

GLASS PERFORMANCE DAYS 2025

# Heat treatment of pre-damaged soda-lime silicate glass and its influence on glass strength



# Content

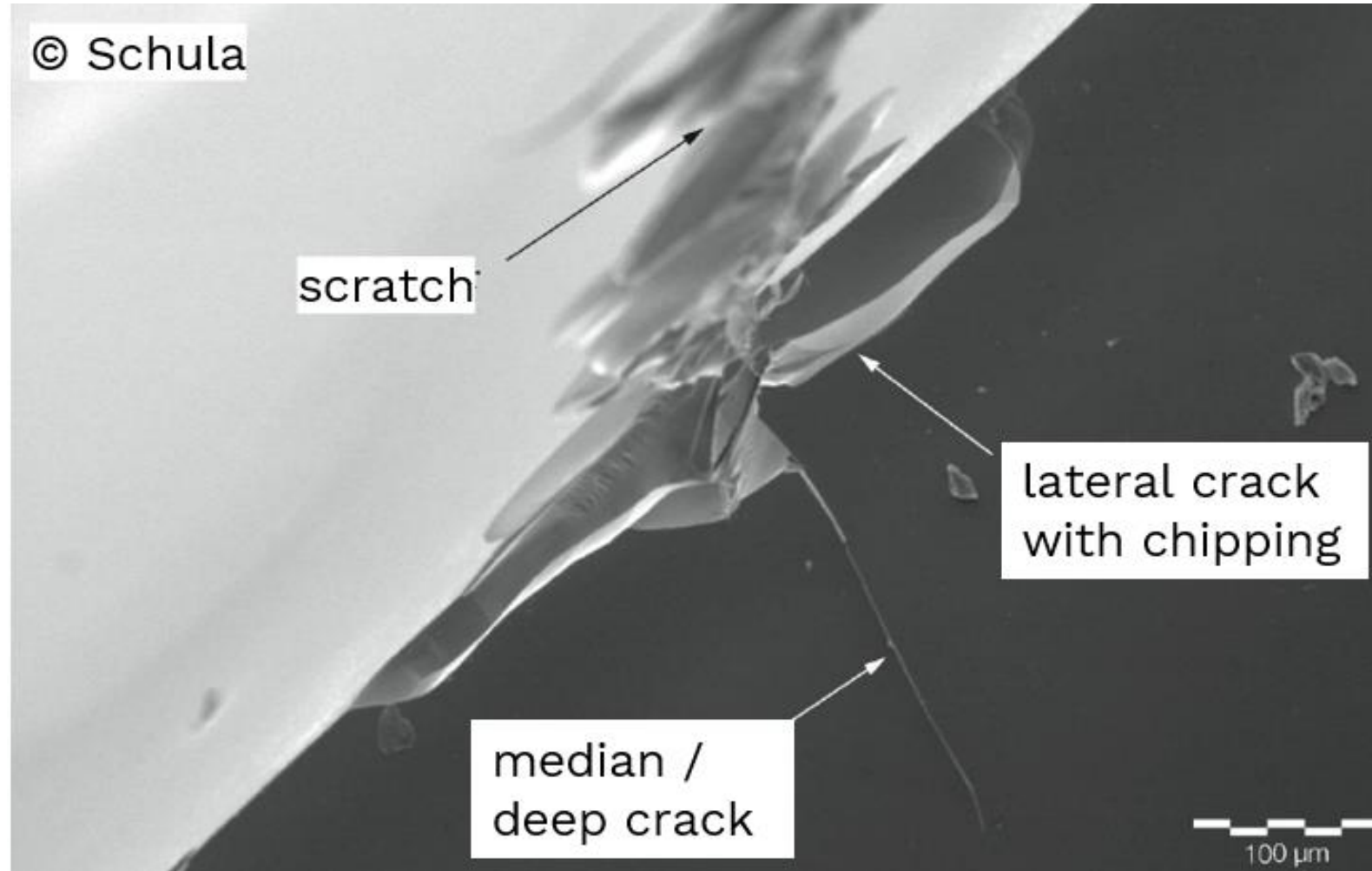
- Motivation
- Theory: crack healing through temperature treatment
- Experimental investigations
- Results
- Summary and Outlook

# Motivation



- 48% - 100% glass in facades<sup>1</sup>
  - building skin influences operational energy
  - renovation wave
  - approx. 1.1 Million t/a glass from buildings<sup>1</sup>
- Circular Economy Action Plan<sup>2</sup>
- minimize resource consumption and waste
- reuse and remanufacturing

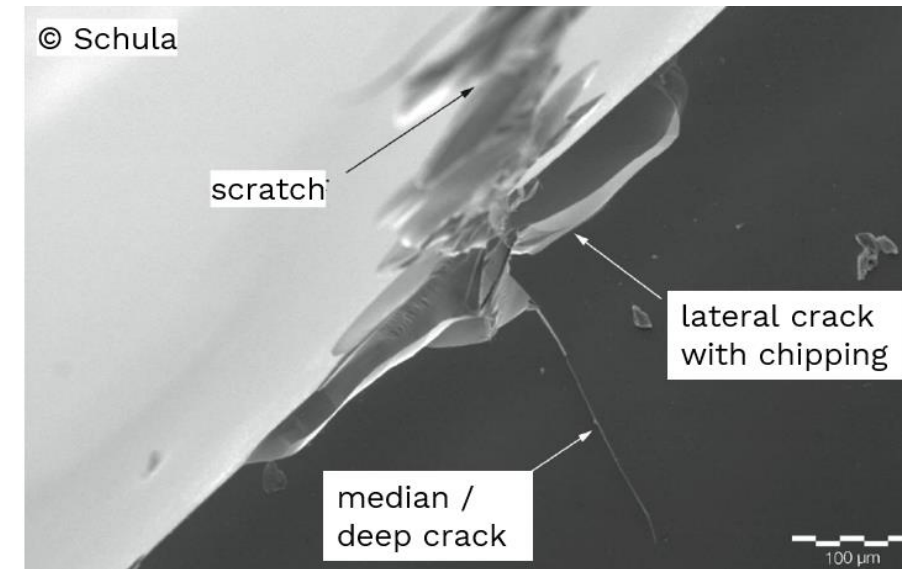
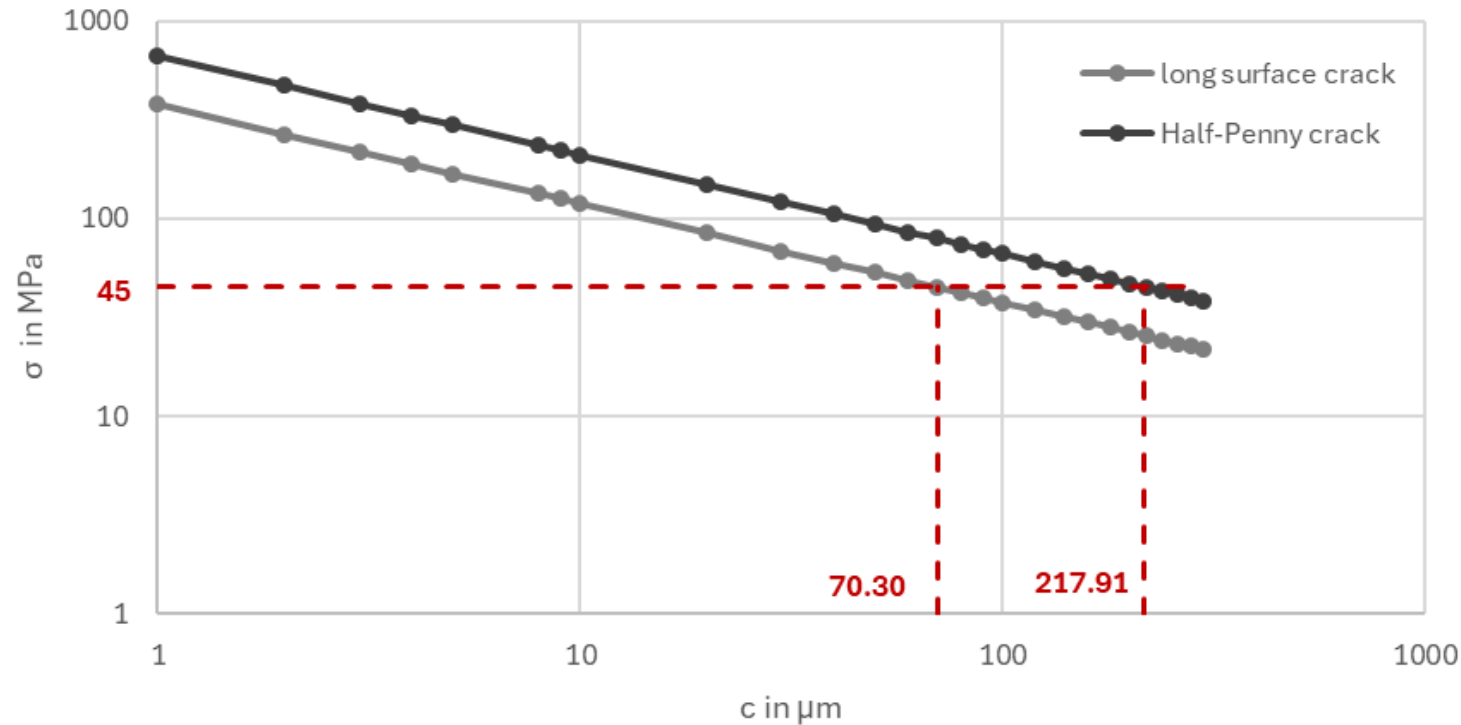
# Motivation



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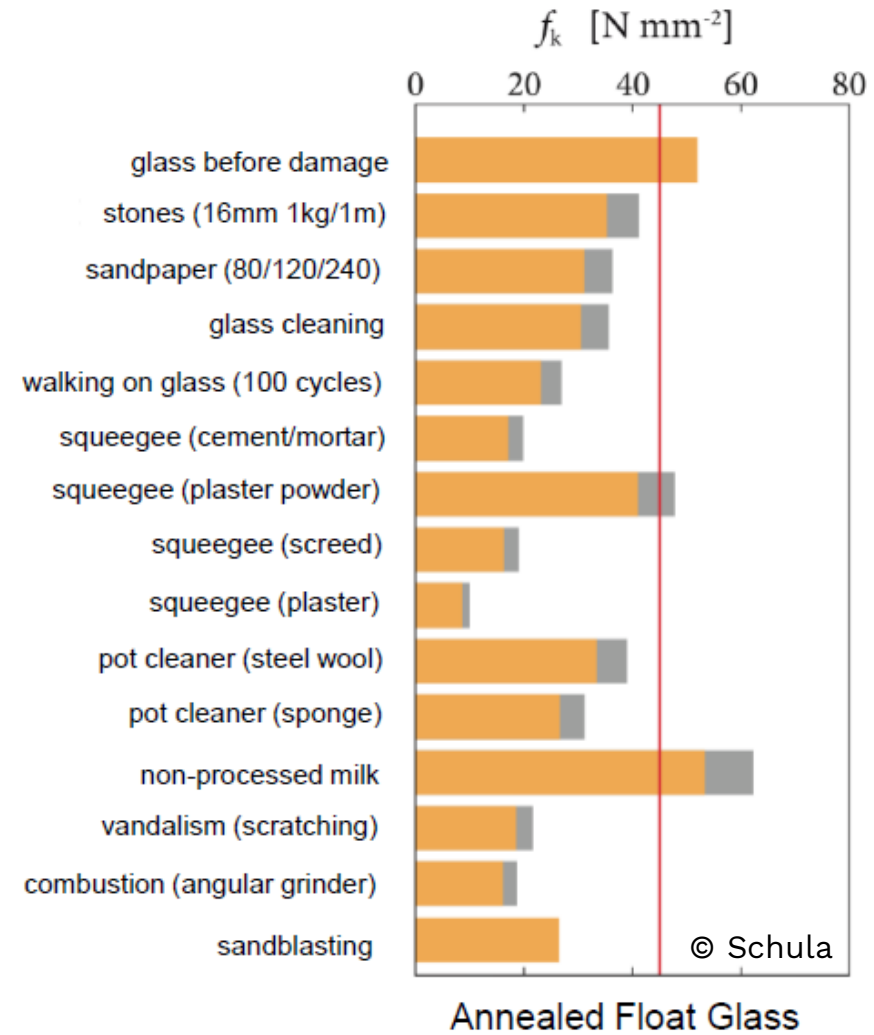
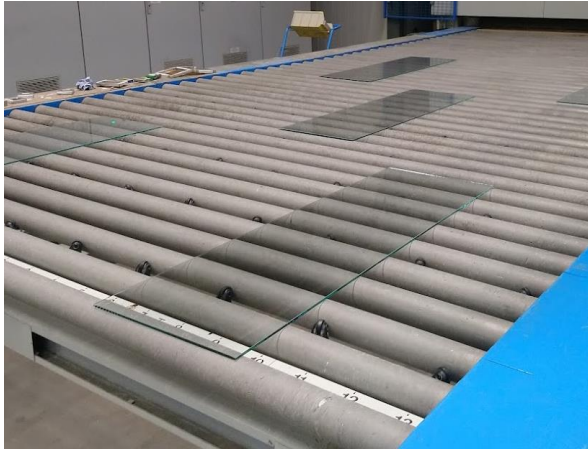
- $\sigma_a$  applied stress
- $c$  crack depth
- $K_I$  stress intensity factor, fracture at  $K_I = K_{IC} = 0.75 \text{ Nmm}^{-2}\text{m}^{0.5}$
- $Y = 1.1215$  long surface crack;  $Y = 0.637$  half-penny crack

$$K_I = \sigma_a \cdot Y \sqrt{c \cdot \pi}$$





# Motivation





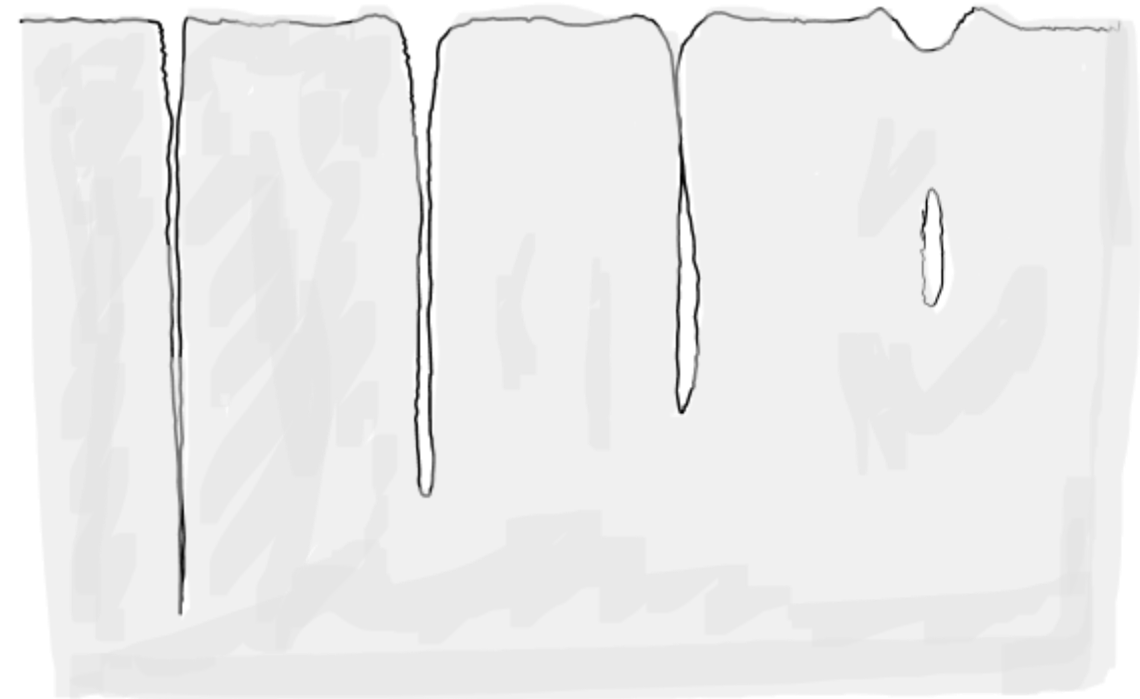
# Theory: crack healing through temperature treatment

Viscous flow:

- smooth crack tips and relaxation of stress
- bridge the crack, reduce the crack depth or even fill it

Viscosity dependent on:

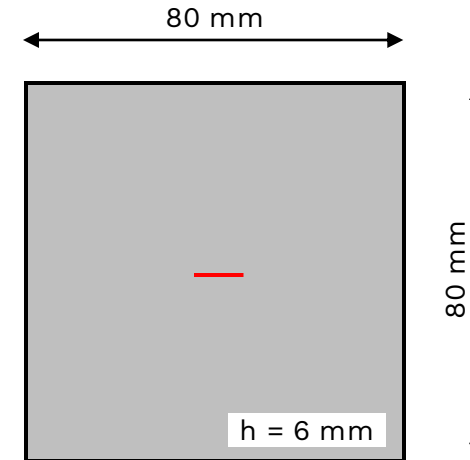
- temperature, time and humidity



# Experimental investigations

Samples:

- soda lime silicate glass
- annealed
- 80 mm x 80 mm
- thickness: 6 mm



pre-damage & storage

–



heat treatment

–



ring on ring test

–



microscopy

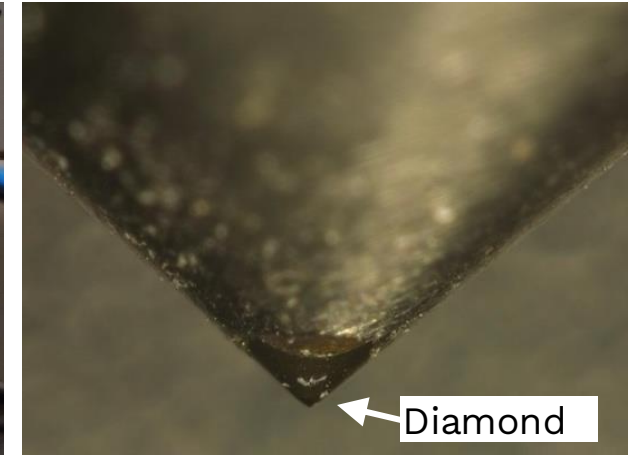
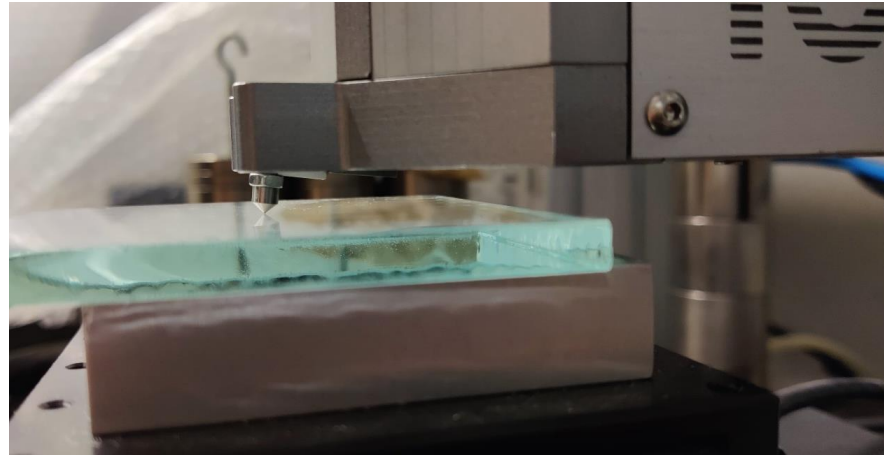
↓  
strength

↓  
crack depth

# Experimental investigations

Pre-damage:

- tin side
- Indenter: diamond, angle  $120^\circ$ ,  $5\ \mu\text{m}$  radius
- length: 4-5 mm
- force: 500 mN
- velocity: 0.1 mm/s



Scratch on  
surface

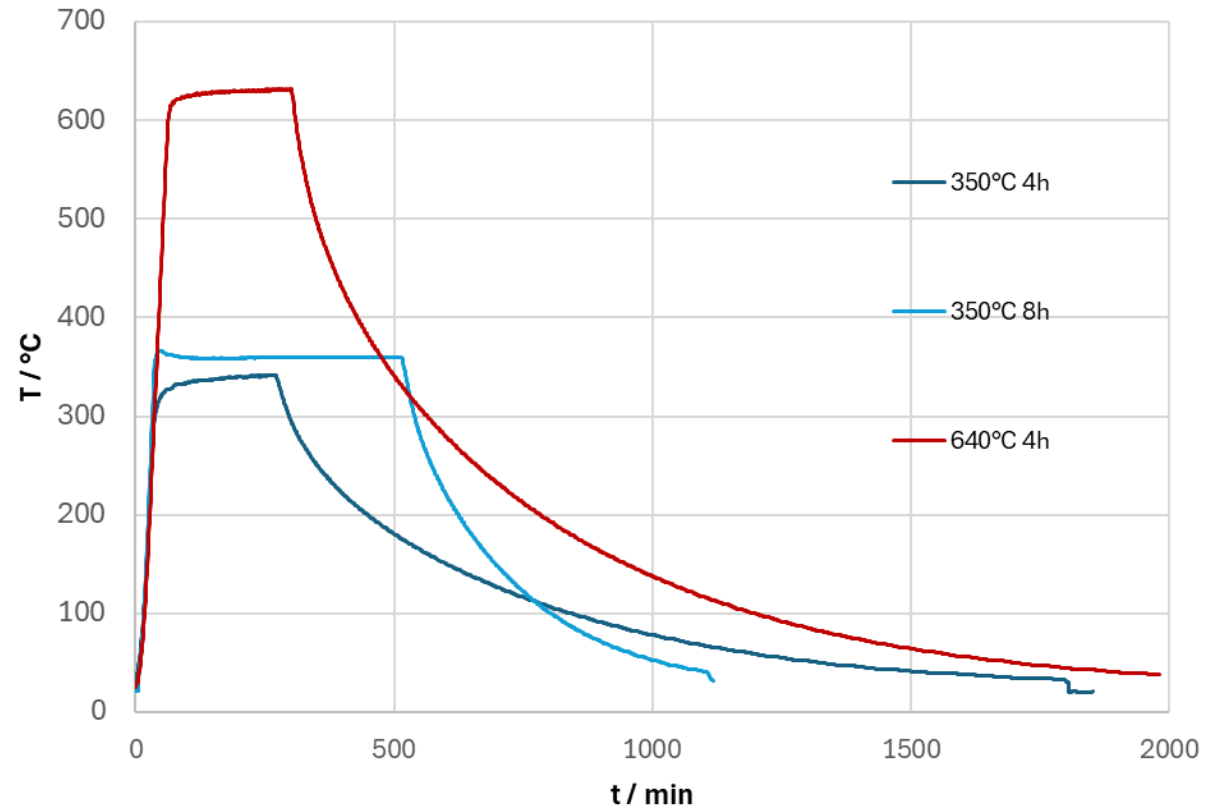


# Experimental investigations

Series	Temperature in °C	Duration at T in h	Amount of samples	Oven
T350_t4	350	4	32	BVD PS 3-400
T350_t8		8	32	Rhode Fusing 290
T540_t1	540	1	32	Rhode Fusing 290
T540_t4		4	32	Rhode Fusing 290
T540_t6		6	32	Rhode Fusing 290
T640_t1	640	1	32	BVD PS 3-400
T640_t4		4	32	BVD PS 3-400
R1	-	-	32	/



# Experimental investigations





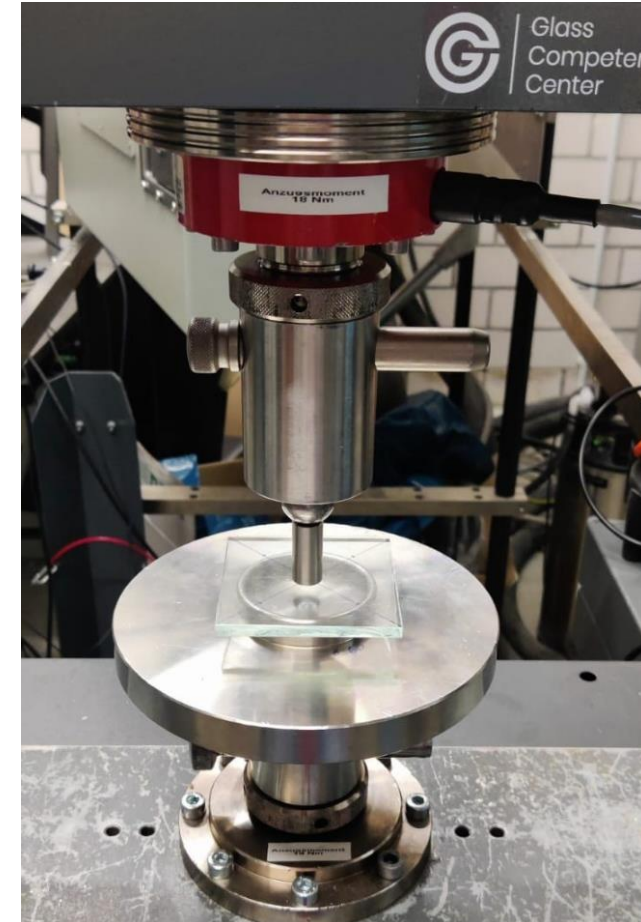
# Experimental investigations

Ring on ring tests based on EN 1288:

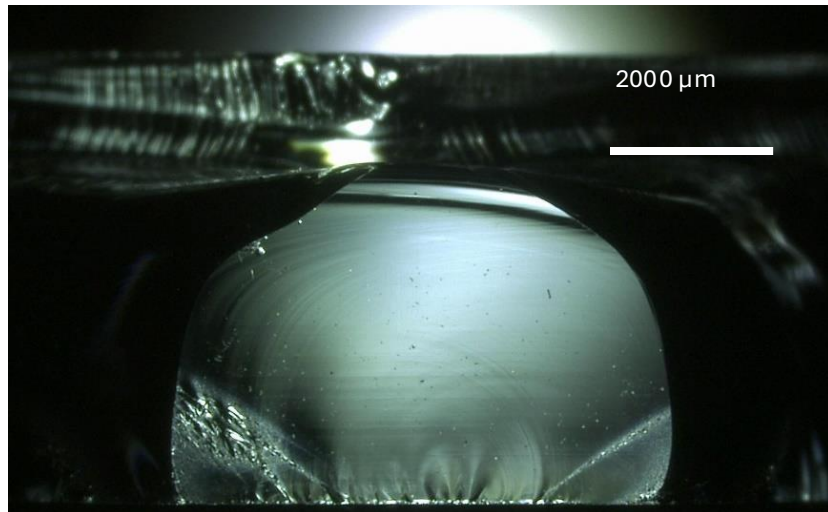
- radius support ring: 30 mm
- radius load ring: 6 mm
- stress rate: 2 MPa/s
- scratch on tensile side

Calculation of fracture stress

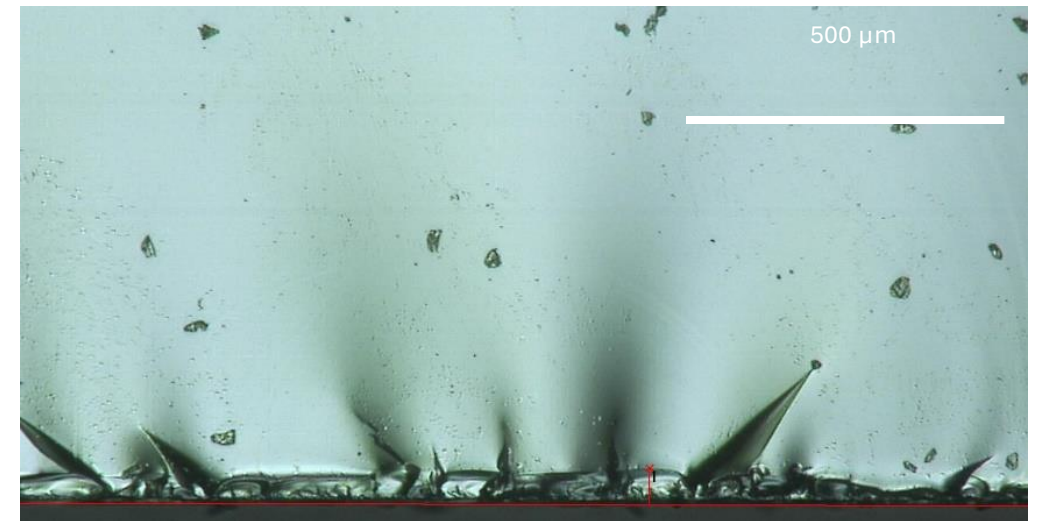
Statistical evaluation



# Experimental investigations



- Fracture mirror

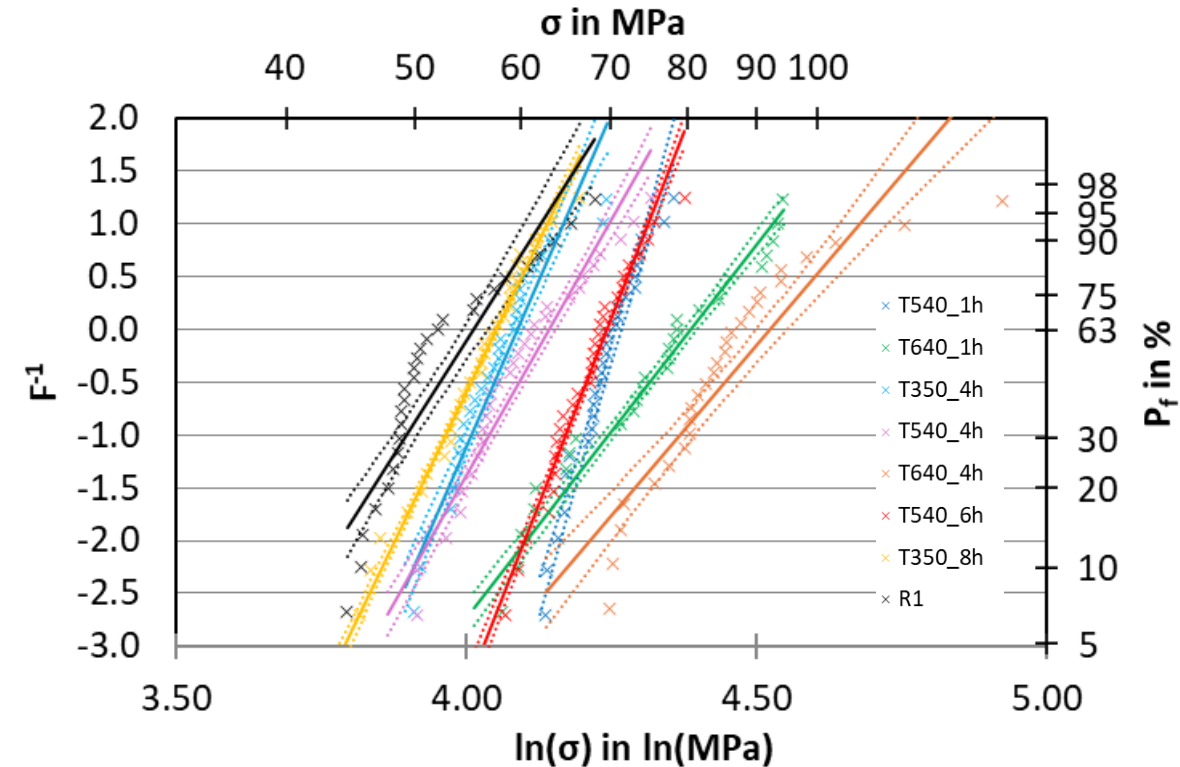


- Measurement of critical crack depth

# Results

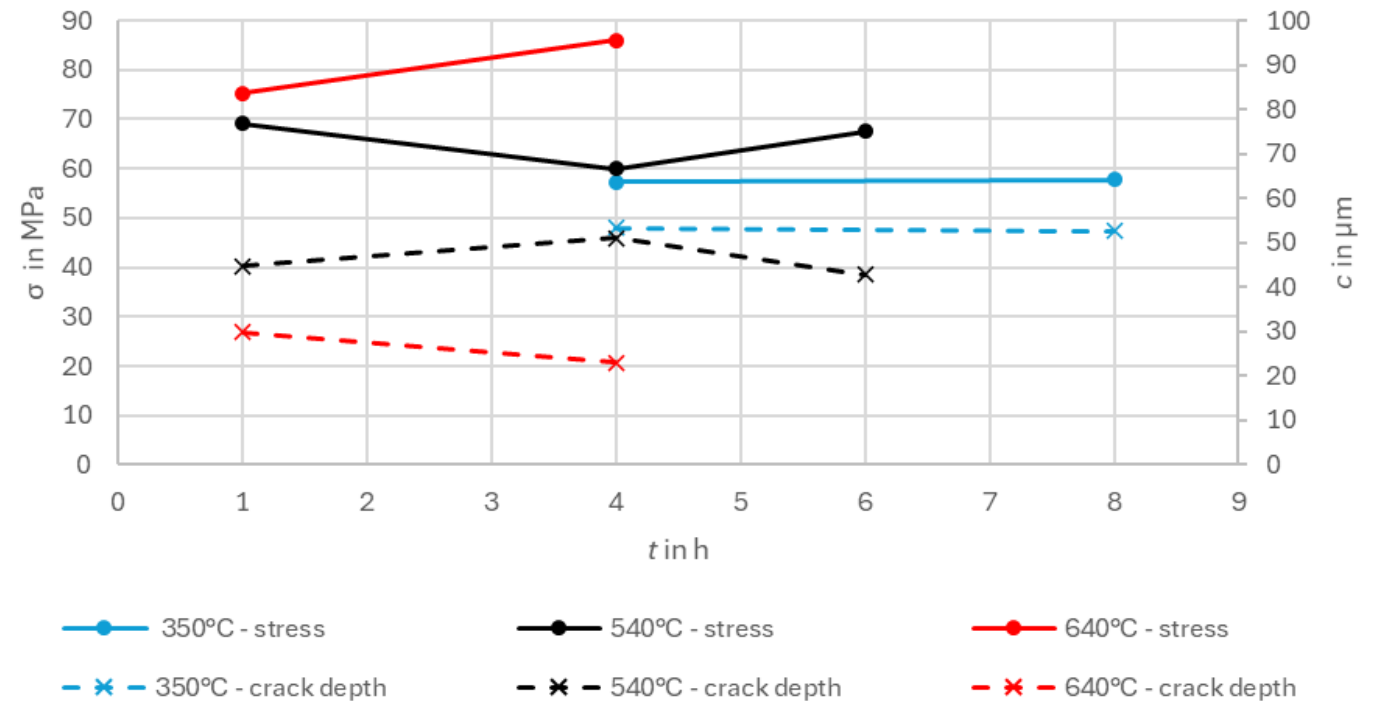
**Fracture stress  $\sigma_a$**  **Evaluation of Weibull**

Series	Mean MPa	Mean/ Mean R1	Stand. dev. MPa	Coeff. of Var. %	5% fractile, 95% conf. MPa
T350_t4	57.3	1.1	4.9	8.6	45.9
T350_t8	57.8	1.1	5.2	9.0	43.9
T540_t1	69.0	1.3	4.0	5.8	59.7
T540_t4	60.0	1.2	6.8	11.3	45.2
T540_t6	67.5	1.3	5.2	7.8	55.7
T640_t1	75.3	1.4	11.4	15.1	51.3
T640_t4	86.0	1.6	14.7	17.1	54.2
R1	52.3	1.0	6.4	12.2	36.9



# Results

Series	Crack depth $c$		Fracture stress $\sigma_a$	
	Mean $\mu\text{m}$	Mean/ Mean R1	Mean MPa	Mean/ Mean R1
T350_t4	53.4	0.9	57.3	1.1
T350_t8	52.7	0.9	57.8	1.1
T540_t1	44.8	0.8	69.0	1.3
T540_t4	51.0	0.9	60.0	1.2
T540_t6	42.8	0.7	67.5	1.3
T640_t1	29.8	0.5	75.3	1.4
T640_t4	22.9	0.4	86.0	1.6
R1	58.0	1.0	52.3	1.0



# Summary

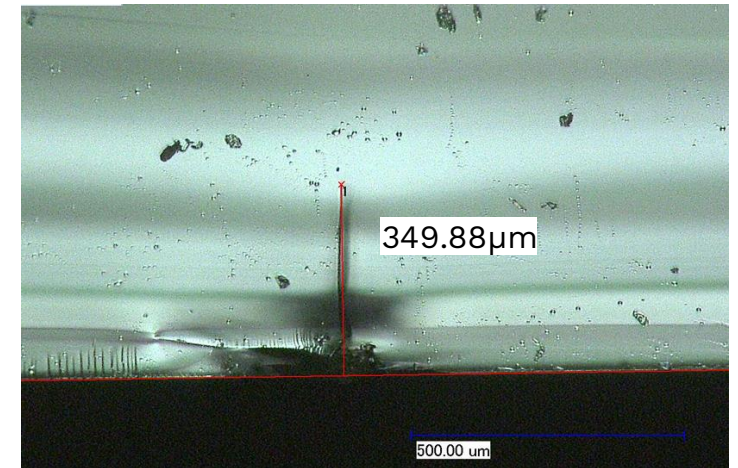
- Pre-damage: 4mm long, average crack depth of 58  $\mu\text{m}$
  - 7 different temperature treatment programmes
- even at low temperatures of 350°C: small increase in strength
- increase in mean fracture stress match the observations of a reduced crack depth
- 4h at 640°C: 1.6 x strength of R1 & 0.4 x crack depth of R1

# Outlook

- Time temperature-equivalence
- Different crack parameters
- Naturally aged glass

## References:

1. Glass for Europe: Flat glass in climate neutral Europe - Triggering a virtuous cycle of decarbonization, 2020
2. European Com., A New Circular Economy Action Plan for a Cleaner and More Competitive Europe, 2020
3. S. Schula. Charakterisierung der Kratzanfälligkeit von Gläsern im Bauwesen, Dissertation TU Darmstadt, 2015



**Thank you  
for  
your  
attention**



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**LinkedIn**



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