Assessment of solar selective absorber coating stability and durability: pertinence of purely thermal aging vs. real concentrated solar aging

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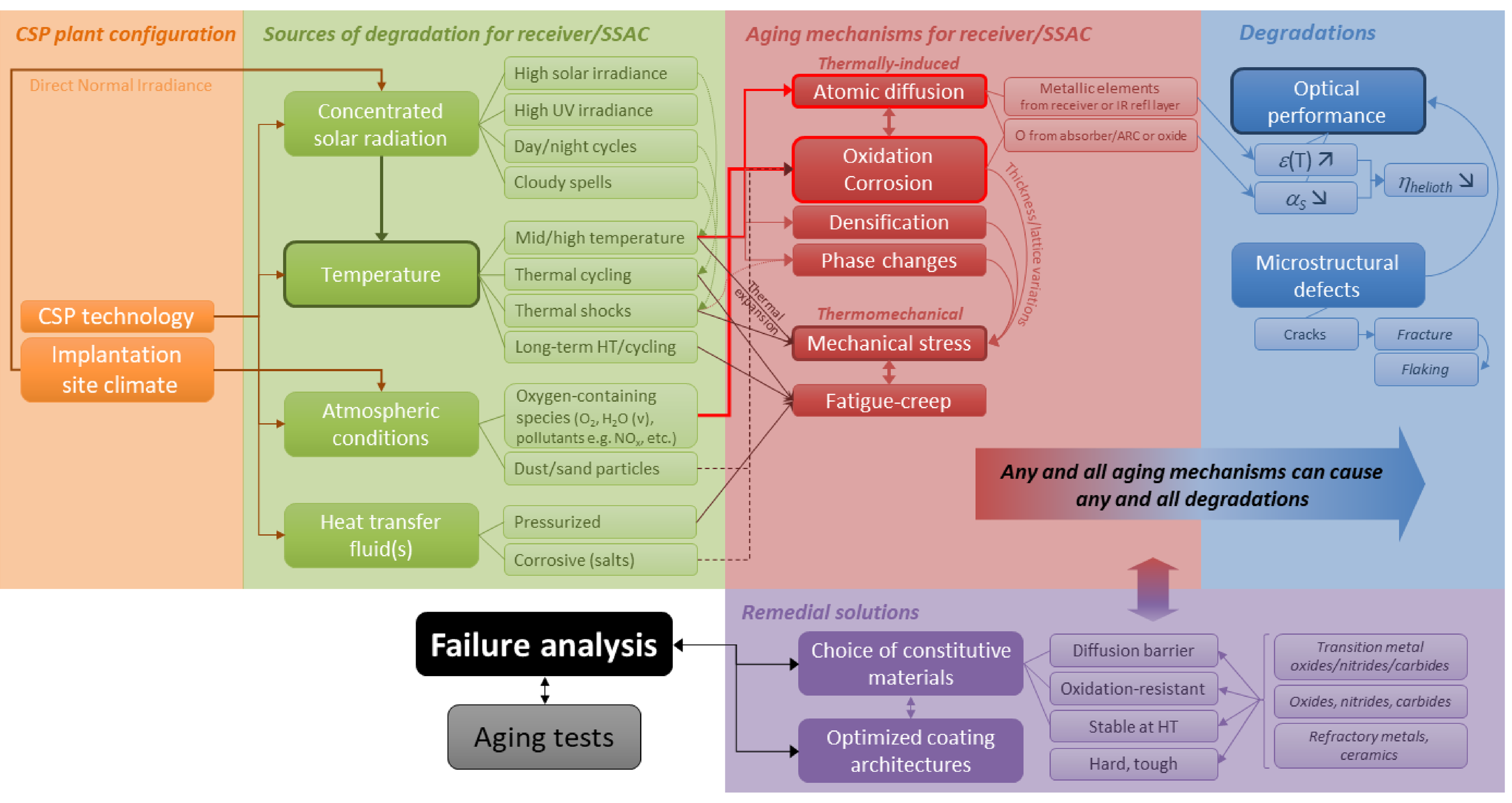
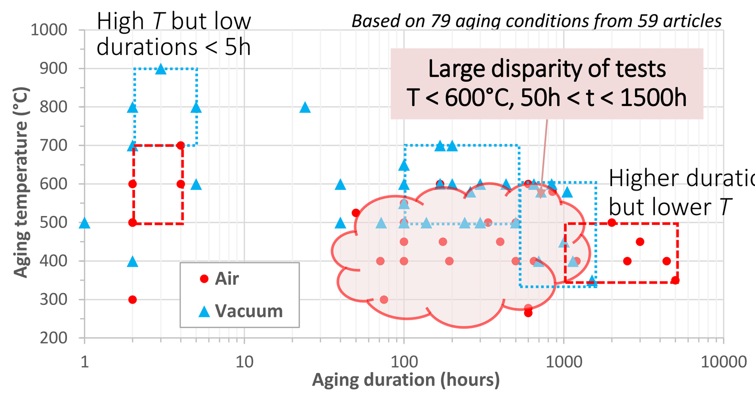
Context – Aging and durability of Solar Selective Absorber Coatings (SSACs)

SSACs provide **high optical performance**: high solar absorptance α_S + low thermal emittance $\varepsilon(T)$ to limit radiative losses = high solar-to-heat conversion efficiency. But they are subjected to demanding **working conditions causing their degradation**:



Classical SSACs aging procedures (extensive literature review) are limited: influence of temperature only (purely thermal aging), conservative conditions, etc.



Vadum-CSP project 2017-2021

(French Occitanie Region/European Funds for Regional Development)

- **Establish a state of the art** on SSACs aging (sources, mechanisms, protocols, facilities)
- Via **experimental studies** on 3 typical HT SSACs (e.g. PVD TiAlN tandem absorber / IREIS), **evaluate** the **pertinence** of classical aging procedures and the **need for new ones**, including more representative **solar** aging
- Towards a **standardization** of SSACs durability assessment?

Main results based on experimental aging tests @ PROMES lab

Purely thermal aging in air (electrical furnace)

SSAC samples

TiAlN tandem absorber: α_S = 0.92, ε(500°C) = 0.35

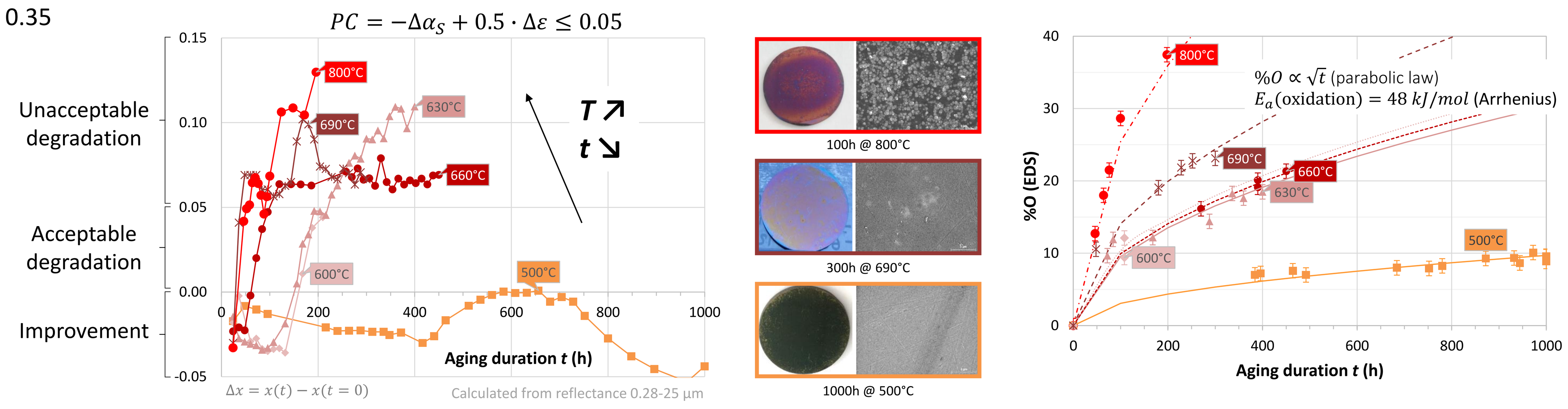
Annealing in static air

@ T_{op} (500°C for linear CSP)

@ T_{acc} >> T_{op} (600-800°C)

Thermconcept ROS 105/900/12 electrical furnace with alumina tube

Evolution of optical properties, surface morphology (macro, SEM) & atomic composition (EDS)

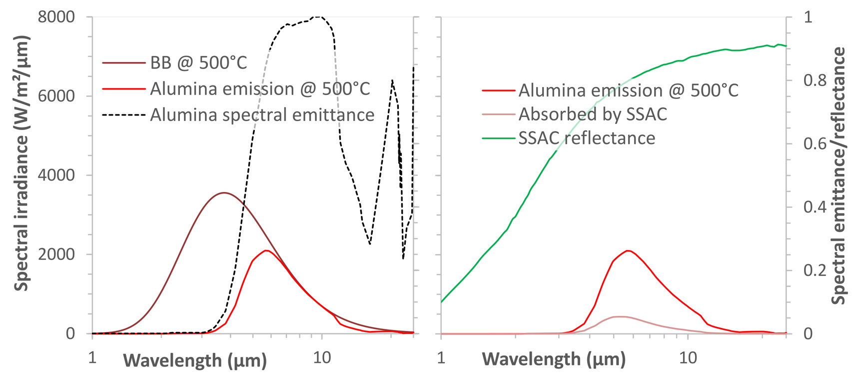


- At T_{op} oxidation beneficial to optical performance: **aging ≠ degradation**
- Acceleration of aging with T ↗ but non-linearity between optical variation and oxidation → **multiple aging phenomena with different kinetics** (e.g. surface morphology) → no lifetime prediction
- **Long duration aging** to observe these phenomena

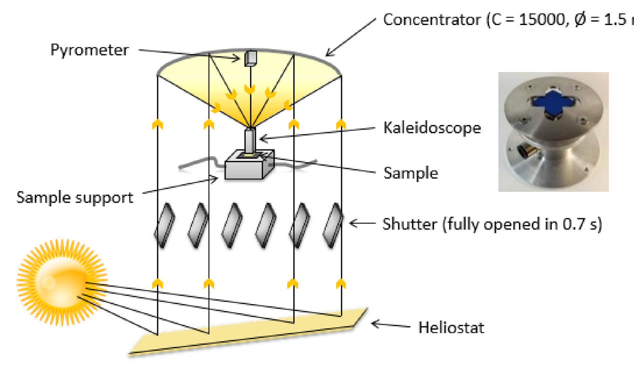
Influence of other CSP parameters?

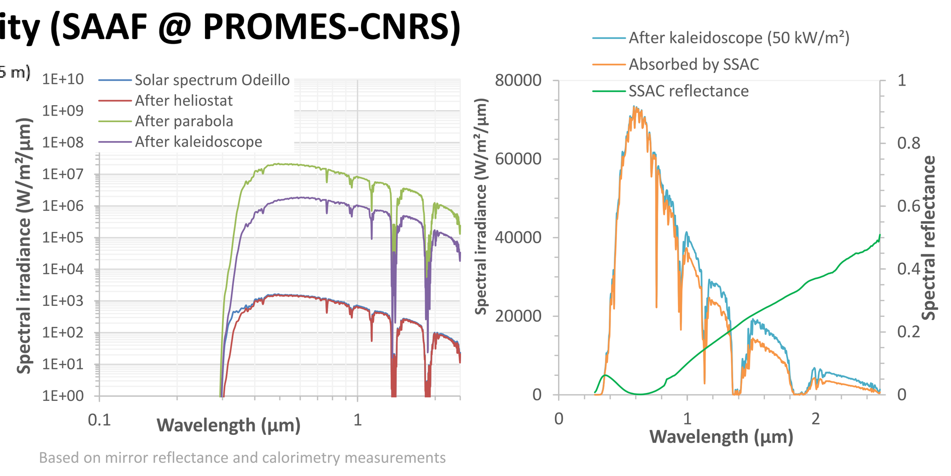
Comparison of purely thermal vs. solar aging conditions

Electrical furnace with alumina tube



Solar Accelerated Aging Facility (SAAF @ PROMES-CNRS)





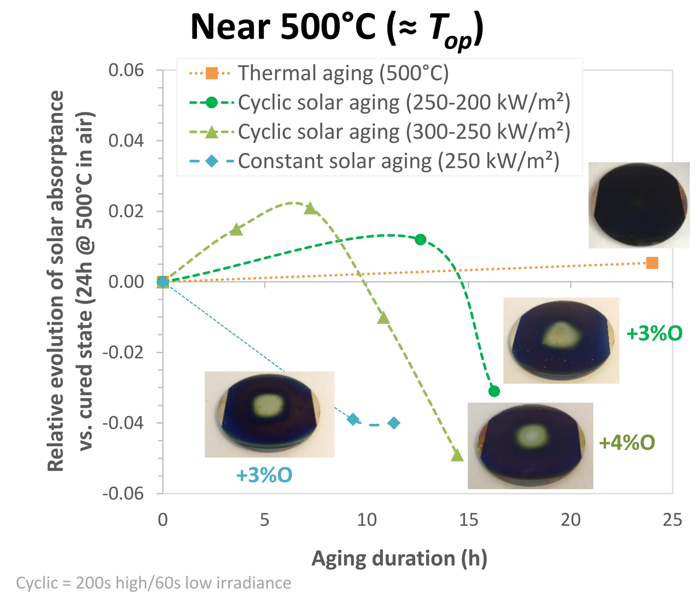
Irradiance levels (kW/m² = kJ/m²/s) / spectral range	Purely thermal aging (electrical furnace) *Received*	Purely thermal aging (electrical furnace) *Absorbed*	Solar aging (SAAF 50 kW/m²) *Received*	Solar aging (SAAF 50 kW/m²) *Absorbed*	Solar/thermal ratio *Absorbed*
UV (0.28 – 0.4 µm)	_	_	0.55	0.52	∞
Solar (0.28 – 2.5 µm)	0.002	0.001	50	45.3	33000
IR (1 – 25 µm)	10.3	1.8	17.3	13.4	7

Same attainable temperatures but energy/photon flux ↗↗ in solar conditions (esp. w/ SSAC selectivity: high α_S, low ε_{IR})

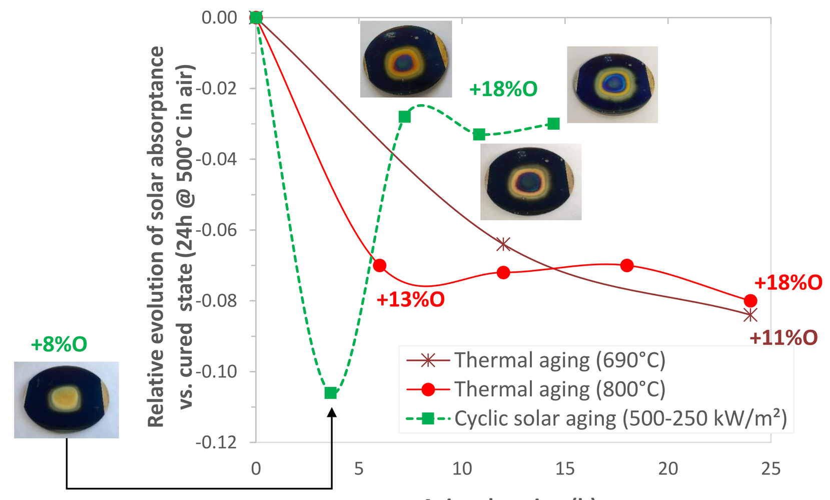
Additional effects of concentrated solar irradiance?

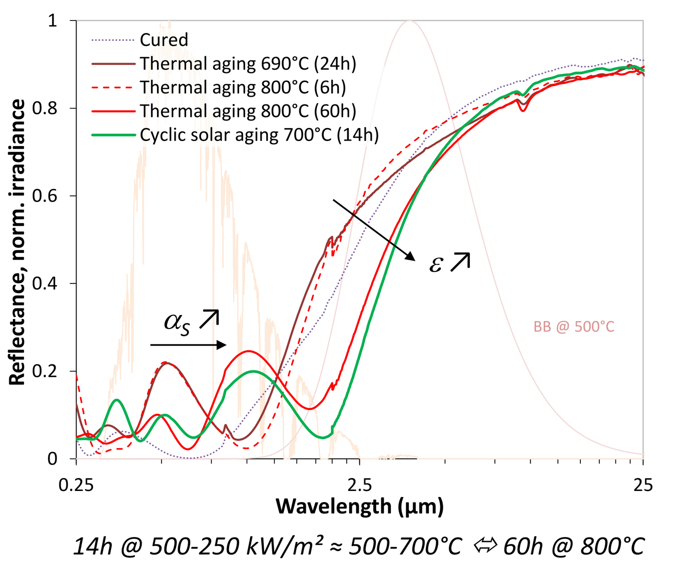
Real concentrated solar aging in air (solar furnace)

Near 500°C (≈ T_{op})



Near 700°C (T_{acc})





14h @ 500-250 kW/m² ≈ 500-700°C ⇔ 60h @ 800°C

Purely thermal aging vs. solar aging at similar T

- Similar thermally-induced phenomena (oxide growth)
- Acceleration of degradation by solar irradiation (stronger/faster)

→ Additional effects due to high photon flux in solar aging

Irradiance (kW/m²) = Energy flux (KJ/m²/s) = Photon flux (photons/m²/s)

→ Including solar aging in aging strategies highly recommended

Constant vs. cyclic solar aging at similar T

Faster/stronger degradation w/ constant solar aging than cyclic solar aging due to higher $I_{eff} = \frac{I_{max} \cdot t_{max} + I_{min} \cdot t_{min}}{t_{min} + t_{max}}$?

Conclusions and future work

- **Aging studies** are necessary to ensure stability and durability of solar (selective) absorber coatings for CST receivers
- **Purely thermal aging** gives relevant information if applied at sufficient temperatures and durations
- **Real concentrated solar aging** shows accelerating effects at similar T, thus is highly recommended for better representativeness of CST
- These findings could be further explored: longer solar aging durations, irradiance at low T, etc.

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