Global Aging and Lifetime Prediction – Polypropylene Absorbers Materials for pumped Systems

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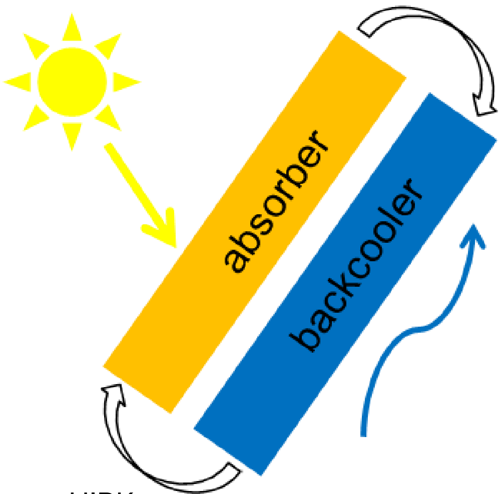
Task 54 Dissemination Workshop

Introduction and Objectives

Development of fully overheating controlled collectors (OHC); max. 95°C

Concept for OHC collector



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Materials for OHC collectors

- Polyolefin absorber material development and aging characterization
- Lifetime estimation for OHC collectors

Requirements

System type & service requirements

- Pressurized system with overheating protection
- service life: 20 years
- region: Graz (Austria)

Key-property requirements for *absorber materials*

- solar absorption: 93-95%
- thermal stability: >100°C
- low temperature capability: -30°C
- long-term stability in water/glycol:
  - 75-100°C: > 3,500 h (DHW)
    > 7,000 h (SH)
  - 0-75°C: > 150,000 h
- pressure: max. 1,5 bar

Experimental: *Aging conditions*

Materials:

Two polypropylene grades (100µm micro-size specimen)

- **PPBα** (B…block; α…crystal form)
- **PPBβ** (B…block; β…crystal form)

Exposure Conditions:

Two different environment media

- Hot Air
- Heat Carrier Fluid (Water + Glycol)

@ Temperatures of 95°C, 115°C and 135°C

100µm thick micro-size specimen (polypropylene)

Evaluated aging indicators:

- Stabilizer analysis by HPLC-MS (Agilent Technologies 1260 Infinity)
- Oxidation temperature (T_{ox}) by DTA (PerkinElmer DSC4000)
- Carbonyl Index (C.I.) by FT-IR (PerkinElmer Spectrum 100)
- **Embrittlement time by tensile testing (Zwick Roell Z2.5)**

1260 Infinity

DSC4000, PerkinElmer

Spectrum 100, PerkinElmer

Z2.5, Zwick Roell

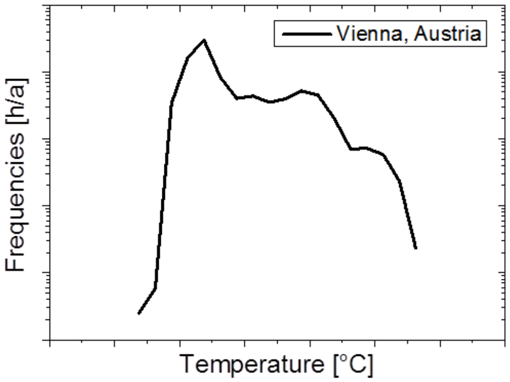
Experimental: *Lifetime assessment*

Methodology and approach

Climatic conditions and heat storage type

↓ Simulation

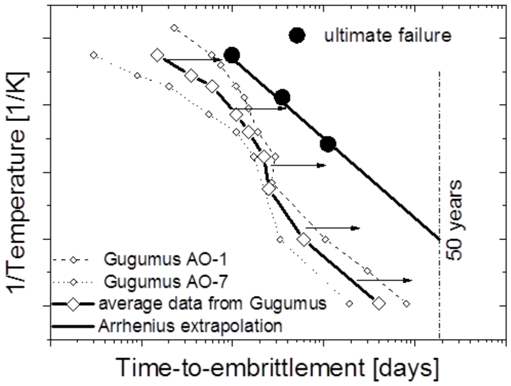
Temperature loading profile



Experimental failure times

↓ Extrapolation

Extrapolated endurance time



Accumulation

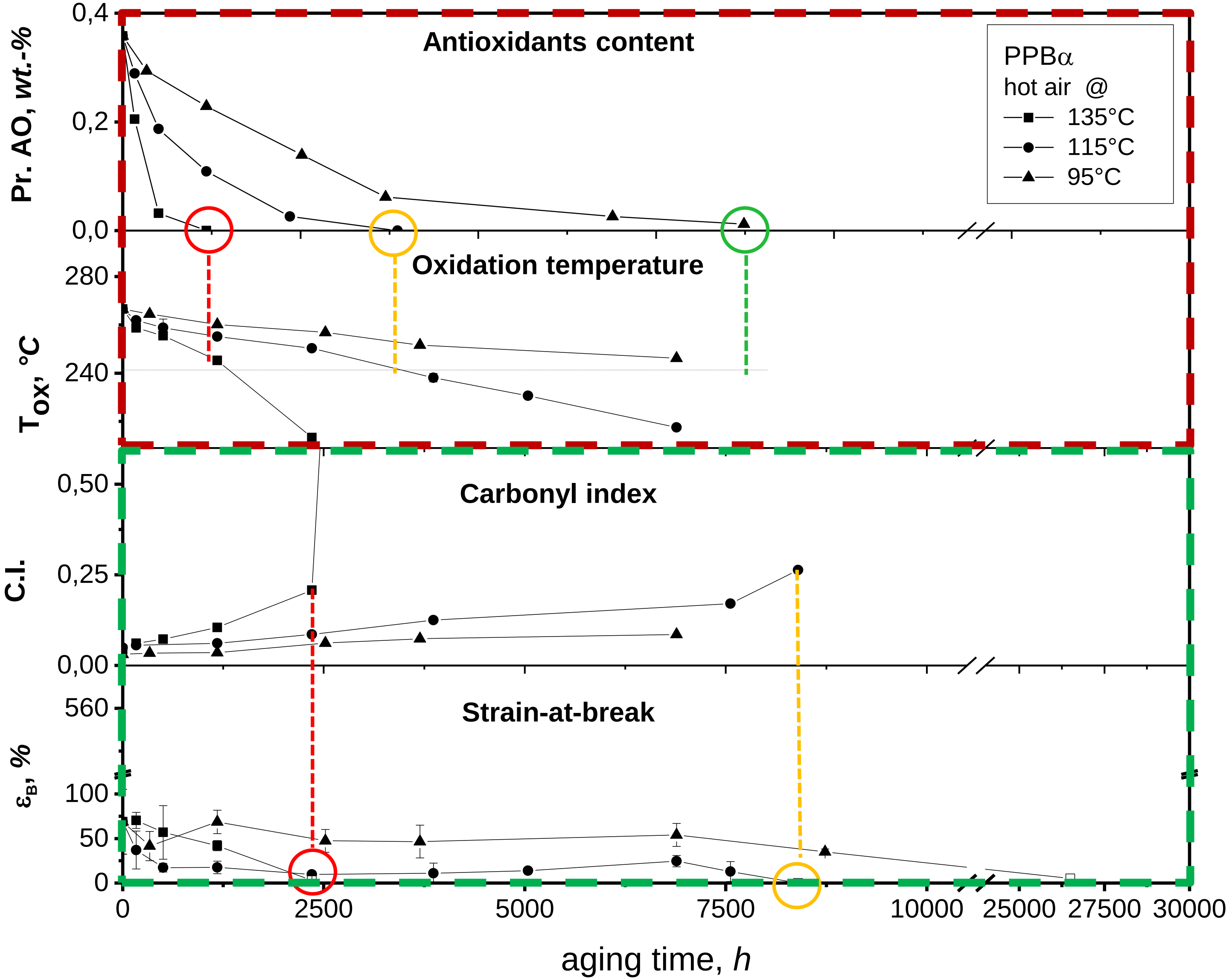
Lifetime assessment

Cumulative damage model (Miner's rule)

$$1/t_f = \sum_{i=1}^{i=n} \left[(t_i/t_{tot})/t_{fi}(T_i,\sigma_i) \right]$$

- **Simulation** of temperature loading profiles (T. Ramschak)
- **Extrapolation** of failure times to service temperature (40-90°C); Arrhenius vs. Gugumus approach
- **Accumulation** and lifetime assessment (Miner's rule)

Results: *Hot air aging behavior of PPBα*



Analytical char.:

good agreement of stabilizer content and oxidation temperature

Technological char.:

agreement of carbonyl index and strain-at-break;

Embrittlement:
2,500 h at 135°C
8,000 h at 115°C
26,500 h at 95°C

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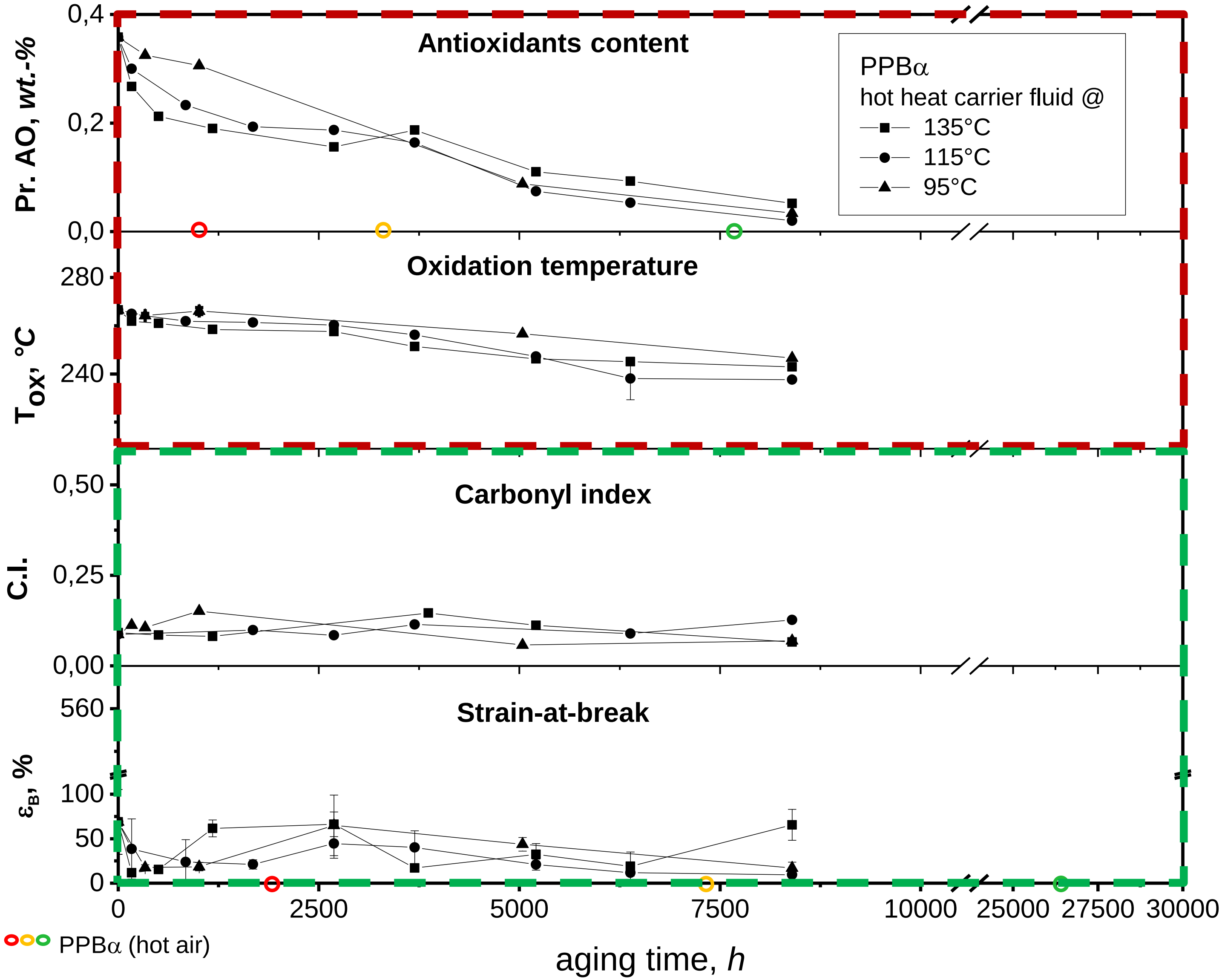
Results: *Hot heat carrier fluid aging behavior of PPBα*

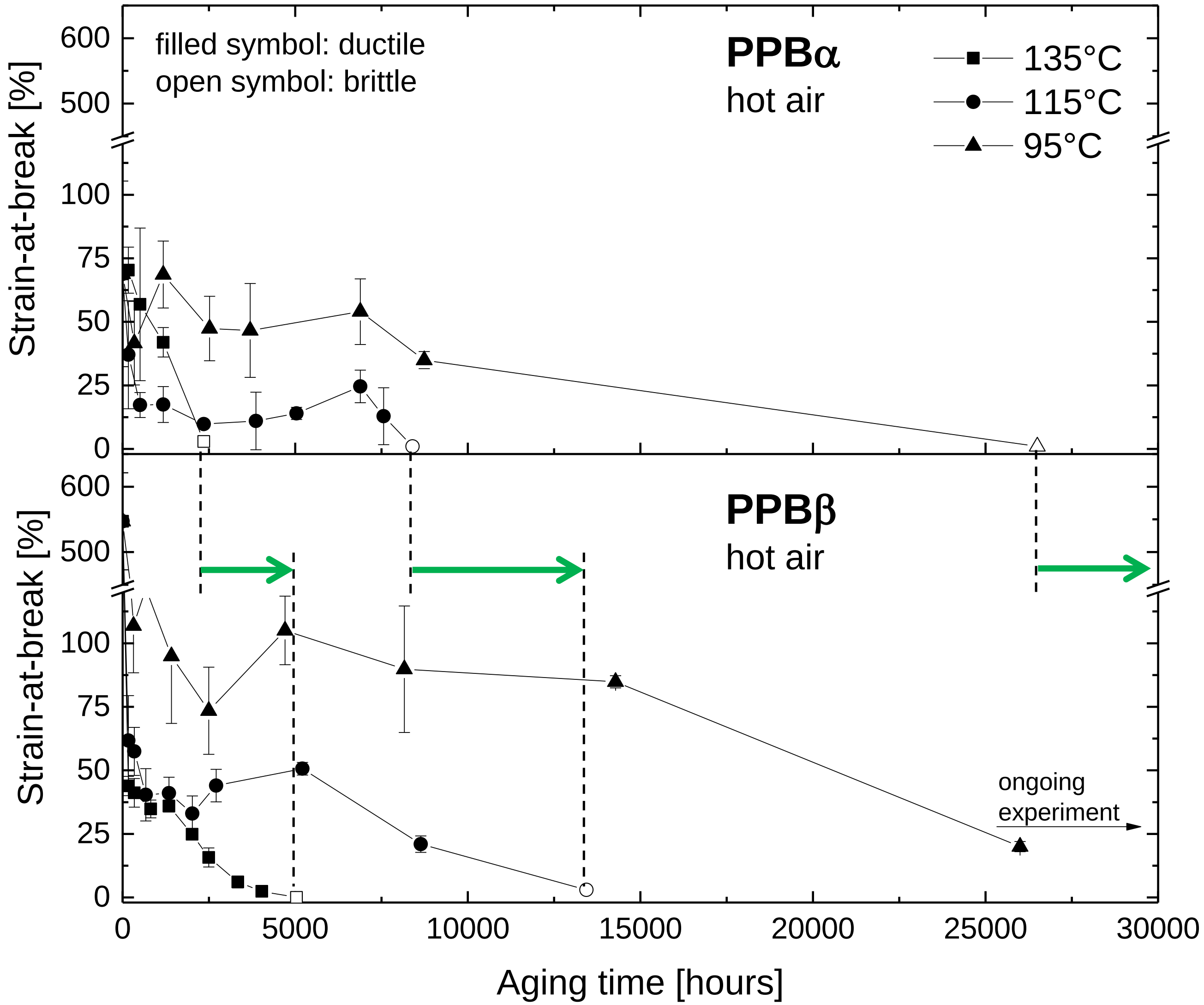


Water/glycol mixture less aggressive than hot air

Retarded stabilizer consumption

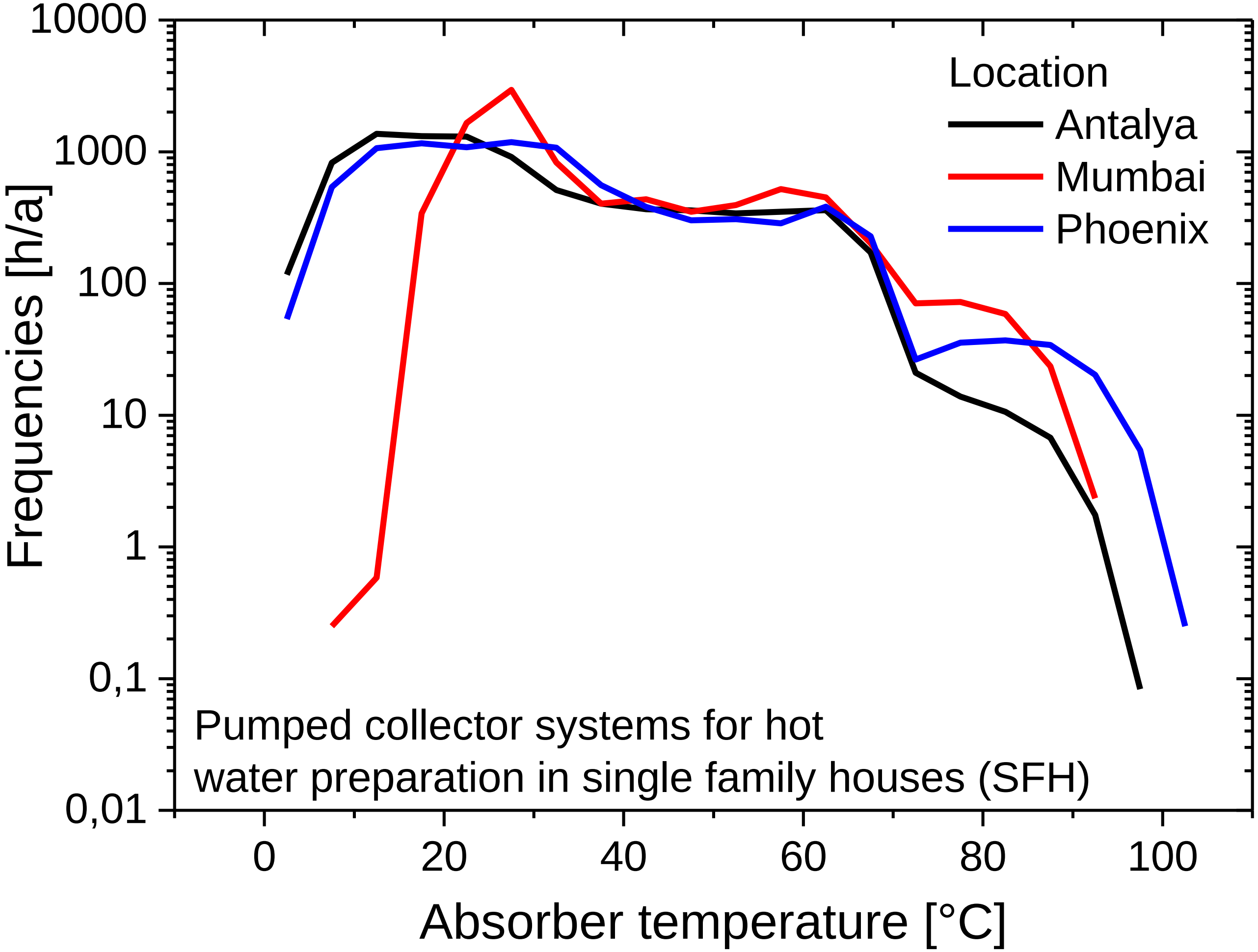
No embrittlement after more than 15,000 hours

Results: *Hot air aging of PPBα and PPBβ (ulitmate failure)*



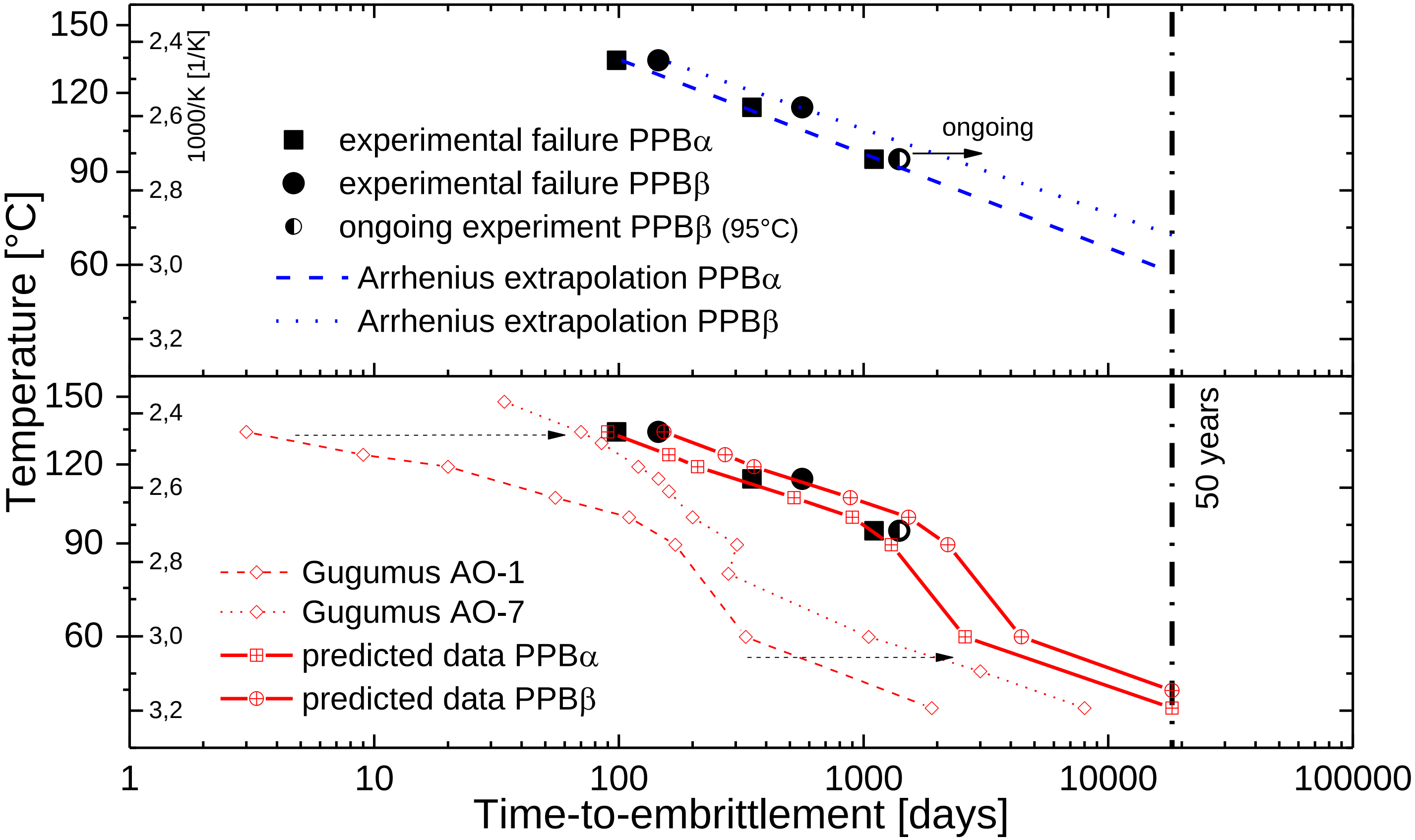
Significant impact of PP-crystal form;
β outperforms α

Results: *Lifetime-Temperature loading profiles for OHC collector*



- Climates:
  - Antalya: mediterranean
  - Mumbai: hot and humid
  - Phoenix: hot and dry
- Due to triggered thermosyphonal backcooling, maximum operating temperatures are below 100°C
- Similar loads in the temperature area of 35 to 65°C for observed climate zones
- Highest loads for Phoenix for temperatures at about 95°C

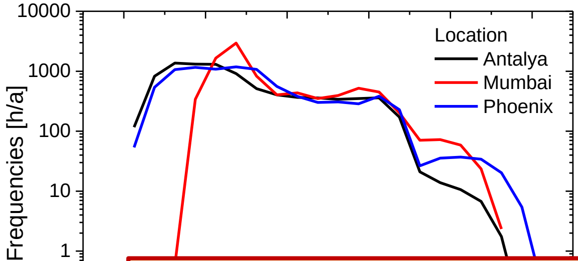
Results: *Extrapolated endurance times*

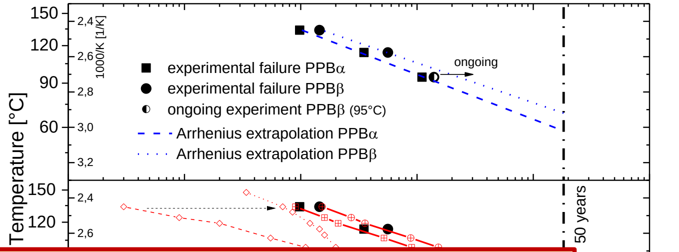


Arrhenius fit:
good correlation for PPBα; ongoing for PPBβ

Gugumus fit:
Temperature dependent aging mechanisms; Literature data for PP-H to be corroborated for PPB (> 10 years (?))

Results: *Deduced lifetime values*





Lifetime modelling:

- *Extrapolation by Arrhenius and Gugumus approach*
- *Cumulative damage model (Miner's rule)*
  → *lifetime* (t_f)

$$1/t_f = \sum_{i=1}^{i=n} \left[\left(t_i / t_{tot} \right) / t_{fi}(T_i, \sigma_i) \right]$$

- Significant dependency on extrapolation method
  - Gugumus approach as conservative method
- Minimal lifetime for hot and humid climate zone Mumbai
- Novel SolPol-grade PPBβ: deduced lifetime a factor of 0.5 higher (Gugumus approach)

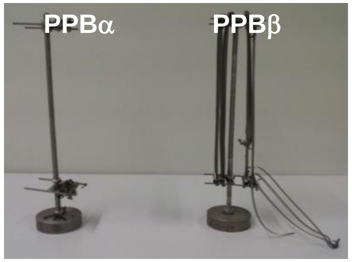
	Lifetime, years	Antalya, TR	Mumbai, IN	Phoenix, US
Arrhenius	PPBα	45	41	41
	PPBβ	47	43	43
Gugumus	PPBα	**24**	**20**	23
	PPBβ	**34**	**29**	32

Improved performance due to material morphology

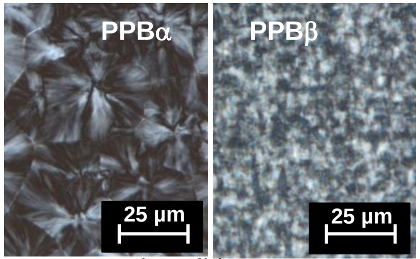
Summary and Conclusion

Aging behavior

- SolPol-grade PPBβ exhibited better long-term performance under service relevant conditions
- Reason: finer sperolithe morphology of the novel grade (PPBβ)
- Hot air exposure is more critical than hot heat carrier fluid (with corrosion inhibitors)



100µm MMS after aging



α- vs. β-spherulitic structure (PPBα vs. PPBβ)

Lifetime assessment

- Temperature loading profiles are significantly dependent on location
- More critical: hot and humid climate zone (e.g. Mumbai, IN)
- Lifetimes vary between 20 and 34 years depending on location and PP-grade (Gugumus approach)
- Novel SolPol-grade exhibited enhanced lifetime (factor of 0.5 better)

Acknowledgement

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