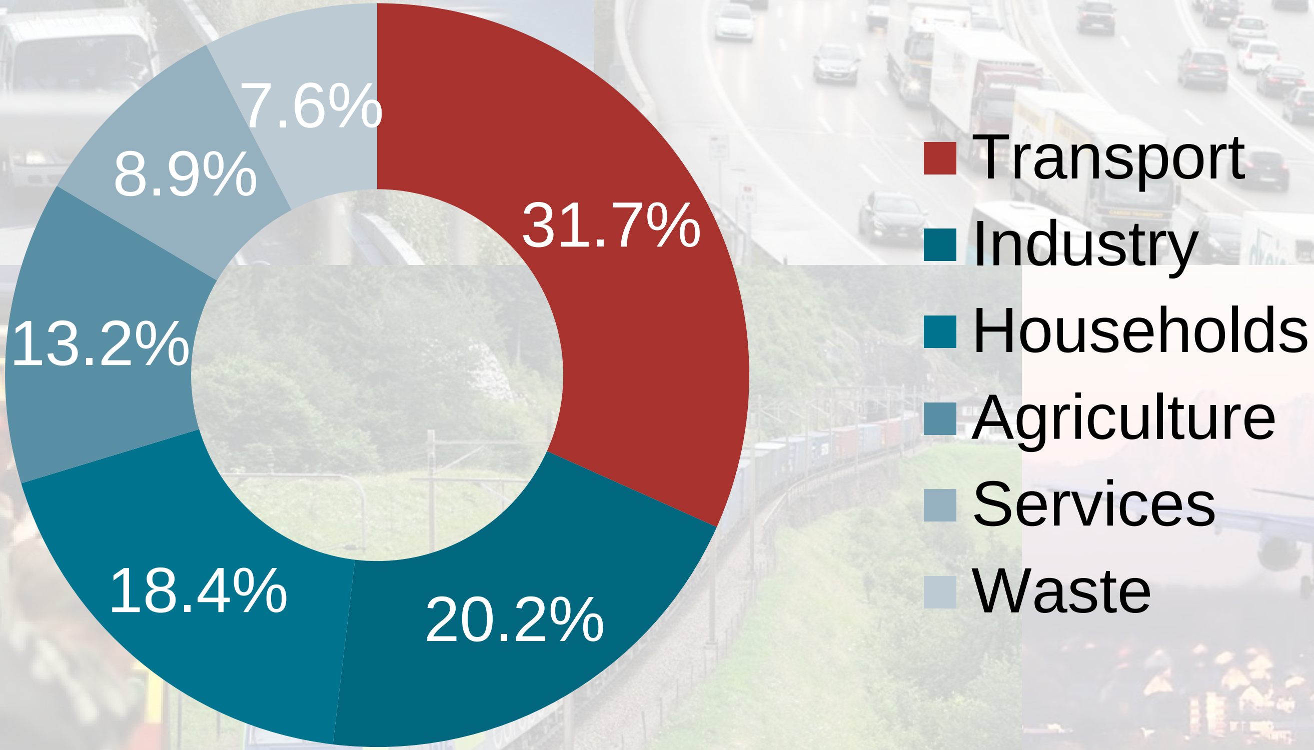
Laboratory of Composite Materials and Adaptive Structures
└ Hybrid bicomponent fibres


PLANZER


Lausanne
Yverdon
Neuchâtel
Lausanne
Yverdon
Neuchâtel
Vevey
Fribourg
Vevey
Fribourg
Bern-Neufeld

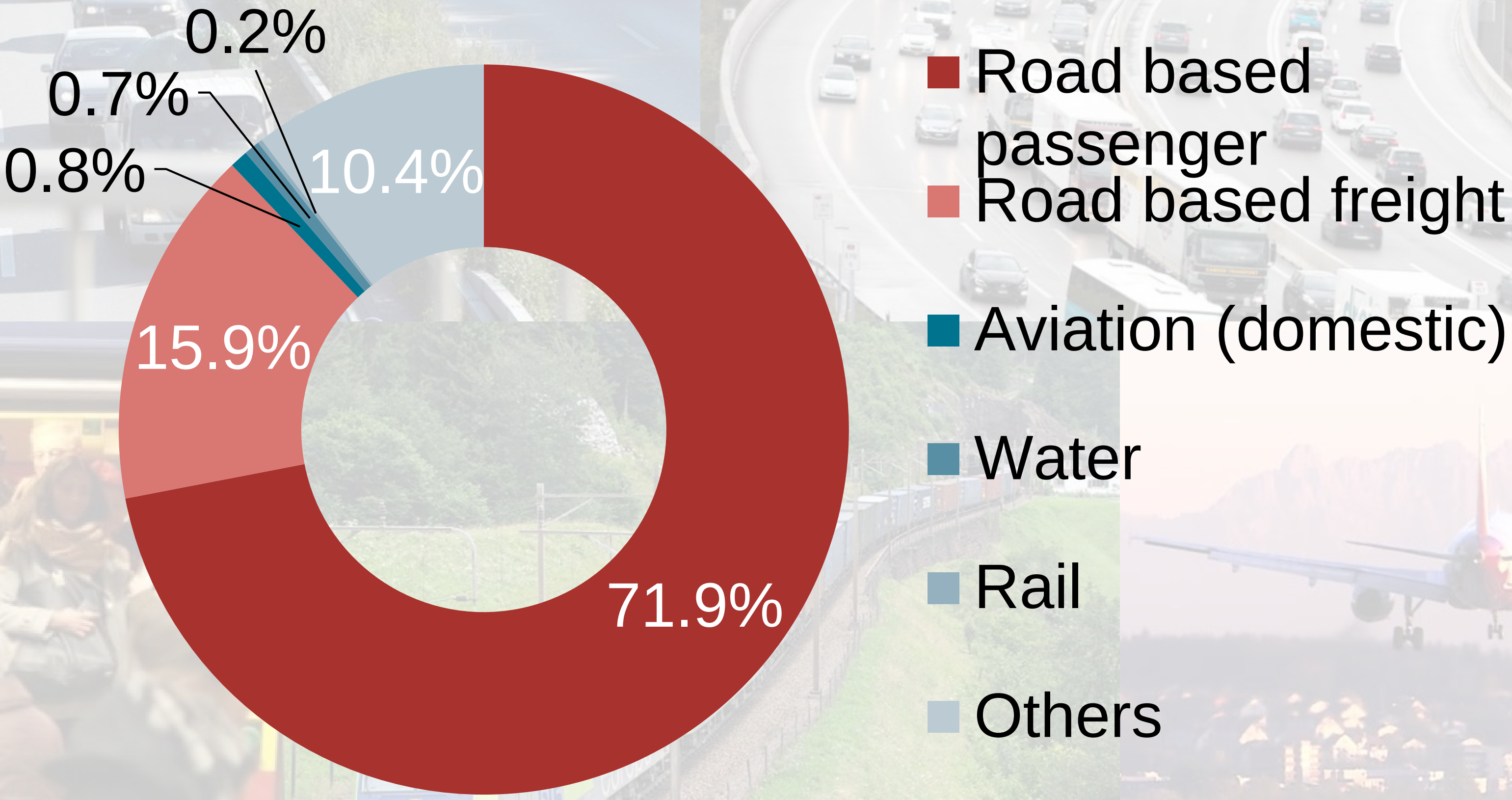

bls cargo
connecting europe
013

Contributions to Swiss GHG emissions in 2016 by sector



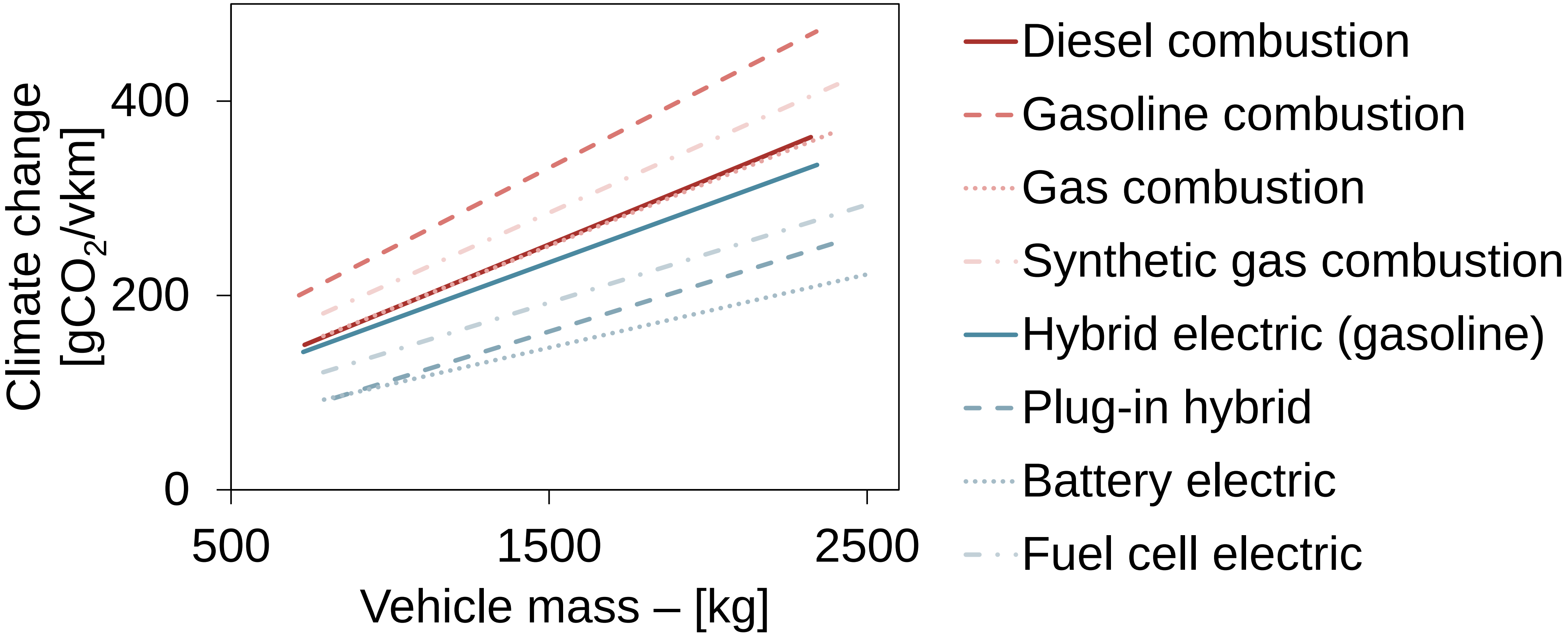
Source: Swiss Federal Office for the Environment FOEN

Contributions to GHG emissions for Swiss transportation sector



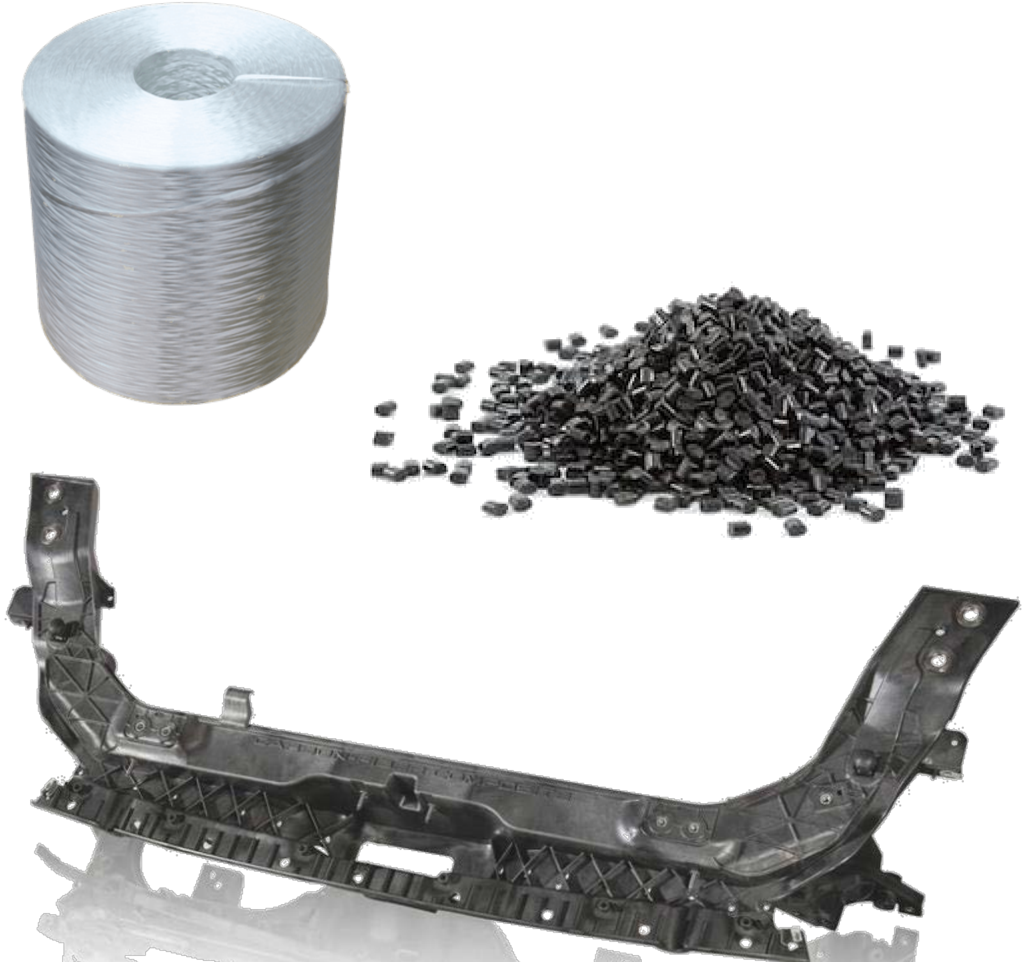
Source: Swiss Federal Office for the Environment FOEN

Sensitivity of climate change caused by passenger cars to their total mass

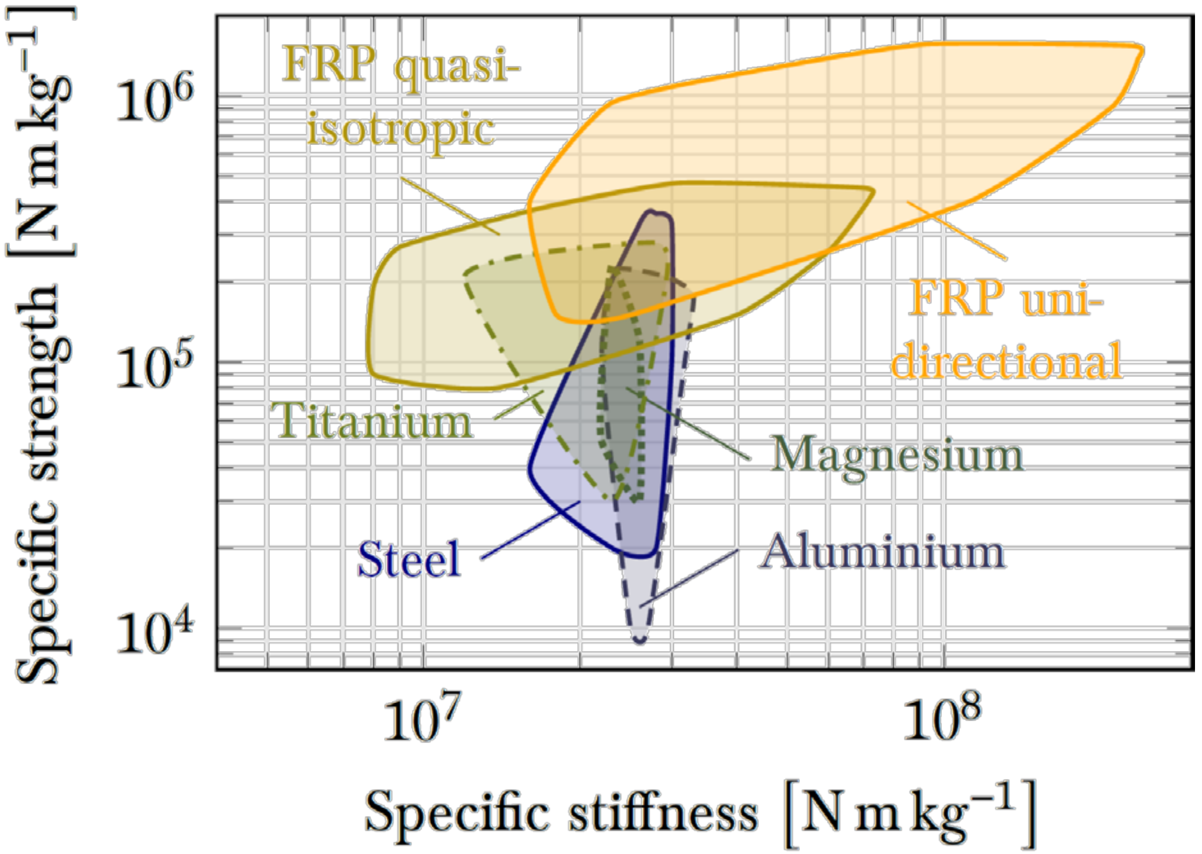


Data adapted from Brian Cox, doctoral thesis, ETH Zürich, 2018. (Trendlines shown)

Fibre-reinforced polymer composites (FRP)



Sources: Wbcomposites, BASF

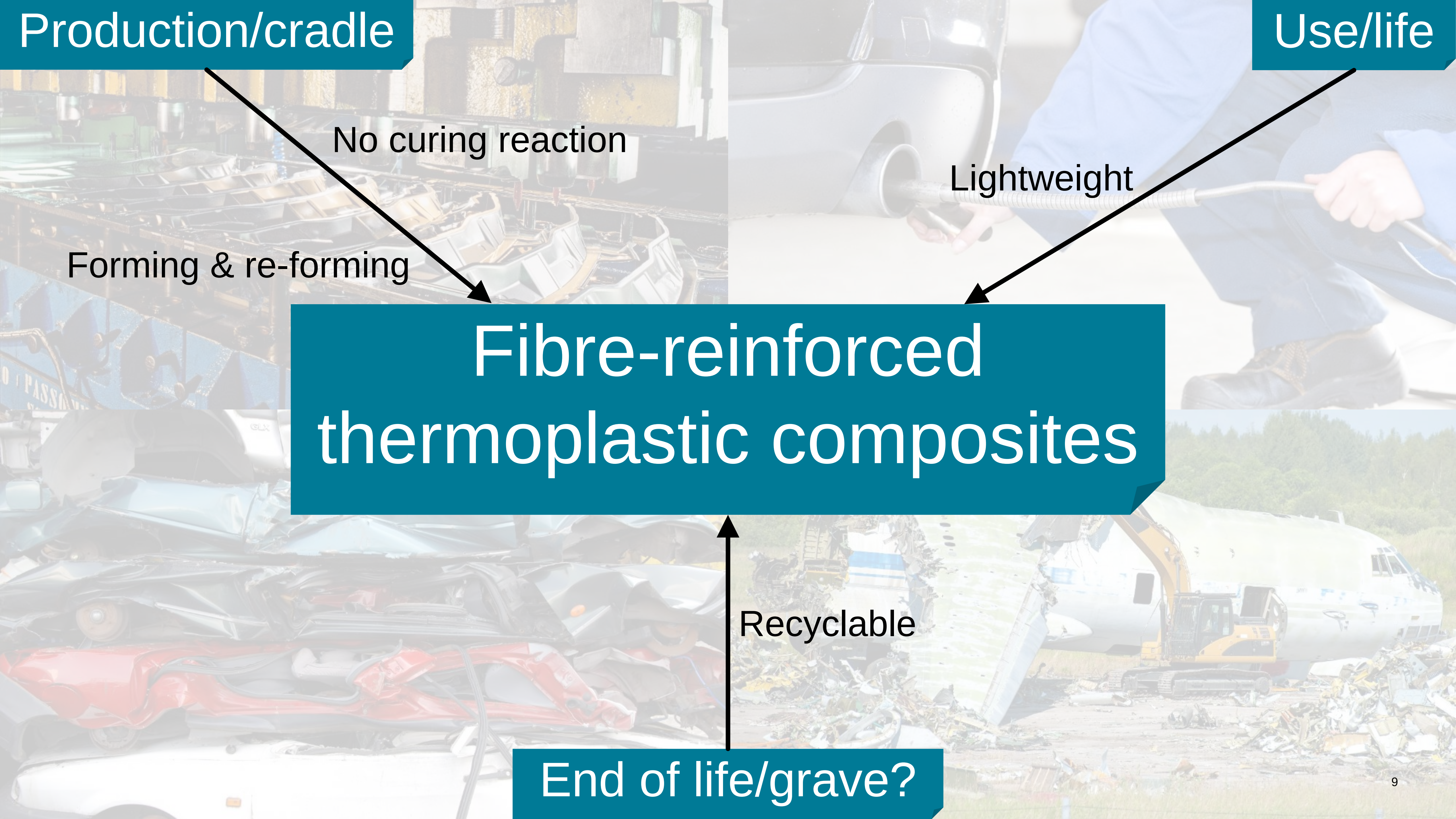


Data taken from CES EduPack software

Production/cradle

Use/life

End of life/grave?

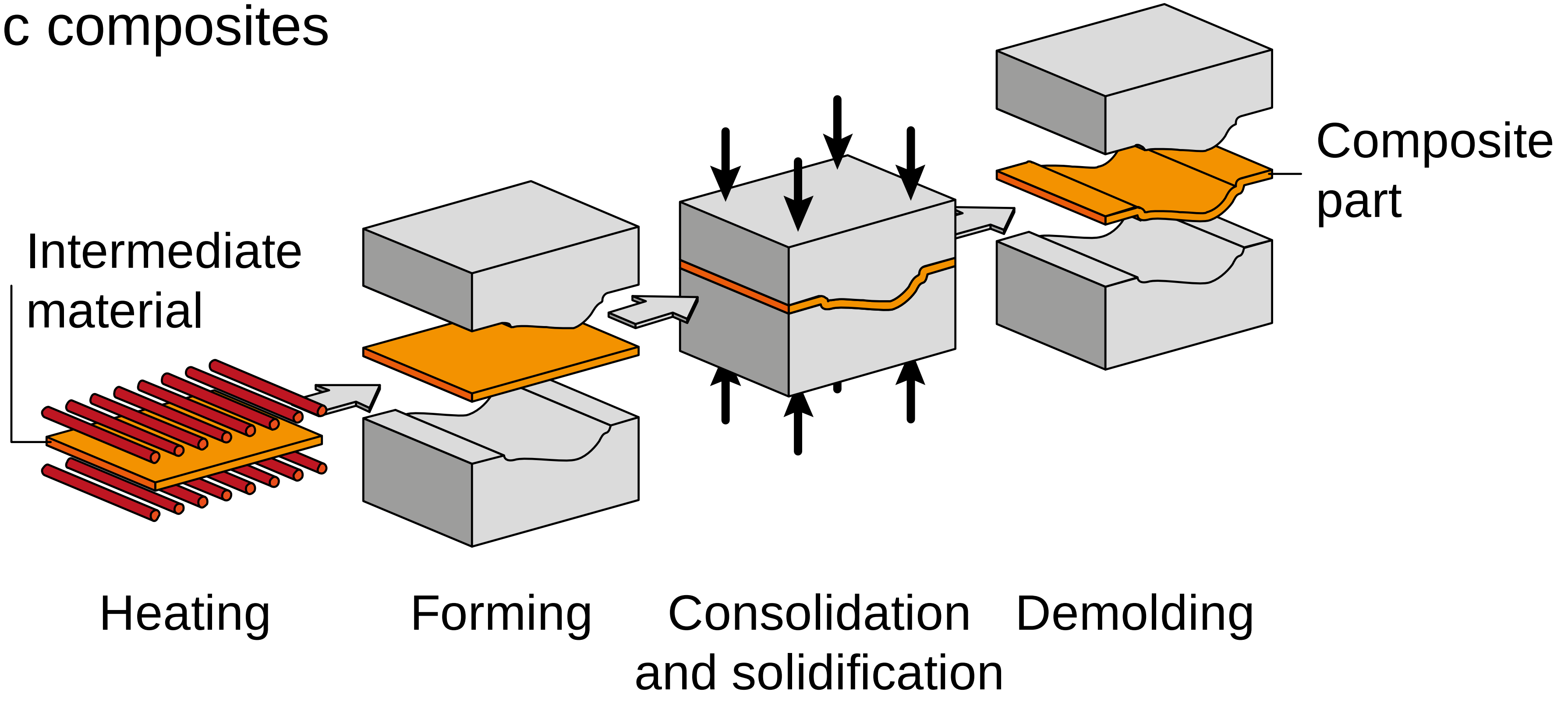

Production/cradle
No curing reaction
Forming & re-forming
Use/life
Lightweight
Fibre-reinforced thermoplastic composites
Recyclable
End of life/grave?

Reduce vehicular energy demand through lightweighting

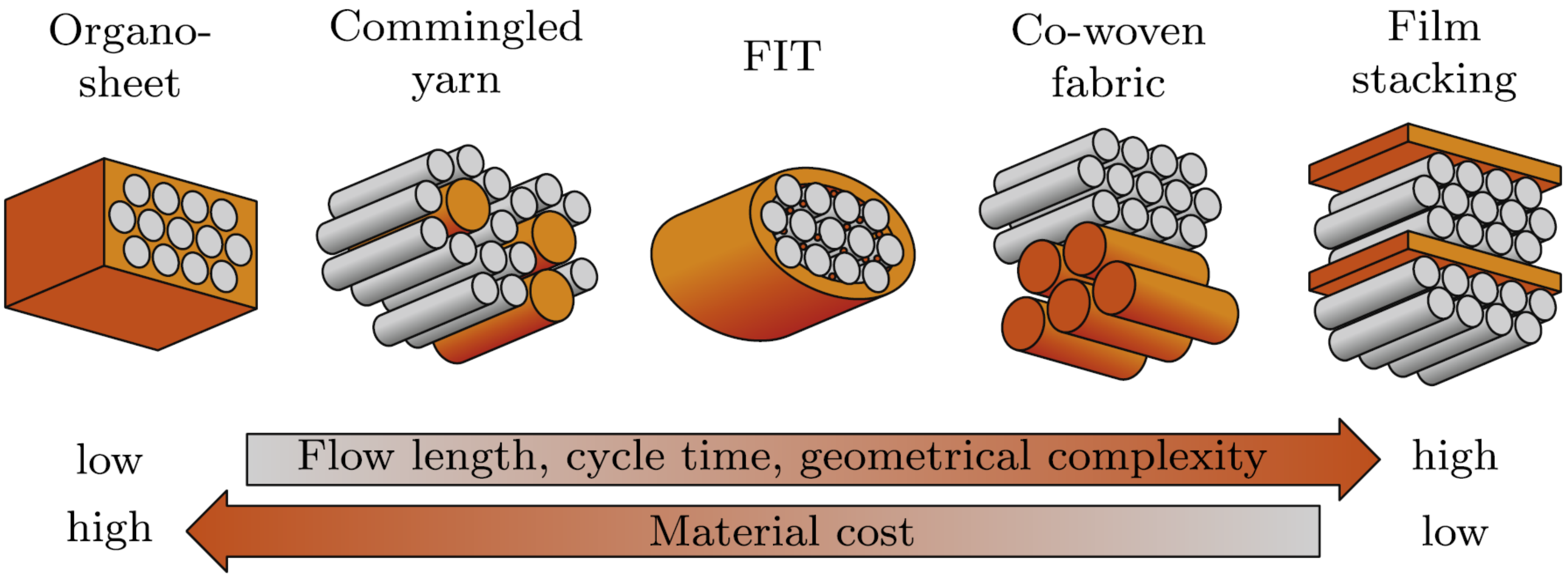
State of the art

State of the art fast part production

Rapid stamp forming of thermoplastic composites



State of the art intermediate materials



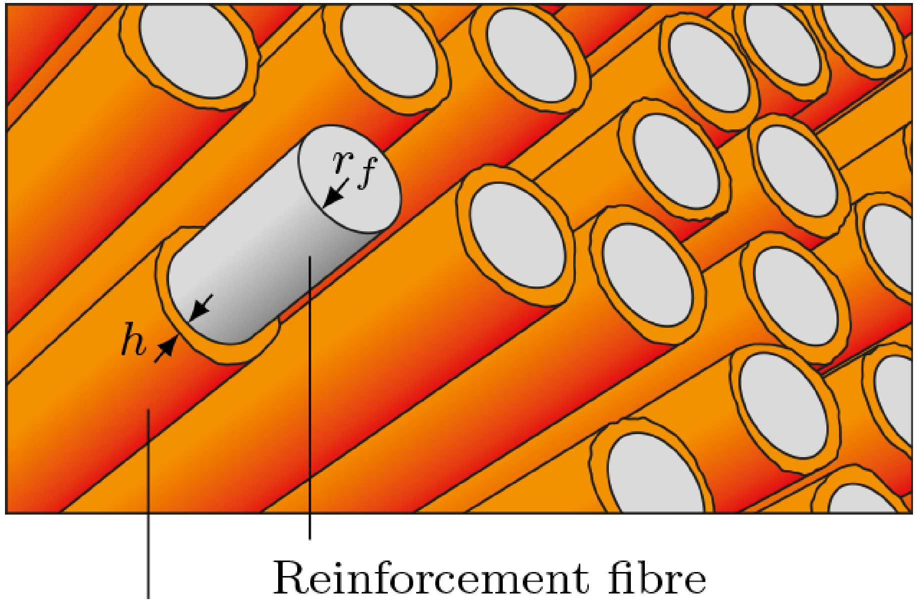
Source: C. Schneeberger, J. C. H. Wong, and P. Ermanni. Hybrid bicomponent fibres for thermoplastic composite preforms. *Compos. Part A Appl. Sci. Manuf.* 103, 69–73 (2017).

Proposed solution

Hybrid bicomponent fibres

Full wet-out

Avoiding impregnation flows



Core fibre radius r_f and sheath thickness h.

Conforming to complex geometries

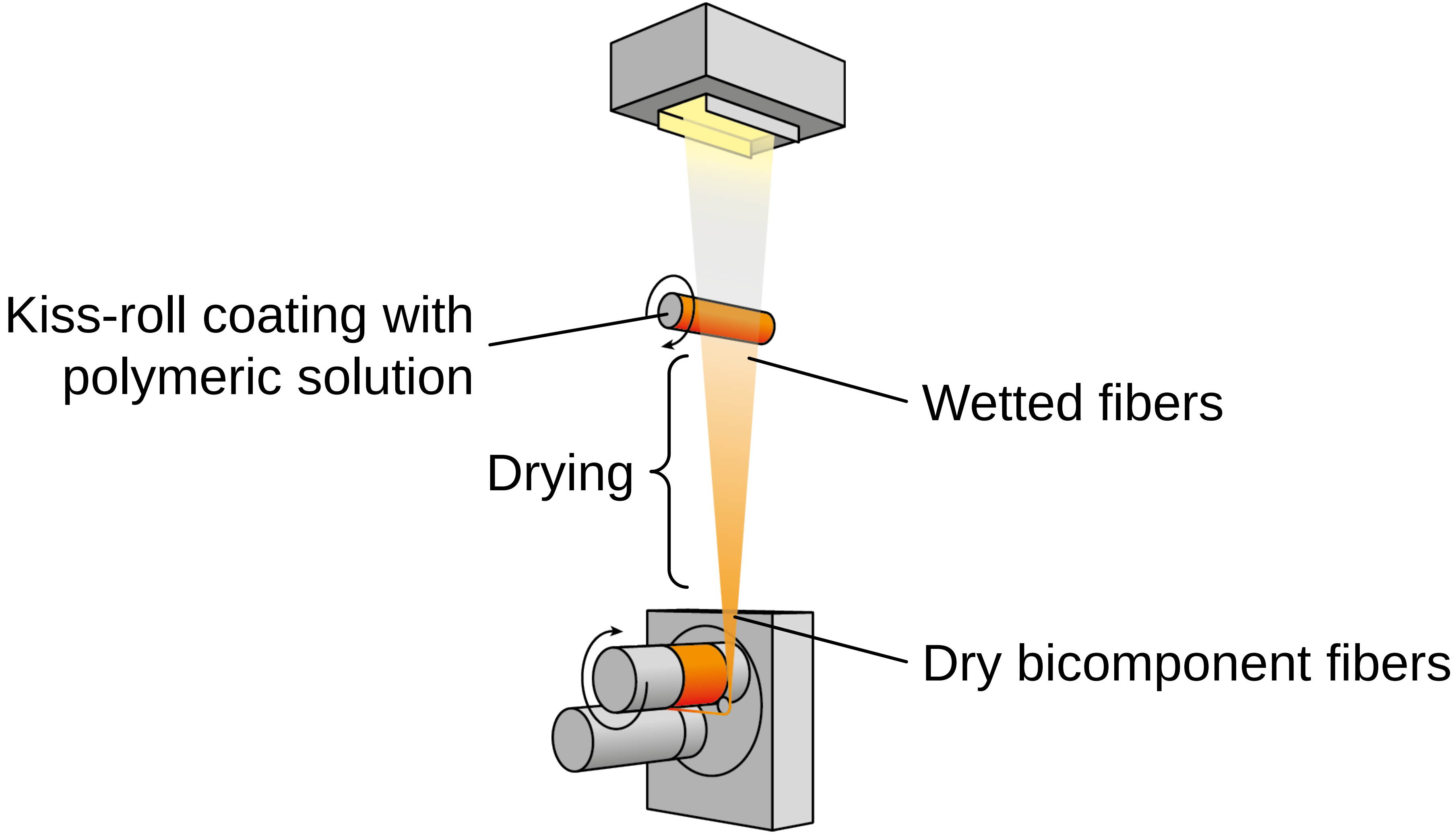
High volume

Source: C. Schneeberger, J. C. H. Wong, and P. Ermanni. Hybrid bicomponent fibres for thermoplastic composite preforms. *Compos. Part A Appl. Sci. Manuf.* 103, 69–73 (2017).

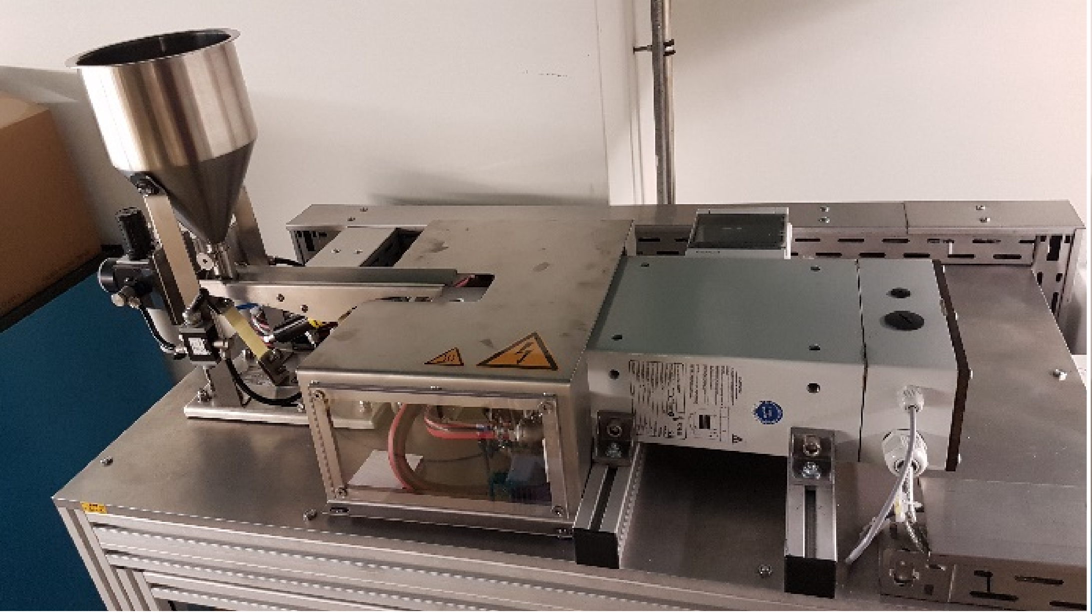
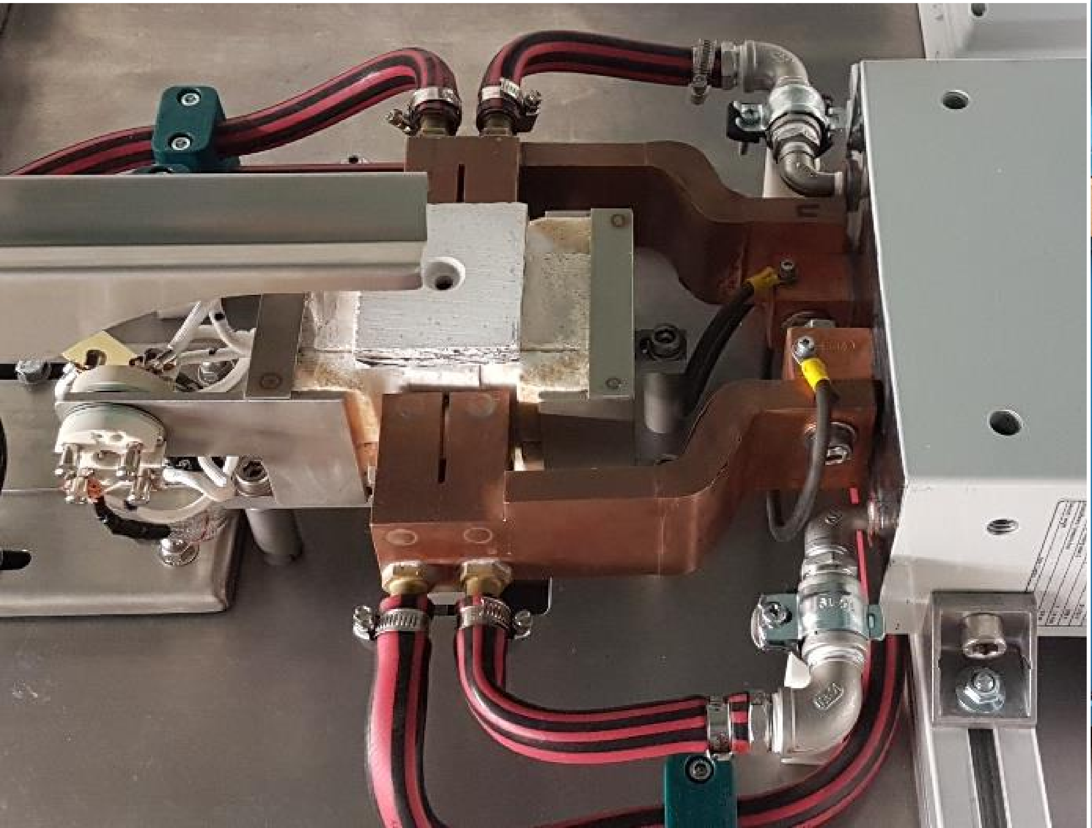
Manufacturing approach

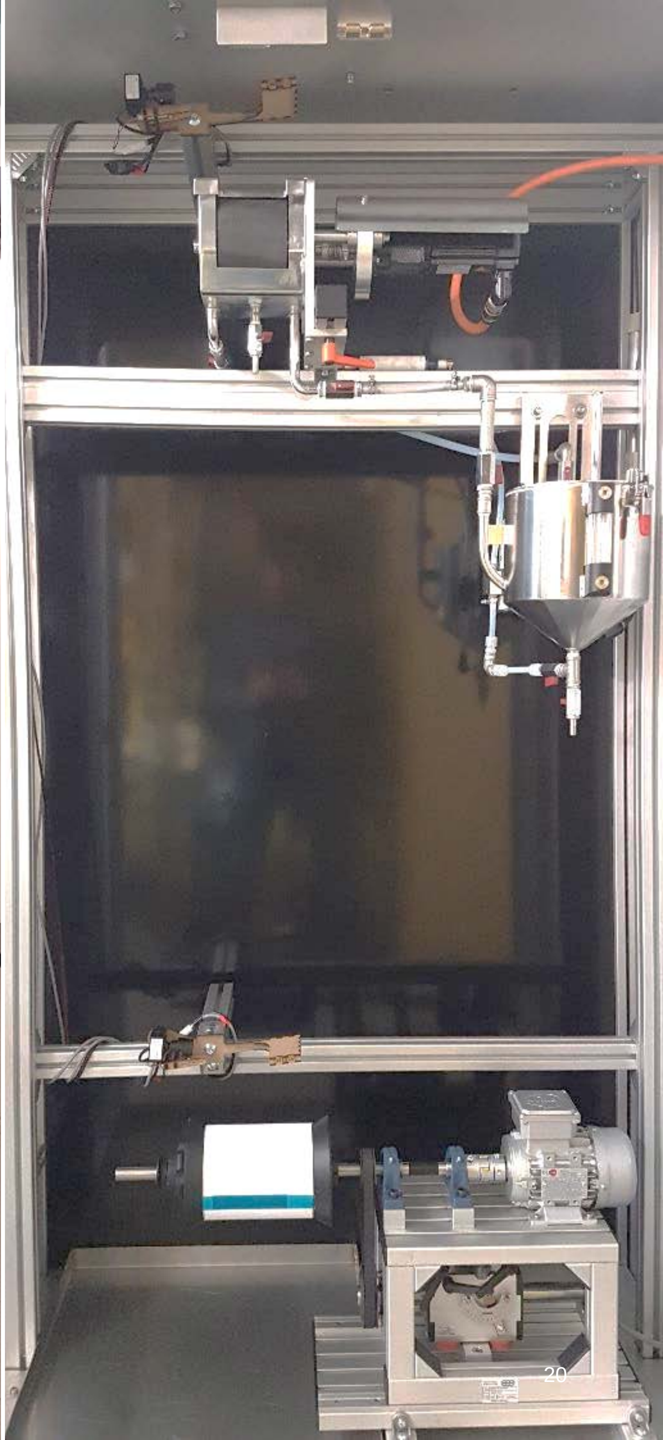
Glass melt spinning

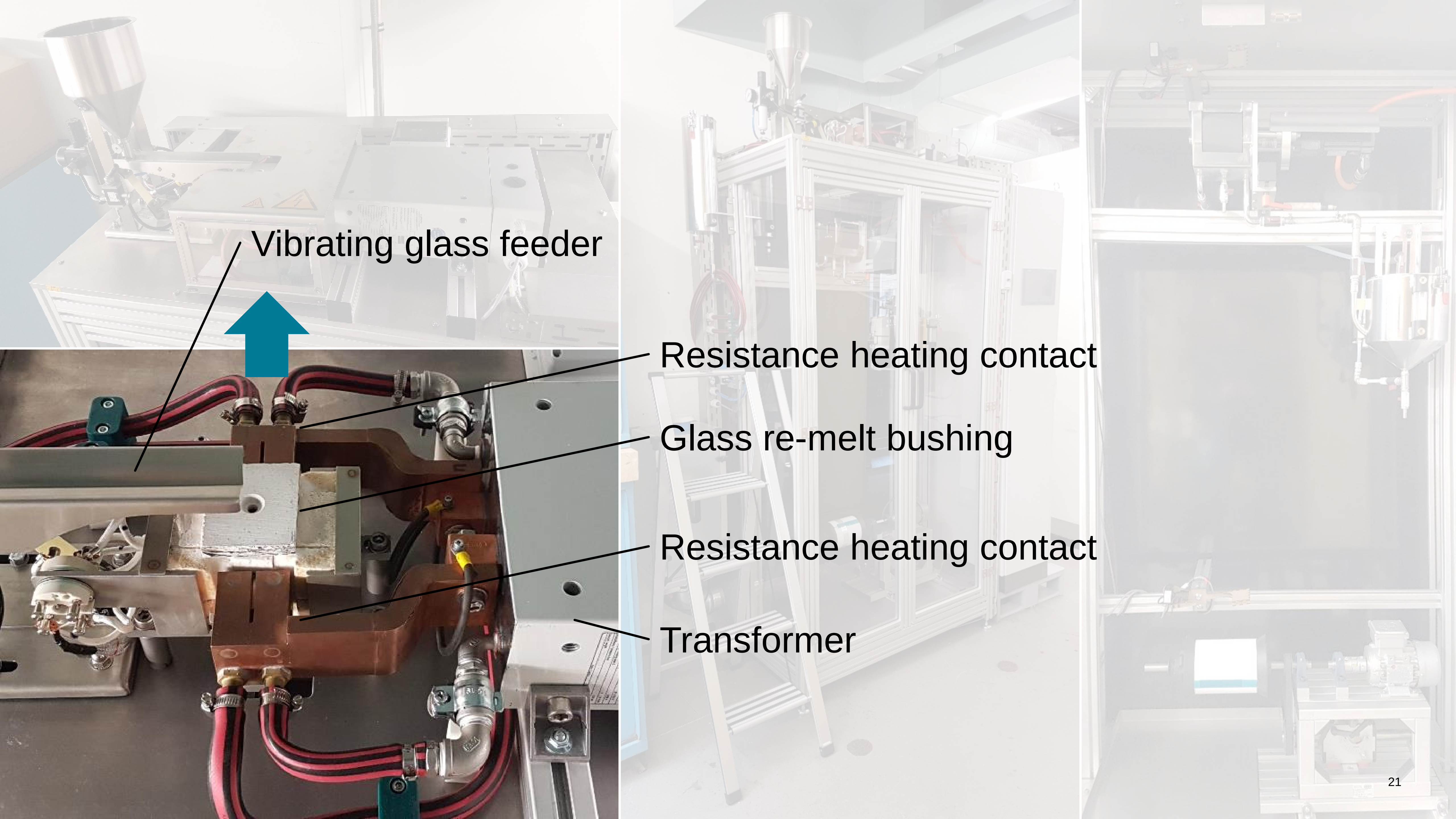
Continuous in-line coating process



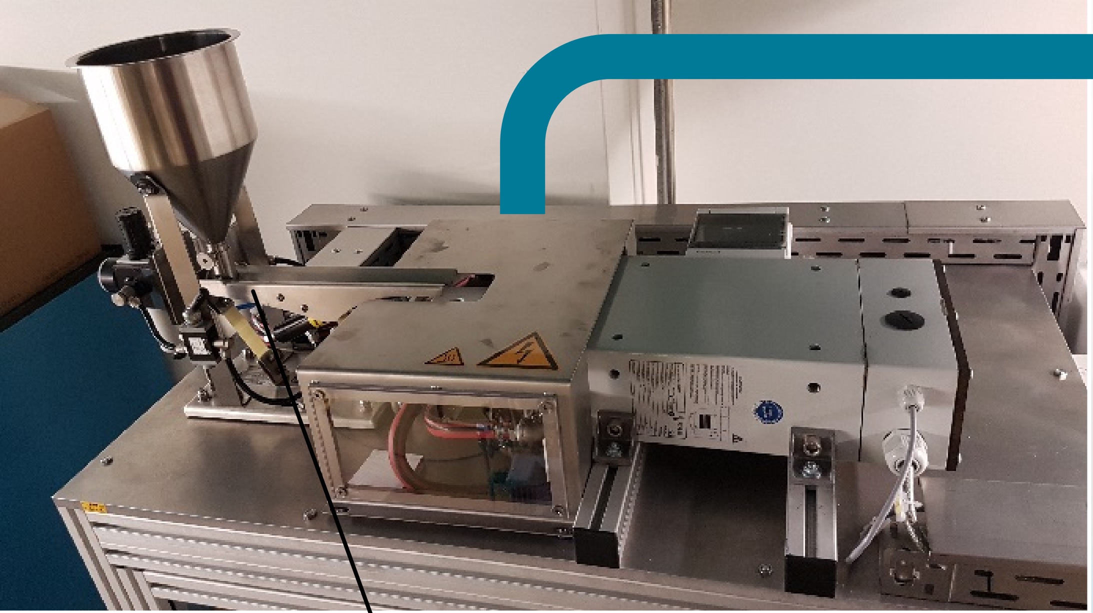
Pilot plant

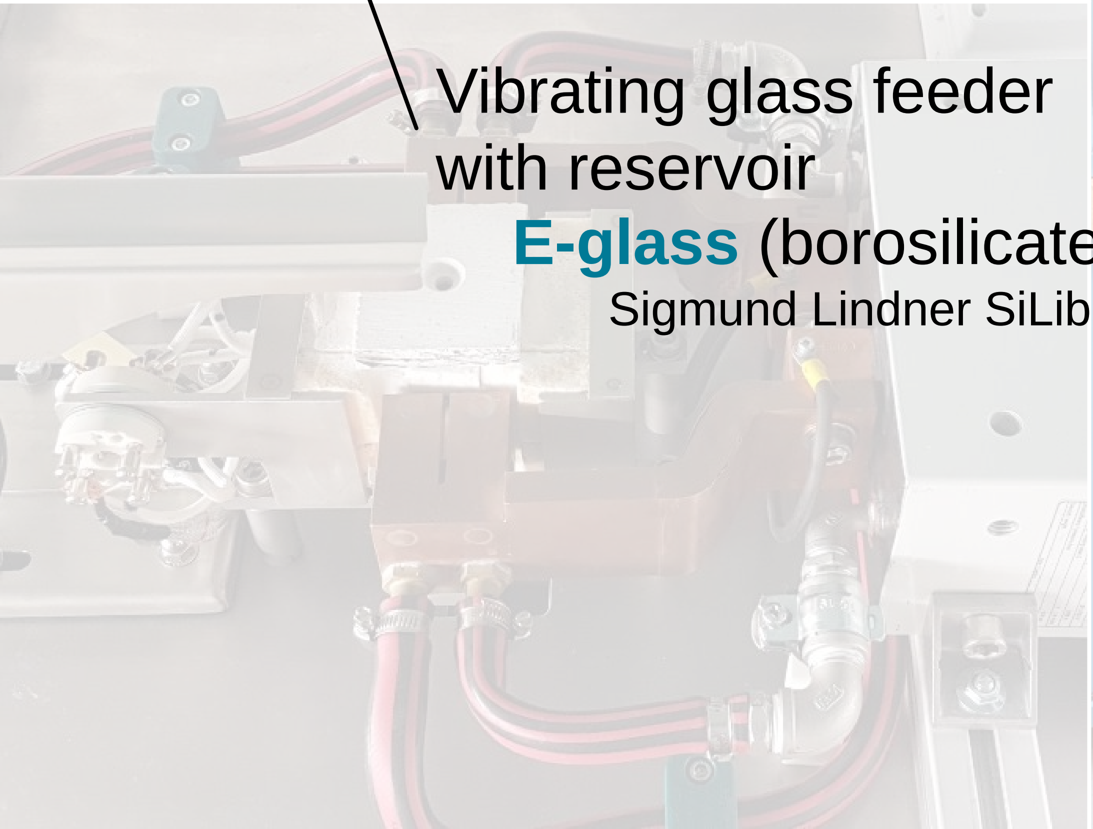







Vibrating glass feeder
Resistance heating contact
Glass re-melt bushing
Resistance heating contact
Transformer

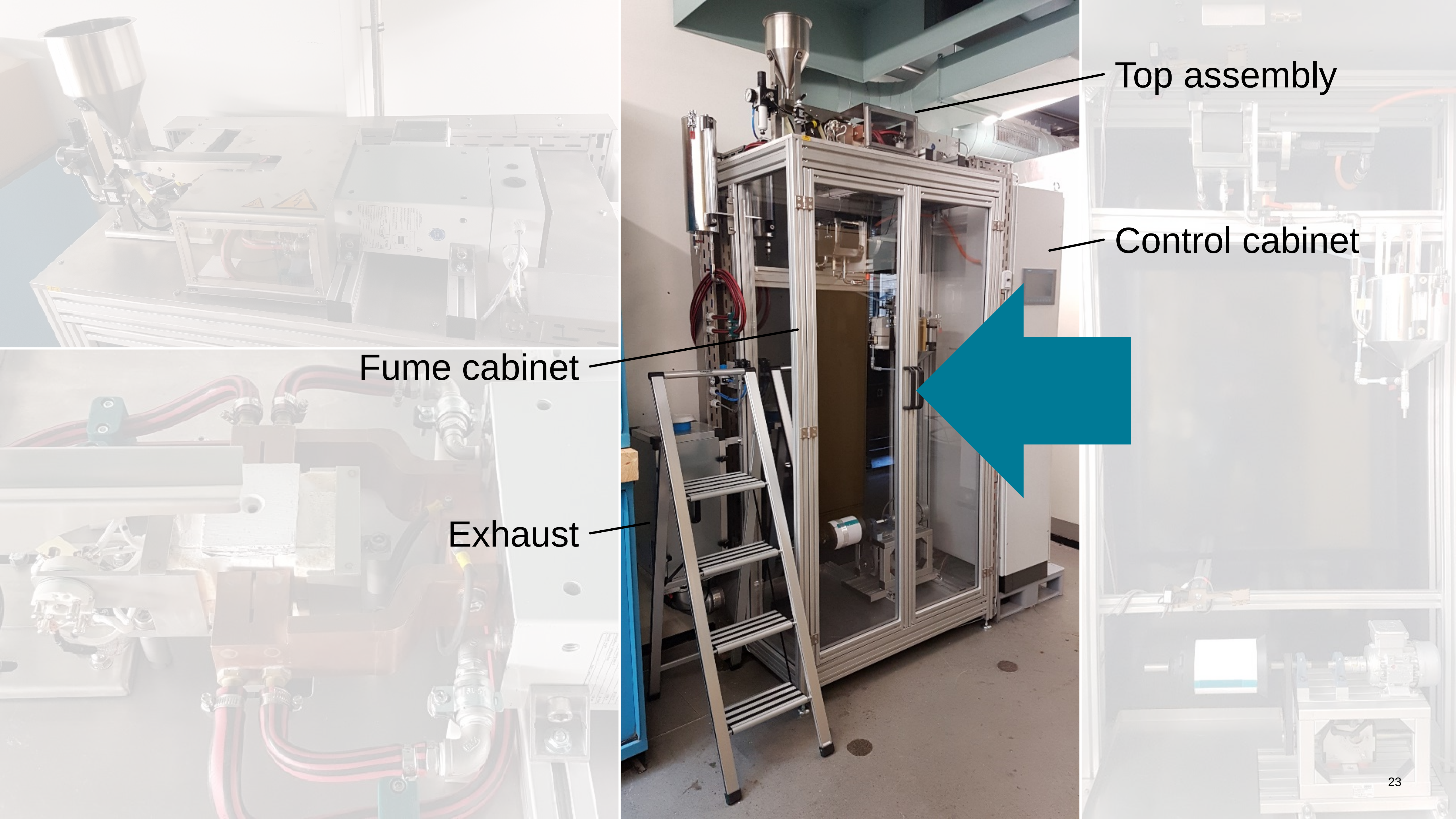


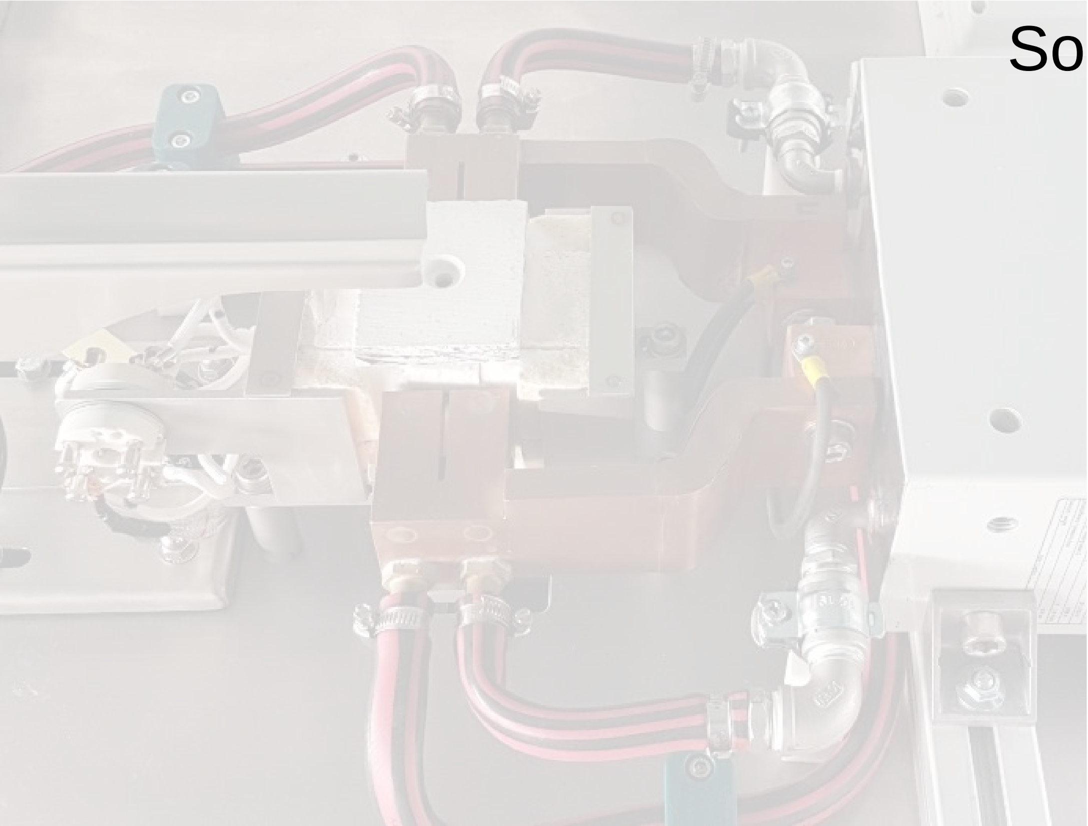


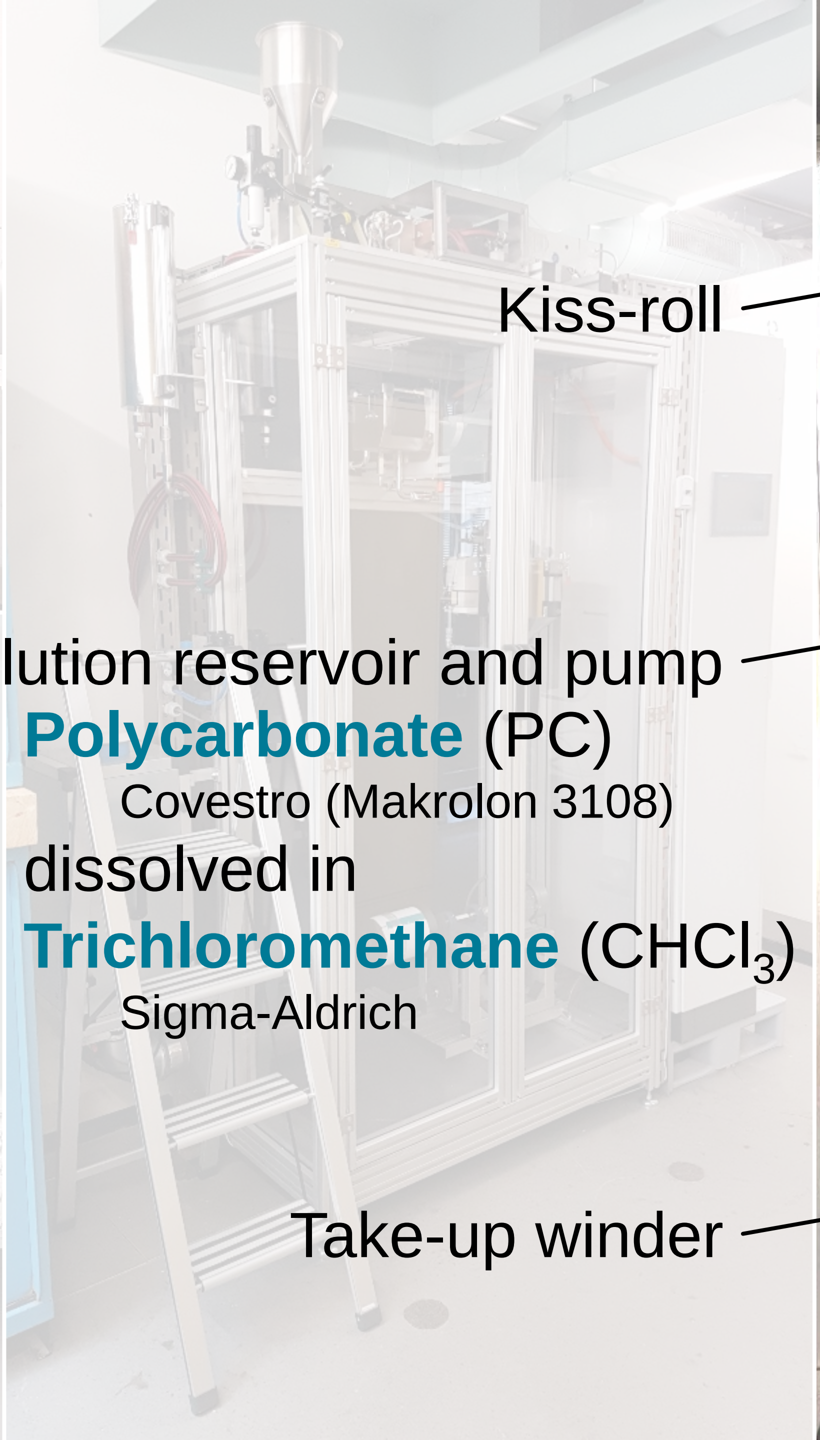
Vibrating glass feeder
with reservoir

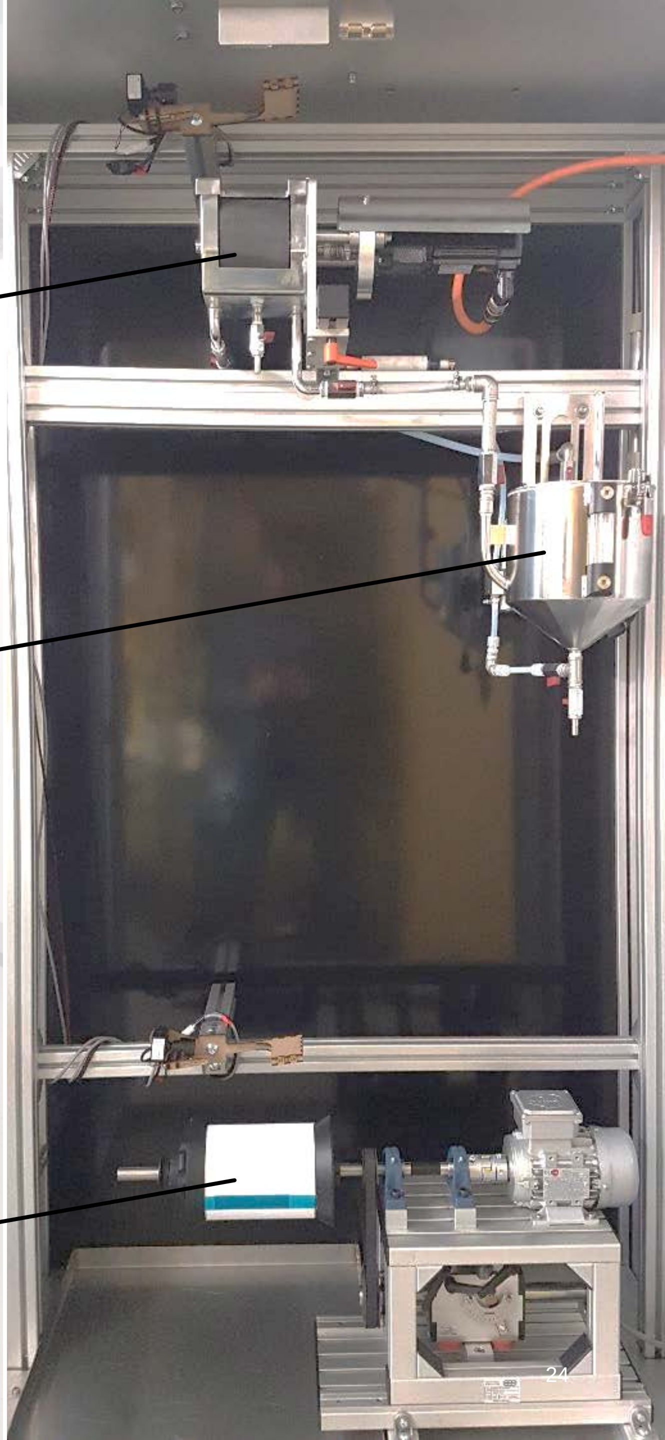
E-glass (borosilicate glass)

Sigmund Lindner SiLibeads SL


Top assembly
Control cabinet
Fume cabinet
Exhaust







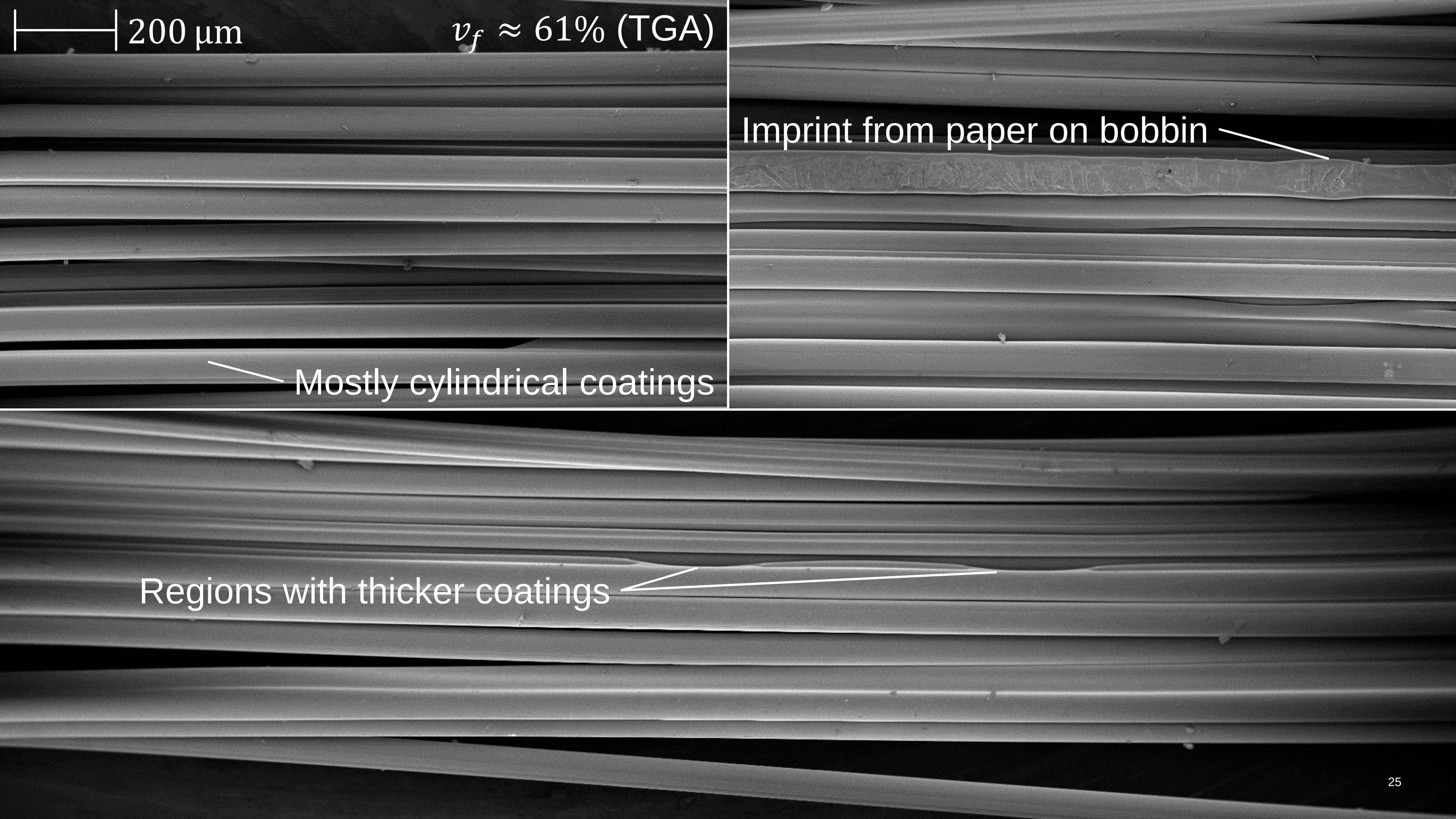
Polycarbonate (PC)

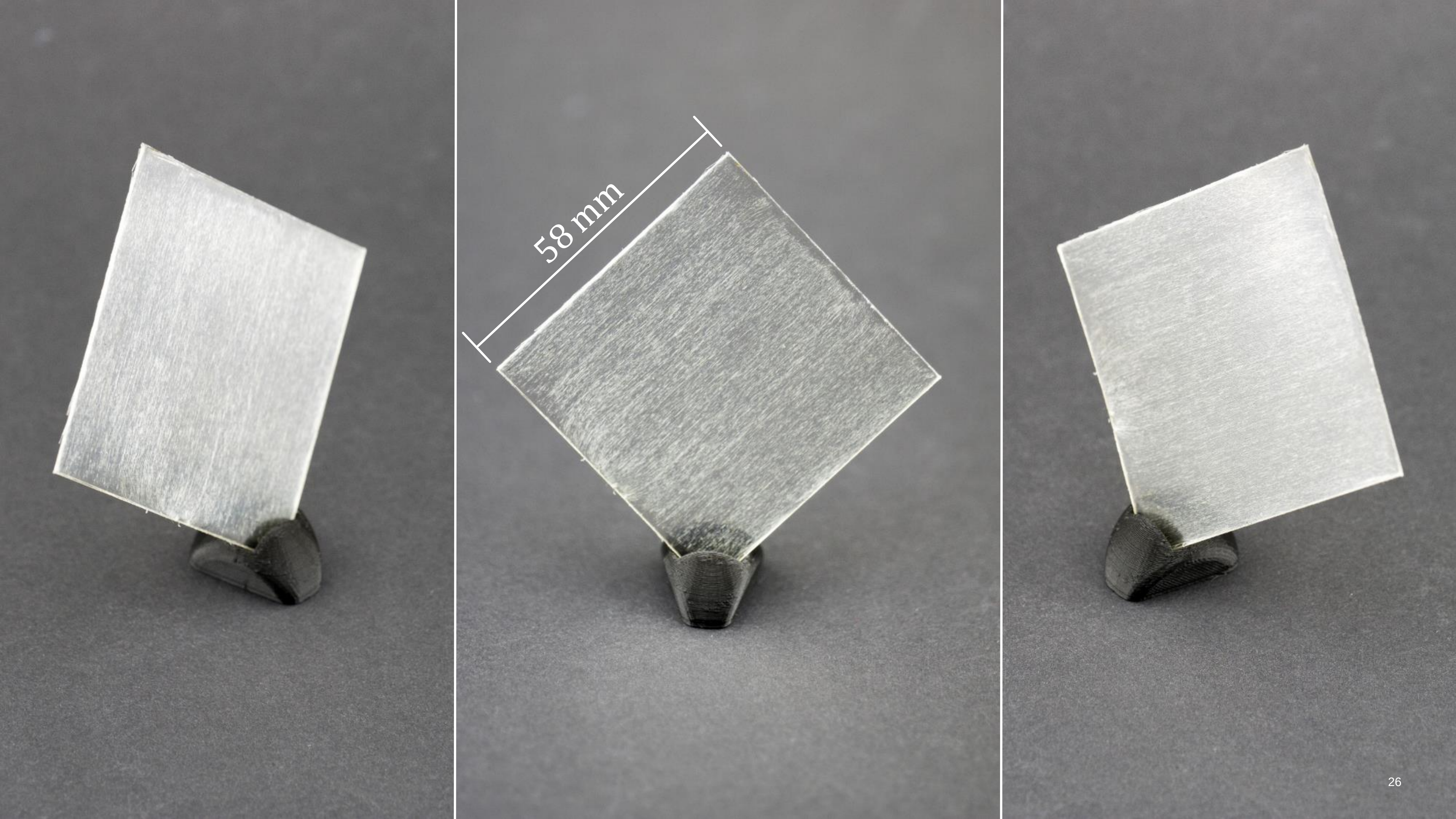
Covestro (Makrolon 3108)

dissolved in

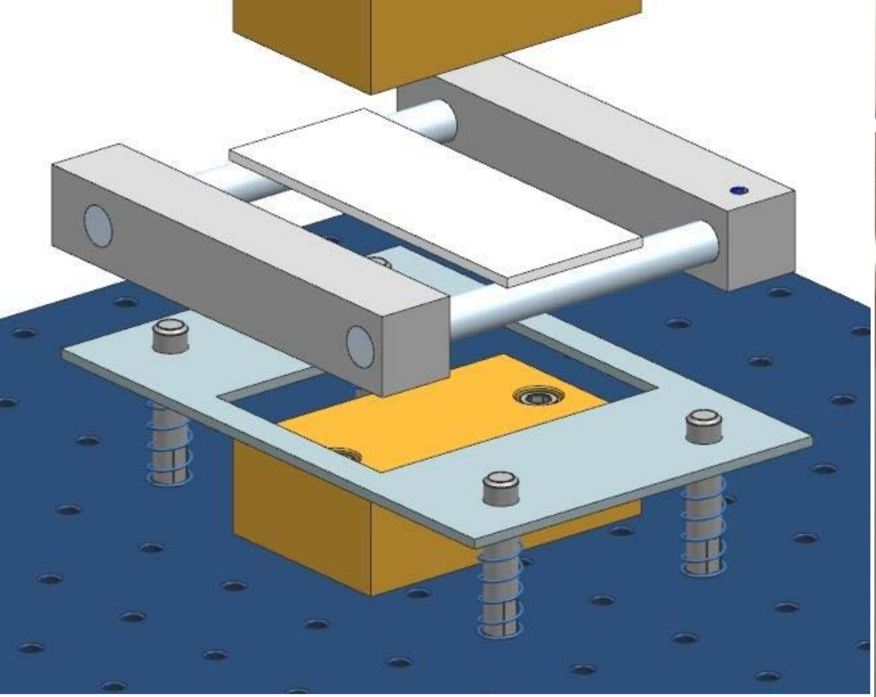
Trichloromethane ($CHCl_3$)

Sigma-Aldrich

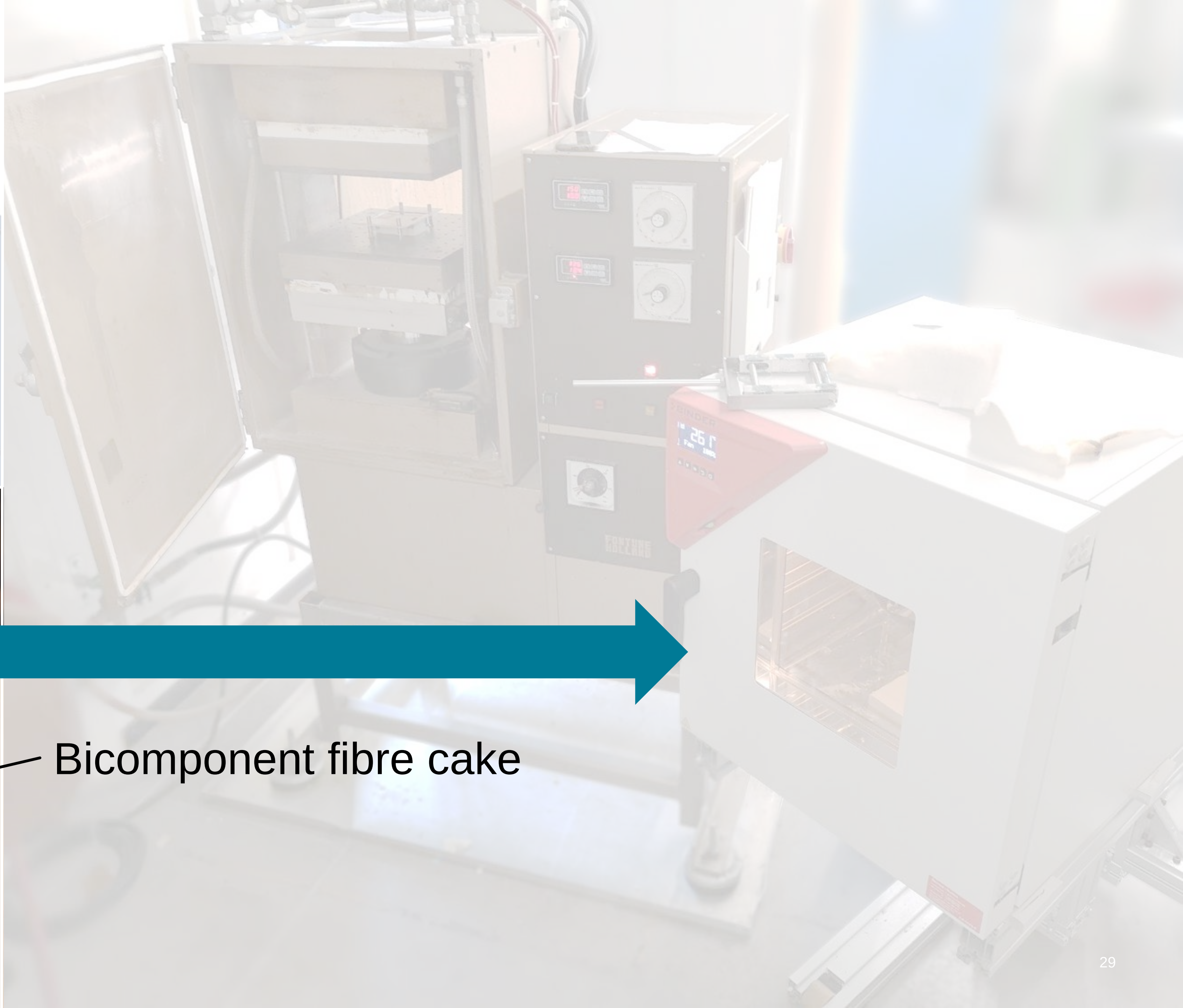

200 μm
$v_f \approx 61\%$ (TGA)
Mostly cylindrical coatings
Imprint from paper on bobbin
Regions with thicker coatings


58 mm

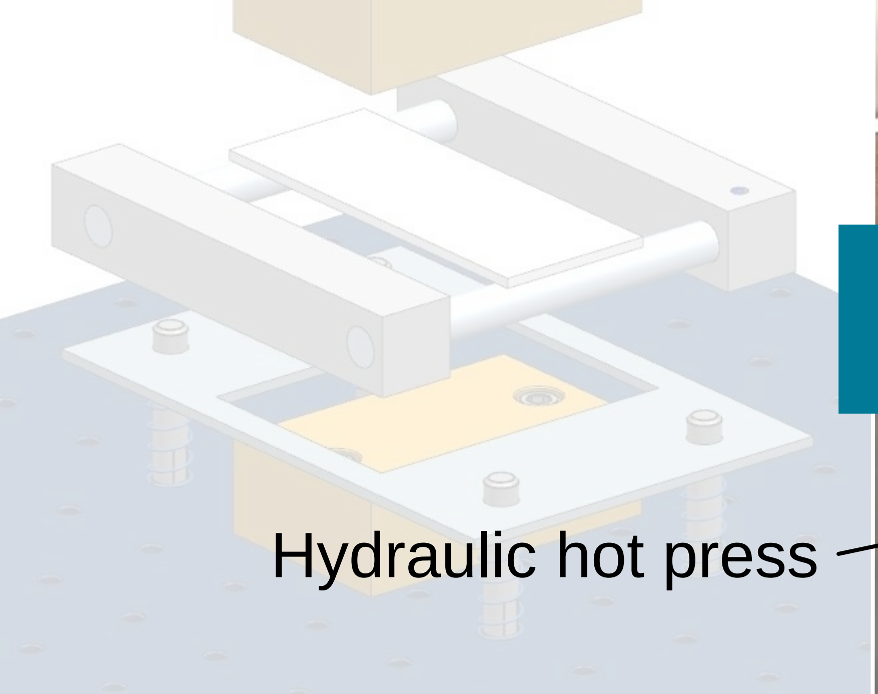
Stamp forming

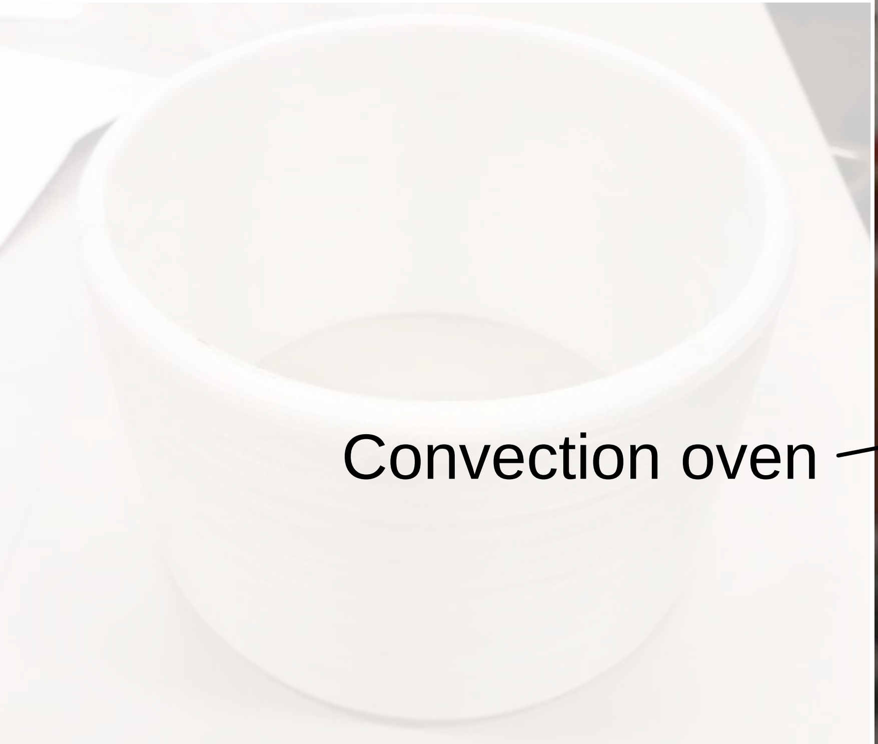


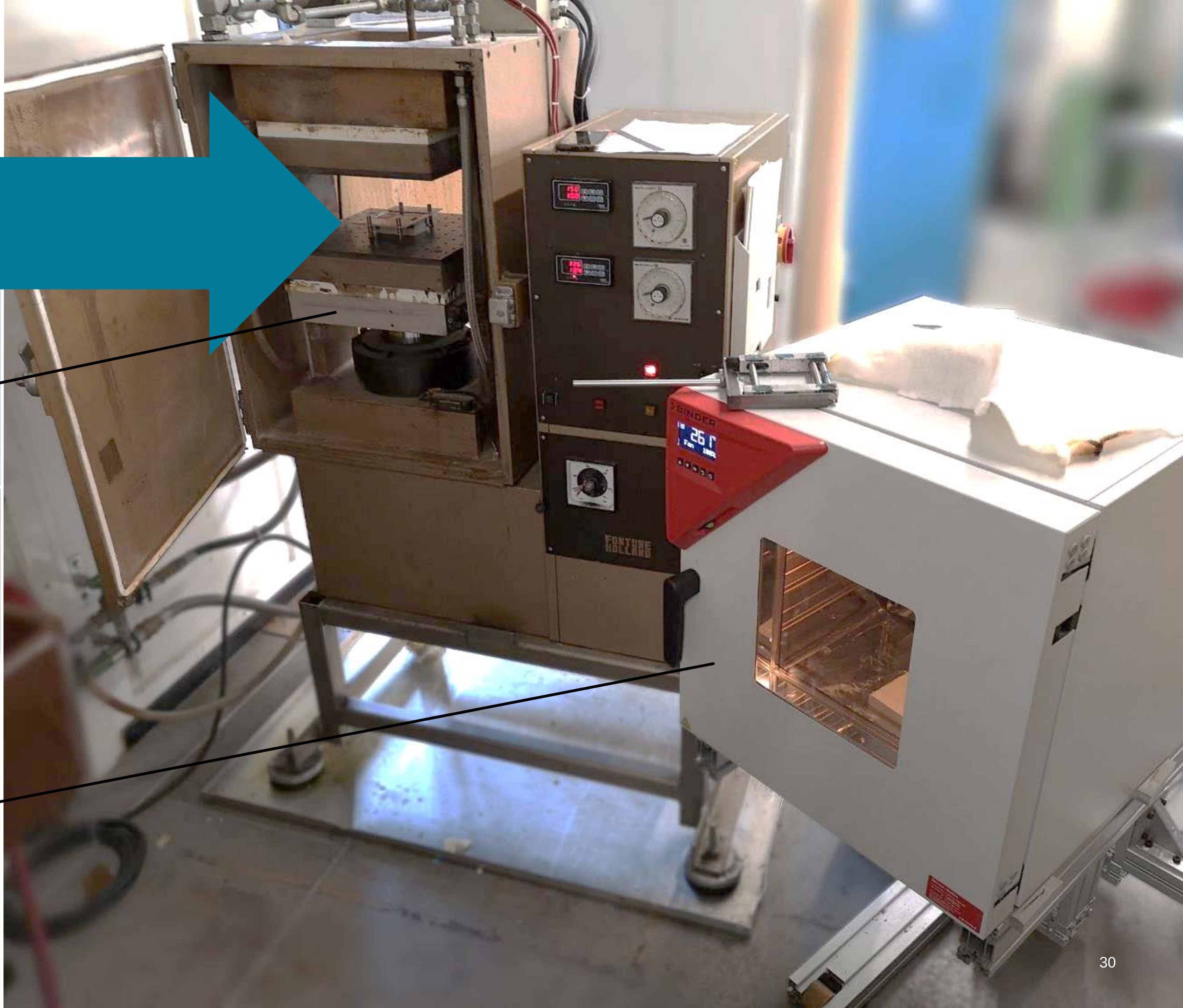

BINDER

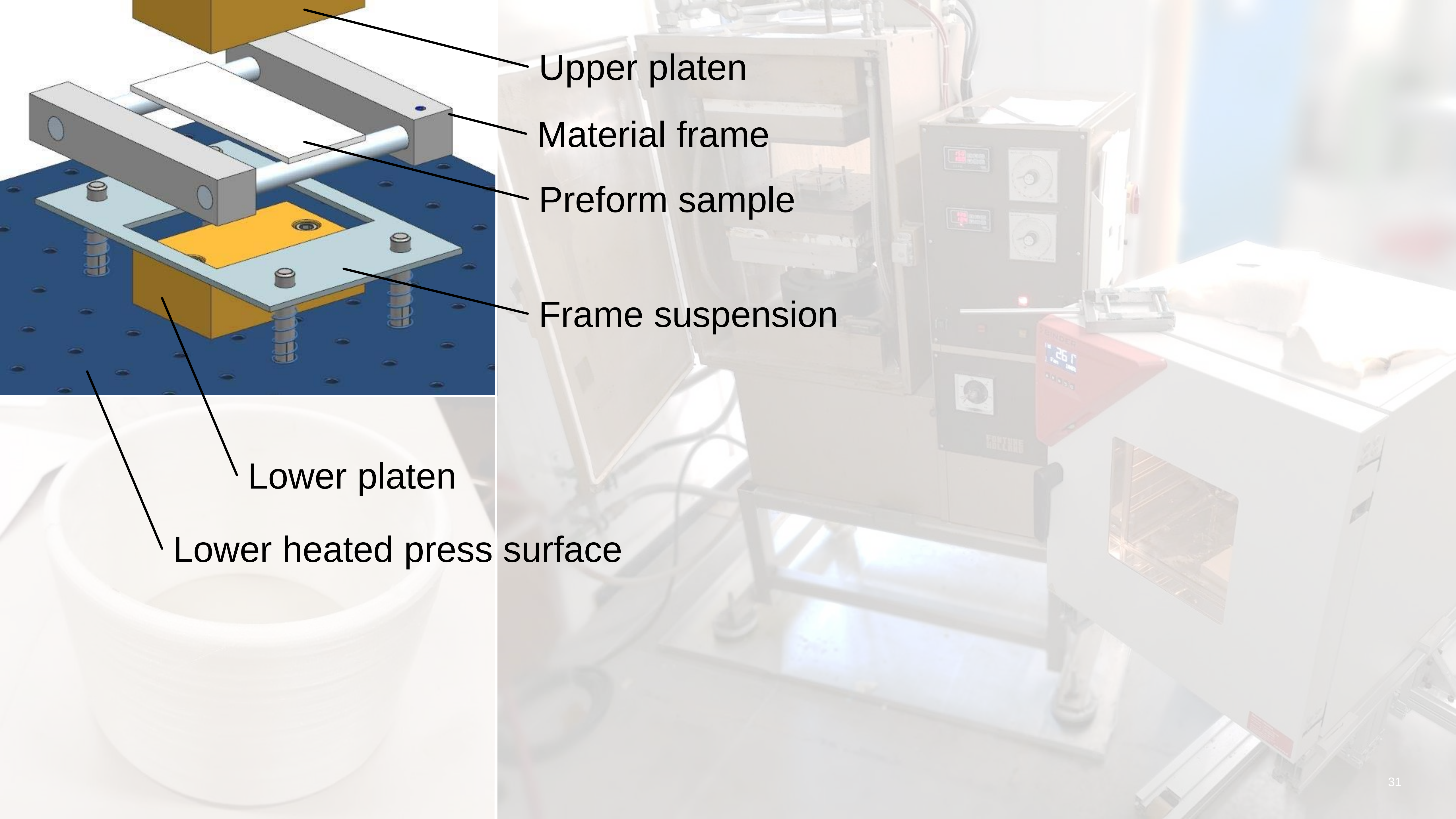


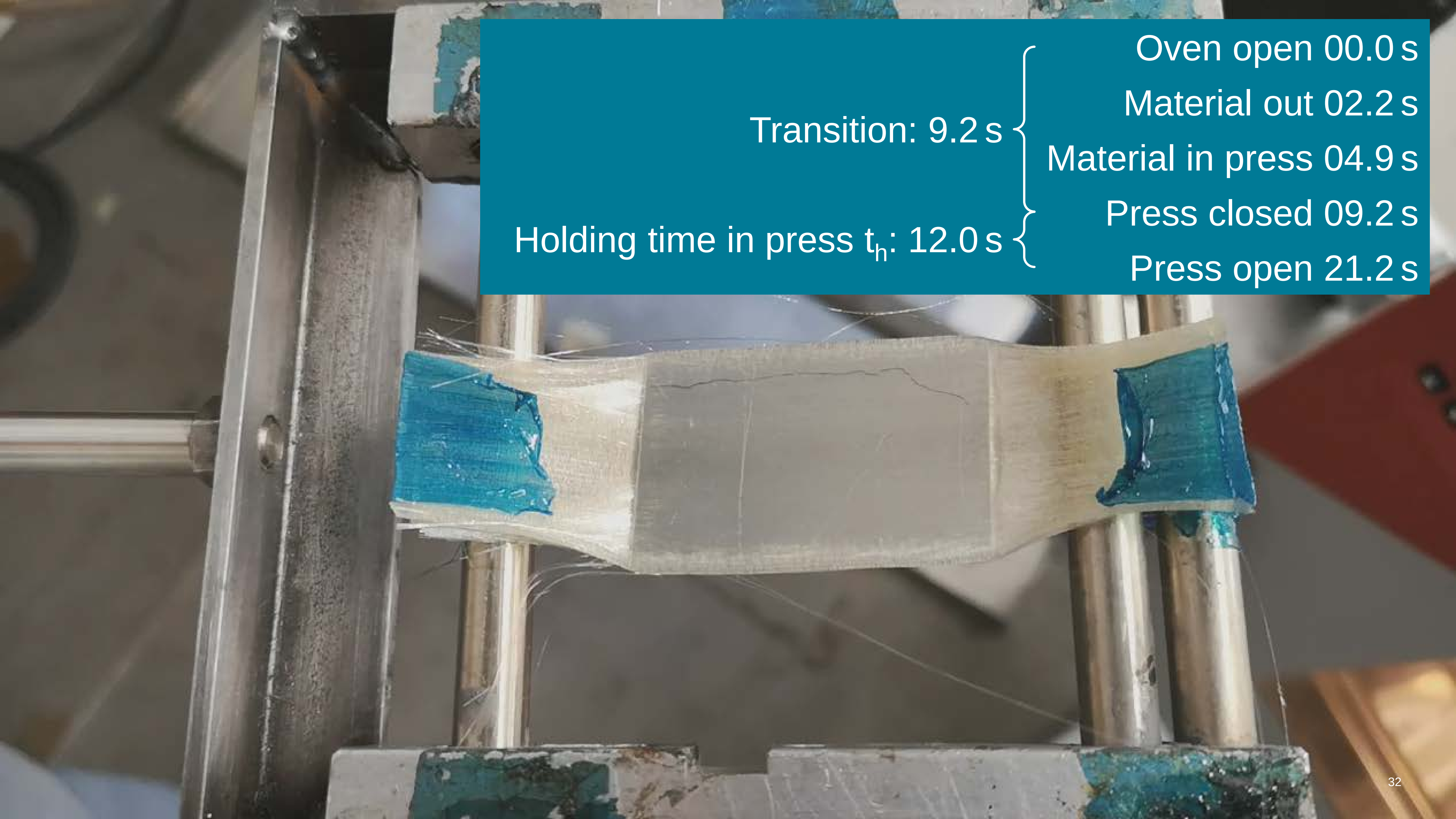
Bicomponent fibre cake





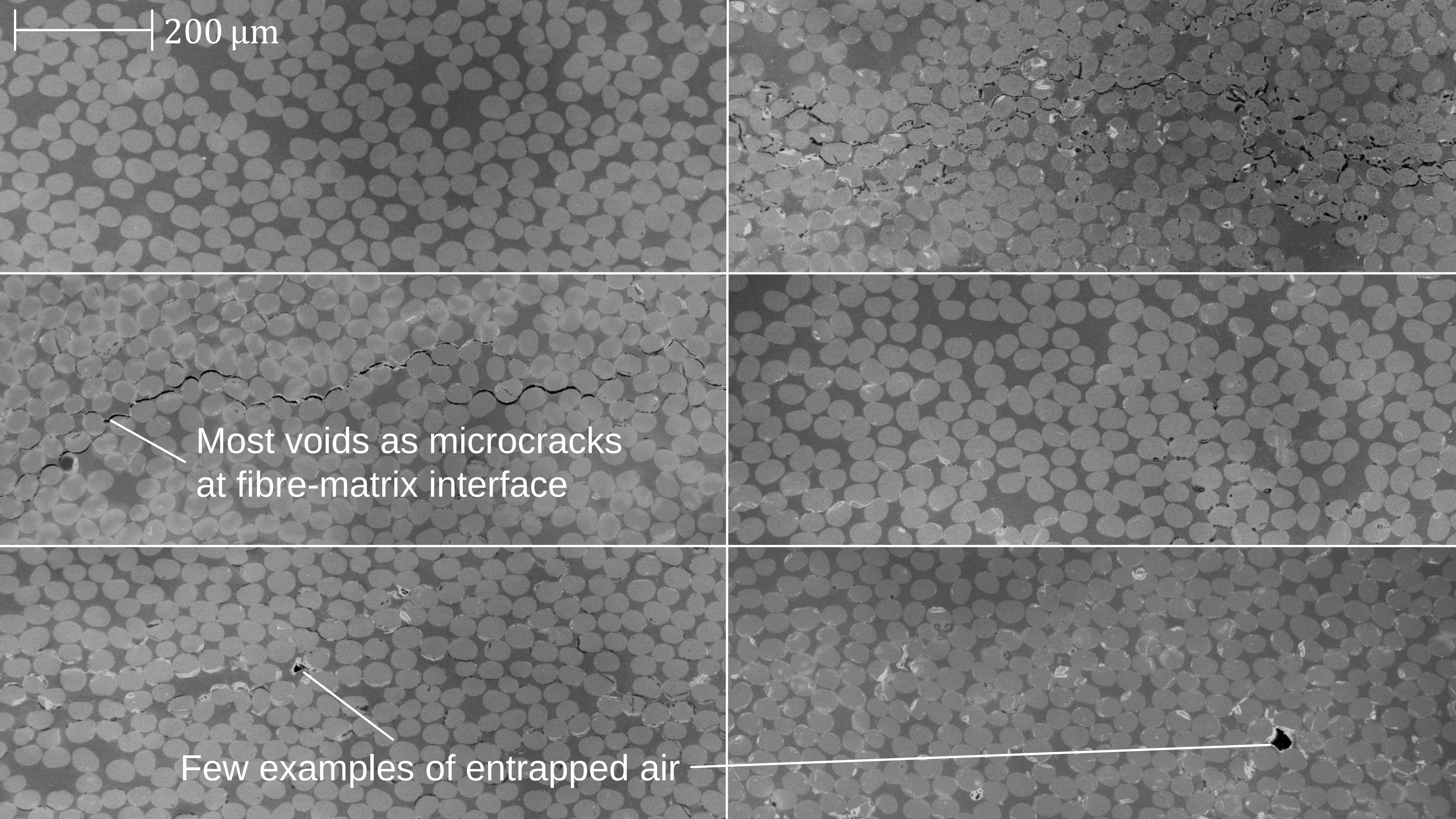

Hydraulic hot press
Convection oven


Upper platen
Material frame
Preform sample
Frame suspension
Lower platen
Lower heated press surface

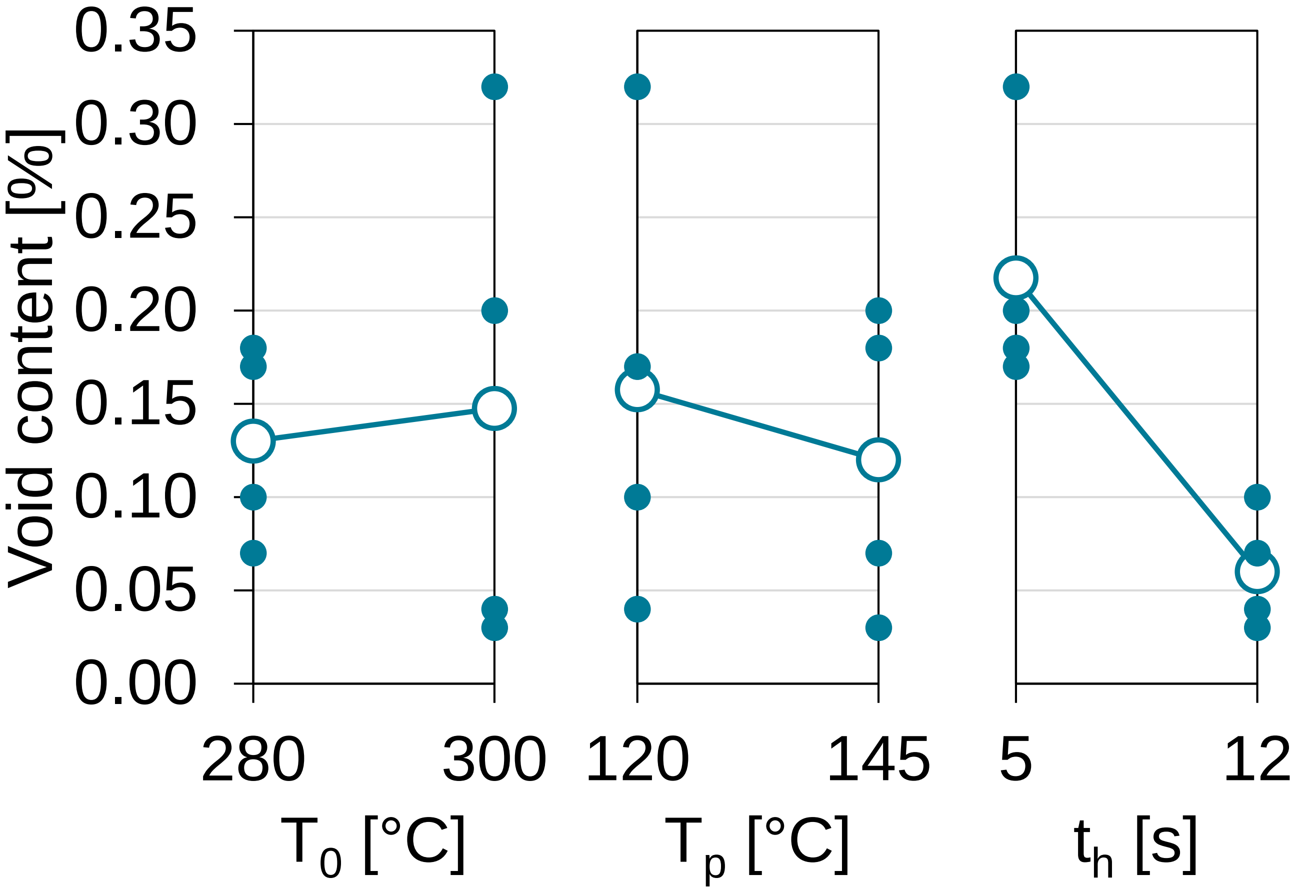


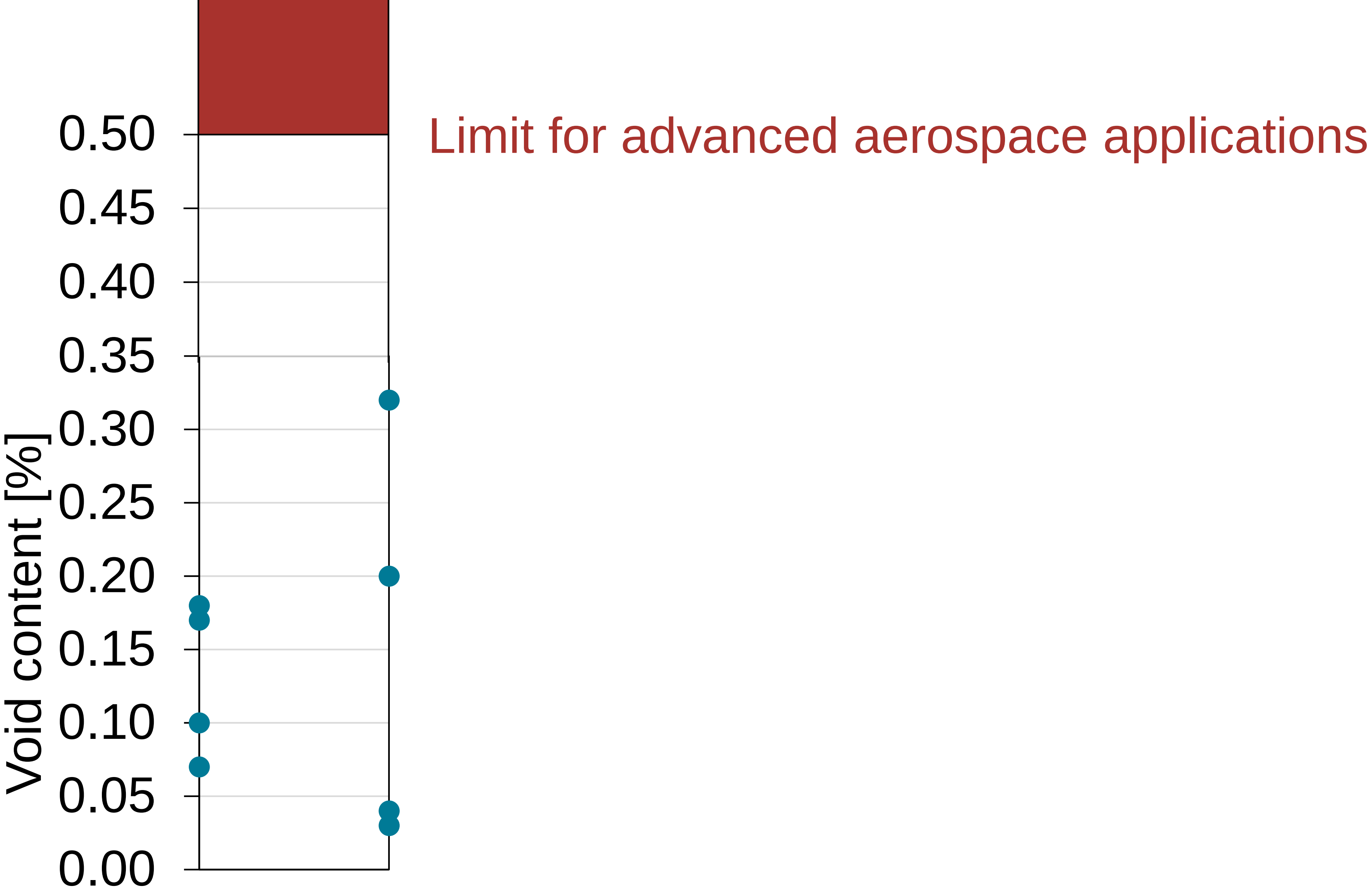
Transition: 9.2 s
Holding time in press t_h: 12.0 s

Oven open 00.0 s
Material out 02.2 s
Material in press 04.9 s
Press closed 09.2 s
Press open 21.2 s


200 μm
Most voids as microcracks
at fibre-matrix interface
Few examples of entrapped air

Main effects on void content



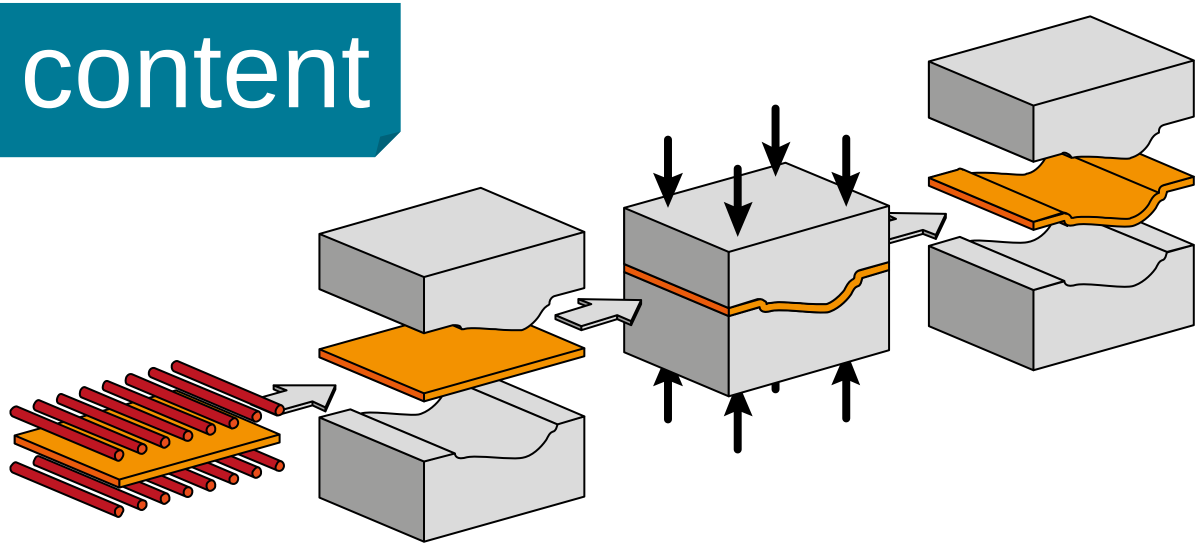


Limit for advanced aerospace applications
Void content [%]
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00

Conclusions

Stamp forming of bicomponent fibre preforms

Low void content



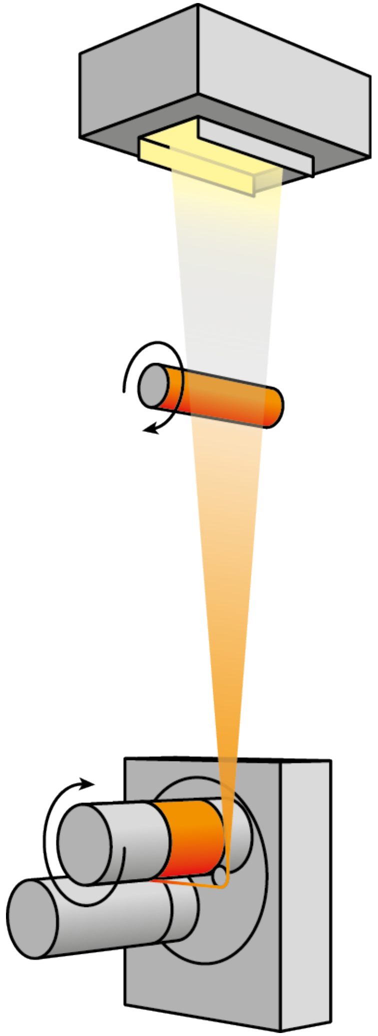
Aerospace quality laminates

Low cycle times (12-22 s)

Continuous in-line coating process

Scalable

High volume throughput possible



Yields separately coated fibers

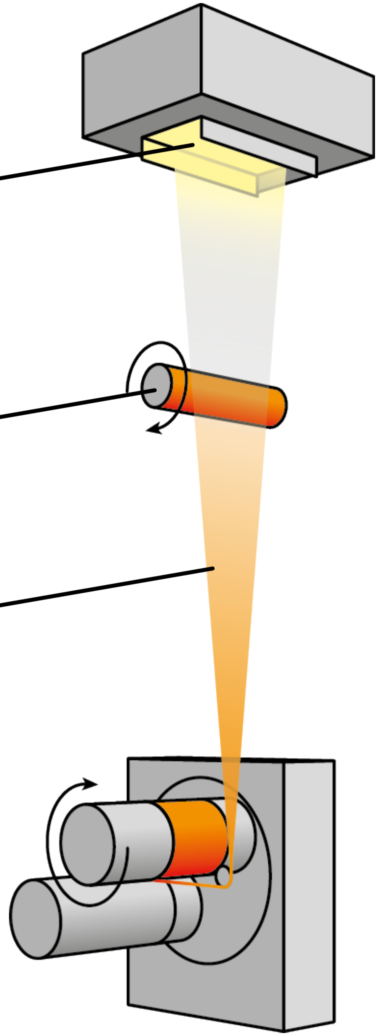
Robust

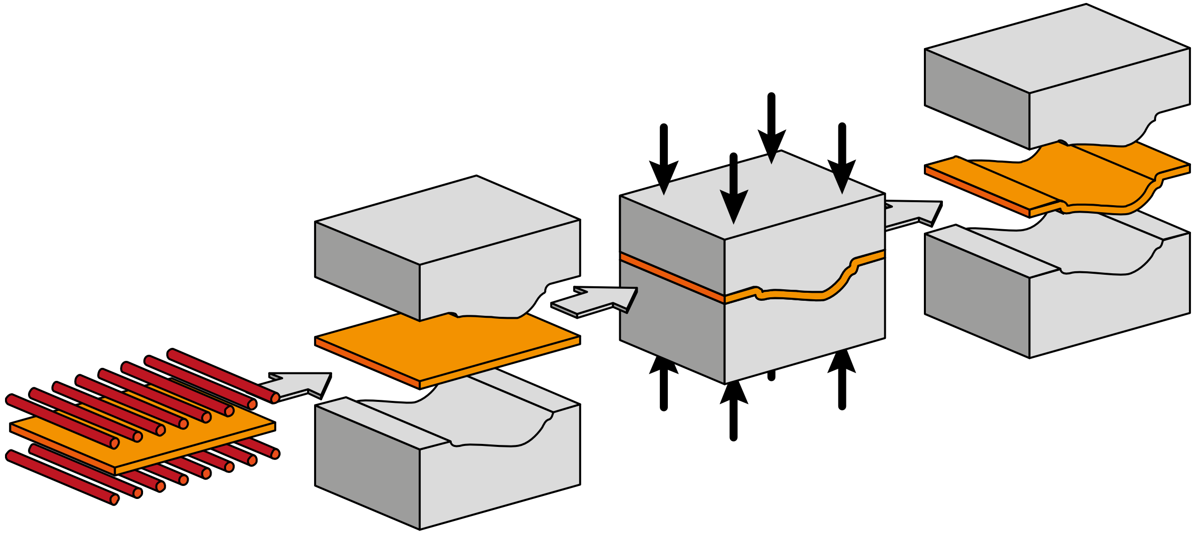
Achievements & outlook

Proof of in-line process ✓

Proof of coating method ✓

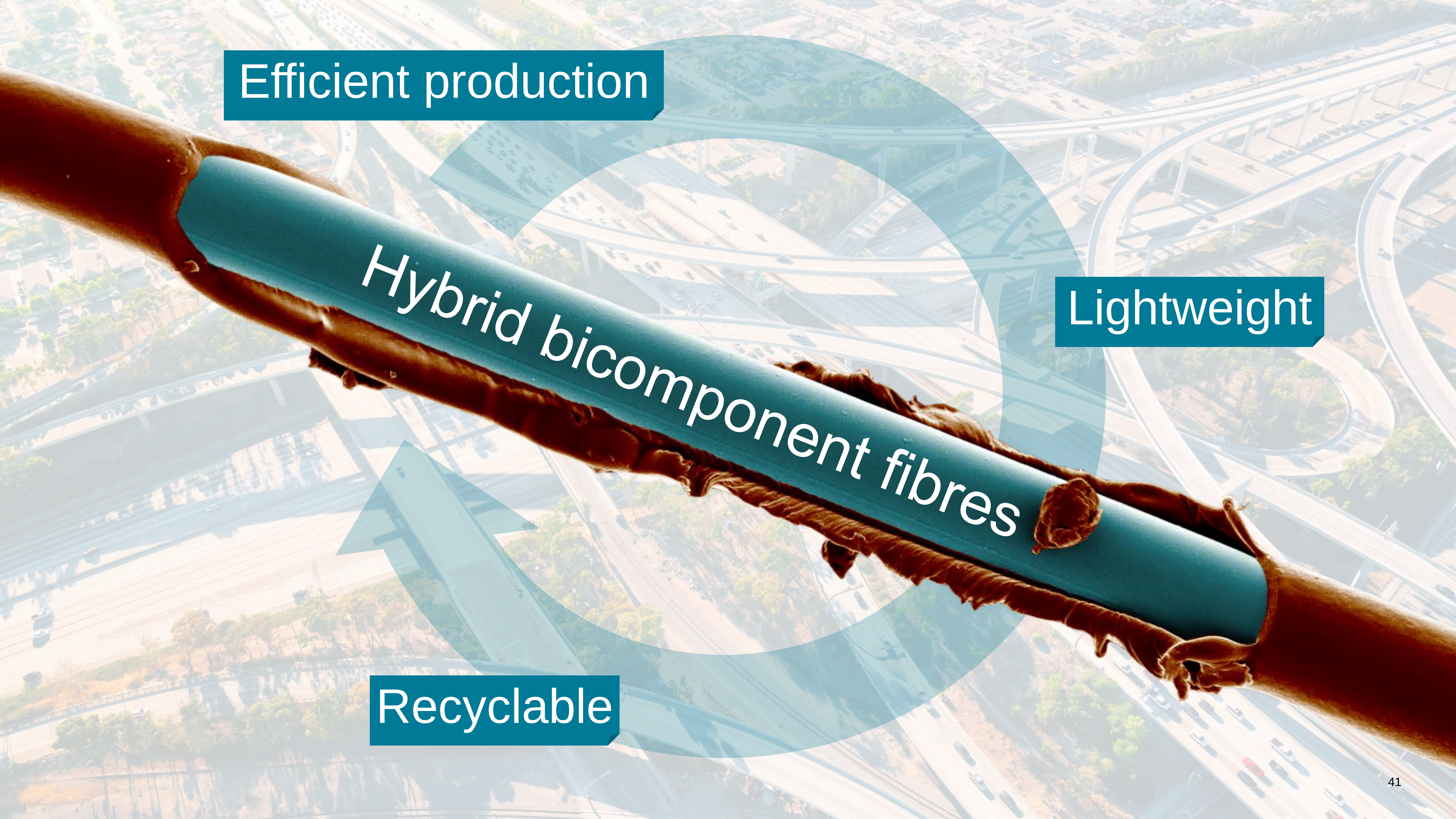
Parallel coating of many filaments ⌛





Proof of consolidation behavior ✓

Life cycle assessment of automotive part production ⌛


Efficient production
Lightweight
Recyclable
Hybrid bicomponent fibres

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CMASLab

Research by:

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- Nicole Aegerter
- Shelly A. Arreguin
- Joanna C.H. Wong
- Paolo Ermanni

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- SEM images taken at Complex Materials lab (ETHZ)
- Rheometry performed at Soft Materials lab (ETHZ)
- Surface tension measurements made at Institute of Polymer Engineering (FHNW)