OPTICAL PERFORMANCE OF HIGH TEMPERATURE AIR-STABLE SOLAR ABSORBER COATINGS BASED ON W/SICH PLASMA MULTILAYERS

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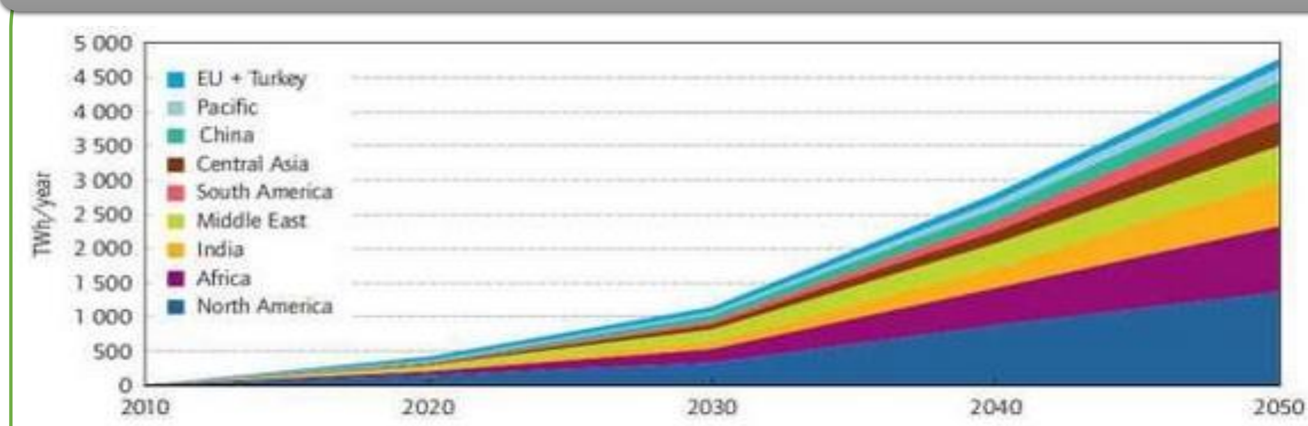
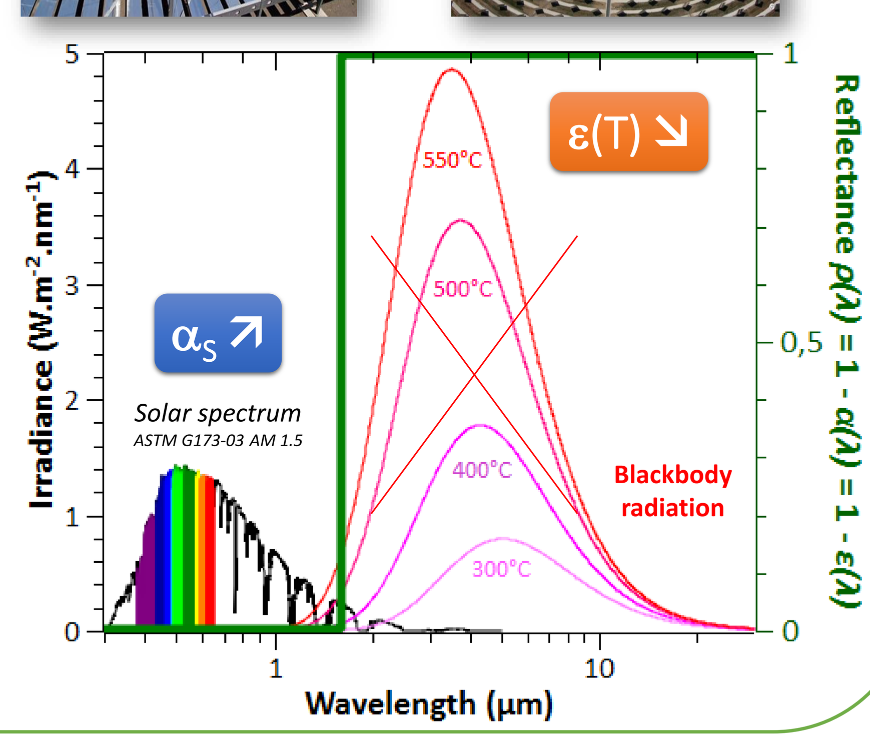
Context : Concentrated Solar Power



CSP 2050 projections in the world

For an ideal solar receiver, spectral reflectance $\rho(\lambda)$
- is low in solar range
- is high in IR range
- increases steeply at λ_{cutoff} ≈ 1.5 – 2 µm (depends on T)



W/SiCH periodic bilayer absorbers

All solar receivers need high optical performance
- High solar absorptance α_S to increase absorbed solar input $\alpha_S CI$
- Low thermal emittance $\varepsilon(T)$ to limit radiative thermal losses $\varepsilon(T)\sigma T^4$

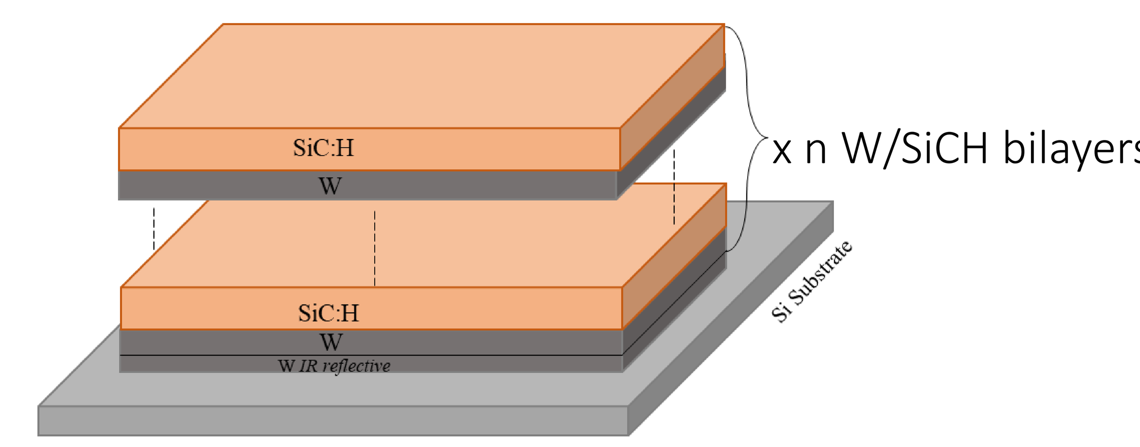
→ High solar-to-heat conversion (heliothermal) efficiency

$$\eta(T) = \alpha_S - \frac{\varepsilon(T) \cdot \sigma(T^4 - T_0{}^4)}{C \cdot I \cdot \eta_{opt}}$$

→ Metallic pipes covered with Solar Selective Absorber Coatings

New generations also need high thermal stability/durability in air

i.e. resistance or adaptation for long durations to:
- high temperatures > 500°C → oxidation, atomic diffusion, etc.
- high thermomechanical stress & thermal shocks → fatigue, creep, etc.
- concentrated solar irradiance



SiC:H : dielectric
- HT stability (T_f = 1400°C)
- variable optical indices

W : metal
- Resistant = HT stability (T_f = 3400°C)
- IR reflective

Deposition technique

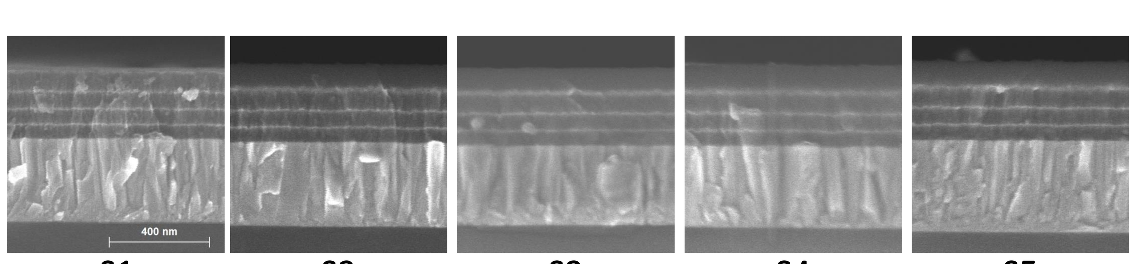
Vacuum plasma reactor
- SiCH: PECVD
- W: PVD (sputtering)

Optical Performance and Thermal stability

- 5 equivalent samples (S1-S5) annealed for up to 96h at 500 °C in air with n = 4 W/SiCH bilayers

- **SEM cross-section images / EDS composition**

→ 4 bilayers remain visible, slight increase in top layer thickness
→ Increase in at.% O content



S1	S2	S3	S4	S5
as-deposited	annealed 12h	annealed 24h	annealed 48h	annealed 96h
1 at.% O	18 at.% O	24 at.% O	16 at.% O	12 at.% O

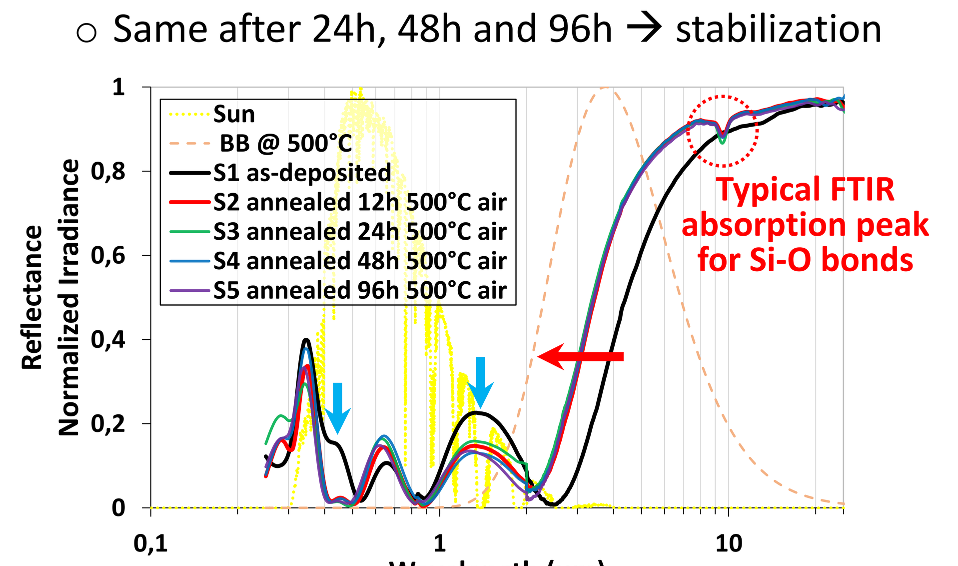
- **Optical performance:** α_S ↗, $\varepsilon(500°C)$ ↘, $\eta_{heliotherm}$ ↗

Samples	α_S	$\varepsilon\ (500°C)$	$\eta_{helioth}$*	$\Delta\alpha_S$	$\Delta\varepsilon$	$\Delta\eta$
S1-S5 as-deposited	0.896 ± 0.001	0.426 ± 0.007	0.521 ± 0.006	–	–	–
S2 annealed 12h	0.920	0.288	0.667	0.023	-0.141	0.148
S3 annealed 24h	0.912	0.280	0.666	0.016	-0.146	0.145
S4 annealed 48h	0.913	0.286	0.661	0.016	-0.152	0.150
S5 annealed 96h	0.920	0.290	0.665	0.024	-0.128	0.137

* Calculated for T = 500°C, T_0 = 25°C, C = 50, I = 900 W/m², η_{opt} = 0.50

- Annealing 12h @ 500°C in air: optical performance + stability ↗ = curing step
- Oxidation of SiCH top layer + formation of protective/antireflective SiO_x ?

- **Spectral reflectance**
  - Evolution after 12h:
    - %R ↘ in solar range, λ_{cutoff} ↘
    - absorption peak @ 9.5 µm (1050 cm^{-1}) → Si-O ?
  - Same after 24h, 48h and 96h → stabilization



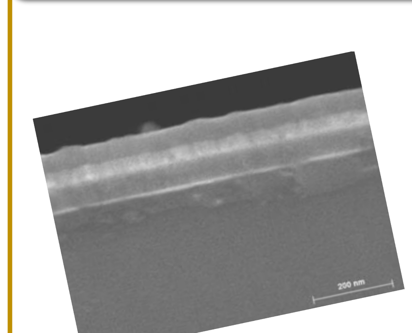
- **Solar aging (SAAF PROMES)** A. Boubault et al. Solar Energy 86 (2012) 3153

Similar trends were observed on sample exposed in solar furnace to concentrated solar irradiance [150 kW/m², 400°C, 1.5h]

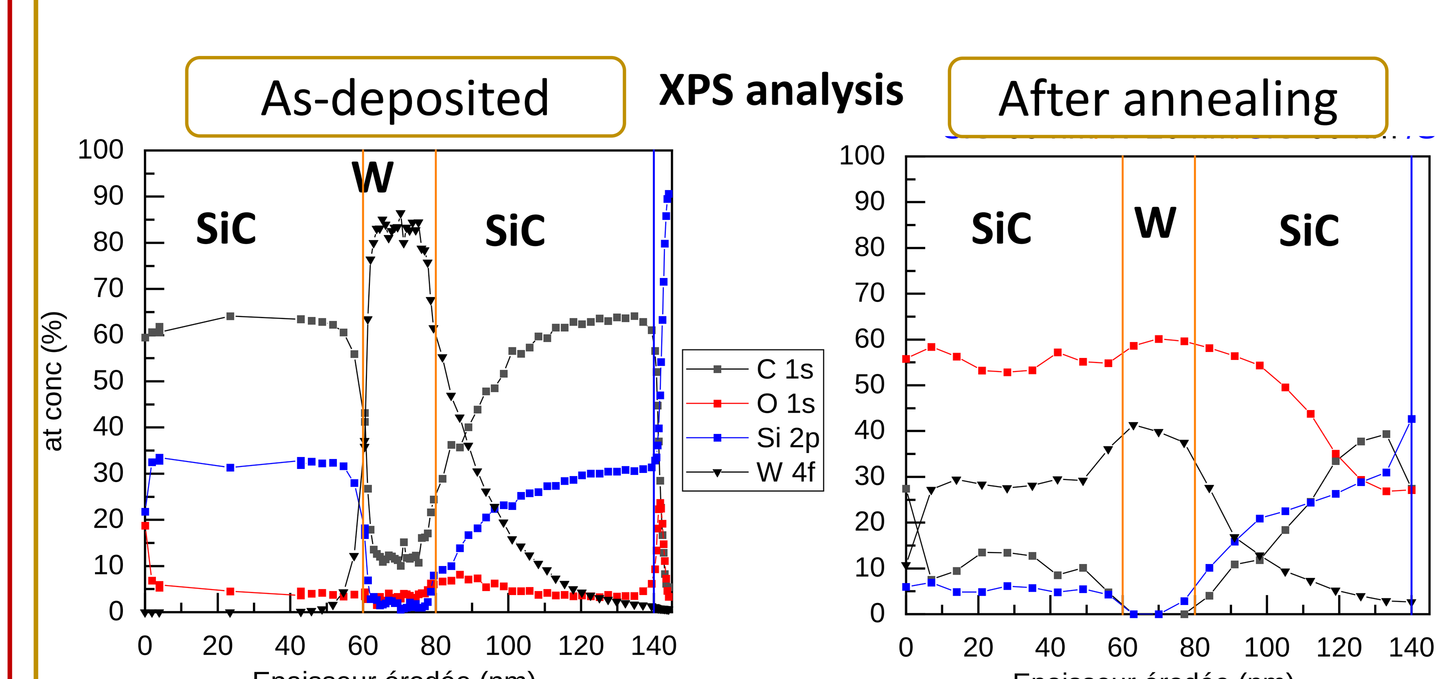
→ Evolutions due to thermally-induced aging phenomena only

- Optical perf. not affected by oxidation of all layers
- W interlayer diffusion → W-SiCH nanocomposites ?

Diffusion phenomenon



- SiCH-W-SiCH 3-layer on Si as-deposited vs. annealed 96h 500°C air



RBS

Layers	Top layer		Bottom layer	
	As-deposited	After annealing	As-deposited	After annealing
% O	3,92	18,94	5,06	42,25

- **W broad profile → W diffusion**
- **C replaced by O → oxidation**

Conclusions and further work

- Plasma deposited (W, SiCH) solar selective absorber coatings with good optical performance and thermal stability in air at 500°C were developed for CSP technologies.
- Annealing of periodic bilayers promotes oxidation and interlayer diffusion, thus improving and stabilizing solar performance.
- Further characterizations and aging tests are underway to investigate the evolution of the material microstructure and its oxidation/diffusion kinetics.

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