RAISELIFE

Raising the Lifetime of Functional Materials for Concentrated Solar Power

Project Overview after 18 months

19th of September 2017

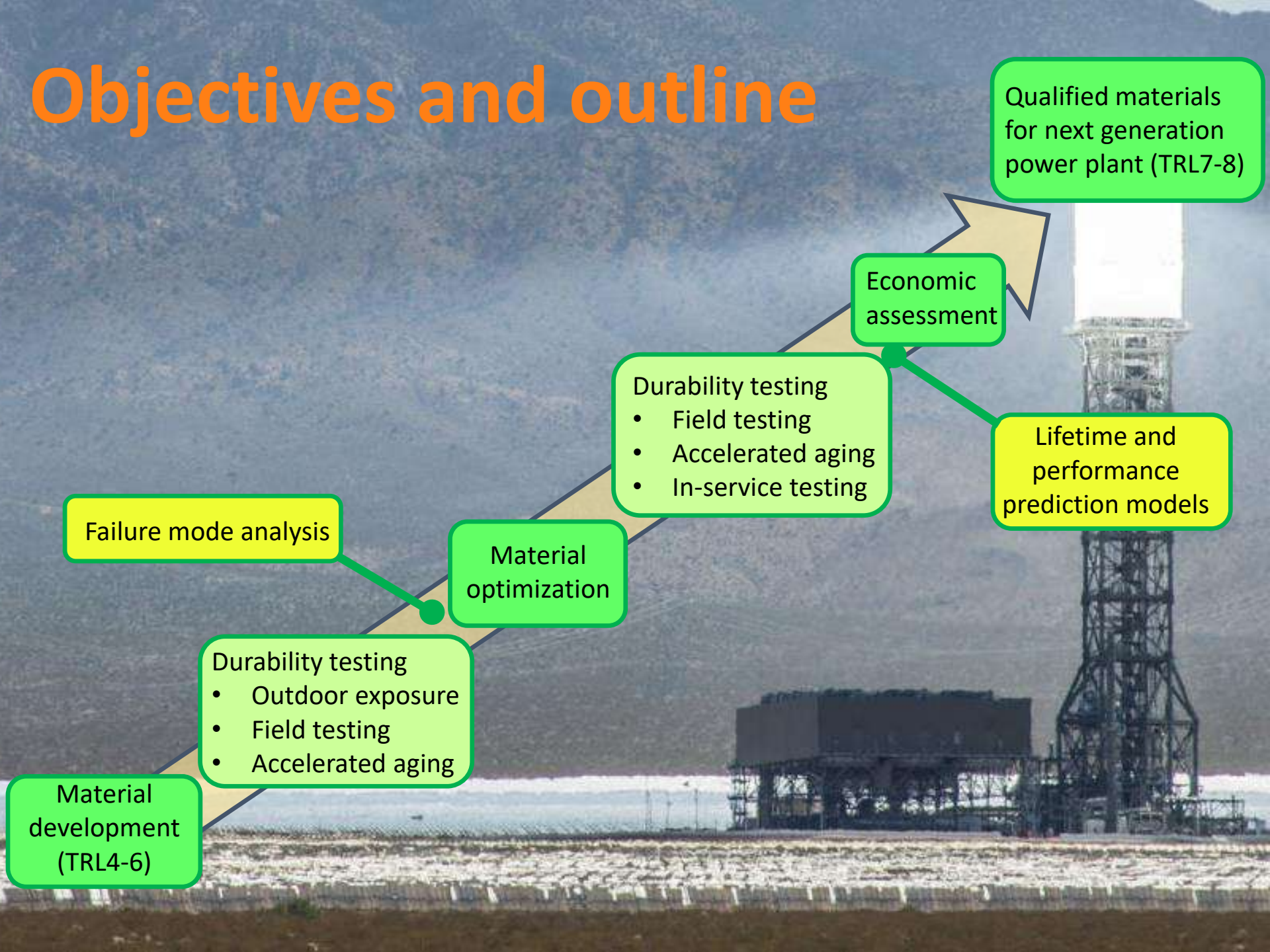
Florian Sutter (DLR)

Project facts

Funded by: EU H2020 program,
Call: NMP-16-2016 Nanotechnologies, Advanced Materials and Production

Duration:	48 months	Budget:
Start date:	01/04/2016	Total cost: 10.5 M€
End date:	31/03/2020	EU contribution: 9.3 M€

Objectives and outline



RAISELIFE materials

Solar field reflectors

- 8 protective back coatings
- 2 anti-soiling coatings
- 1 ultra-thin (200µm) silvered-glass mirrors with composite backing structure
- 4 thin glasses (1mm) with composite backing structure

Solar tower receiver

- 4 absorber coatings (for 650ºC and 750ºC)
- 4 substrate materials
- 2 secondary silver reflectors stable up to 400ºC
- 5 molten salt coatings to protect inner tube walls from corrosion

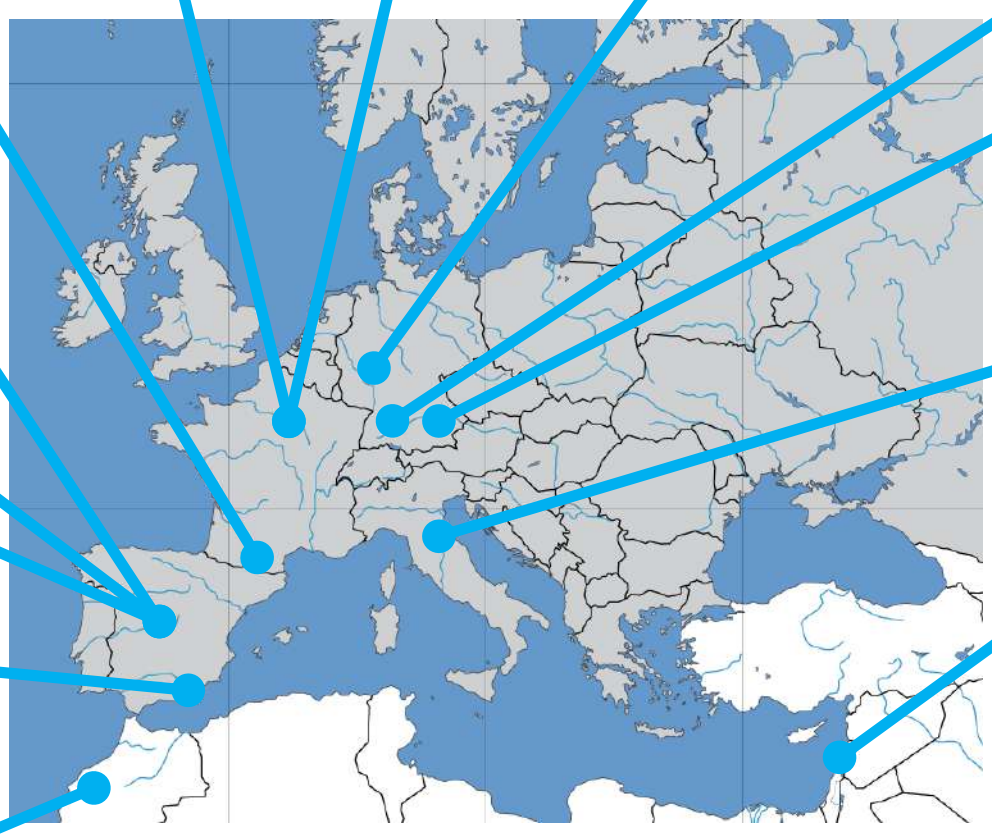
Line focusing receiver

- 2 selective absorber coatings (up to 400ºC)
- 1 abrasion resistant anti-reflective coating

Durability testing, coating optimization, economic assessment

RAISELIFE **Materials with increased lifetime and optical properties for CSP**

RAISELIFE consortium



cnrs
CORNING
vallourec
DECHEMA
Fraunhofer
Ciemat
FLABEG
INTA
soltigua
UNIVERSIDAD COMPLUTENSE MADRID
BrightSource
DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center
MASciR Moroccan Foundation for Advanced Science, Innovation and Research

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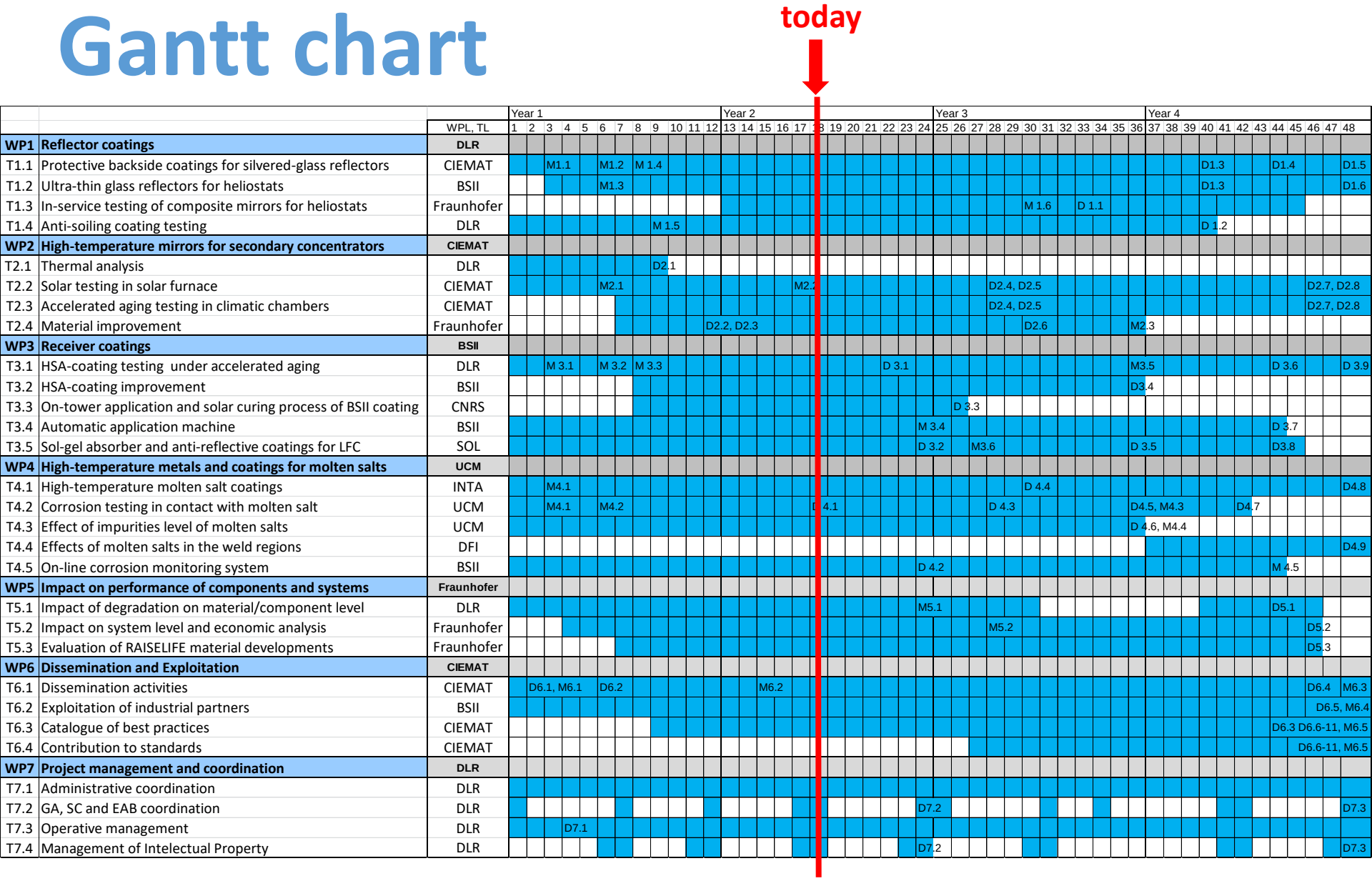
Gantt chart



		WPL, TL
WP1	**Reflector coatings**	**DLR**
T1.1	Protective backside coatings for silvered-glass reflectors	CIEMAT
T1.2	Ultra-thin glass reflectors for heliostats	BSII
T1.3	In-service testing of composite mirrors for heliostats	Fraunhofer
T1.4	Anti-soiling coating testing	DLR
WP2	**High-temperature mirrors for secondary concentrators**	**CIEMAT**
T2.1	Thermal analysis	DLR
T2.2	Solar testing in solar furnace	CIEMAT
T2.3	Accelerated aging testing in climatic chambers	CIEMAT
T2.4	Material improvement	Fraunhofer
WP3	**Receiver coatings**	**BSII**
T3.1	HSA-coating testing under accelerated aging	DLR
T3.2	HSA-coating improvement	BSII
T3.3	On-tower application and solar curing process of BSII coating	CNRS
T3.4	Automatic application machine	BSII
T3.5	Sol-gel absorber and anti-reflective coatings for LFC	SOL
WP4	**High-temperature metals and coatings for molten salts**	**UCM**
T4.1	High-temperature molten salt coatings	INTA
T4.2	Corrosion testing in contact with molten salt	UCM
T4.3	Effect of impurities level of molten salts	UCM
T4.4	Effects of molten salts in the weld regions	DFI
T4.5	On-line corrosion monitoring system	BSII
WP5	**Impact on performance of components and systems**	**Fraunhofer**
T5.1	Impact of degradation on material/component level	DLR
T5.2	Impact on system level and economic analysis	Fraunhofer
T5.3	Evaluation of RAISELIFE material developments	Fraunhofer
WP6	**Dissemination and Exploitation**	**CIEMAT**
T6.1	Dissemination activities	CIEMAT
T6.2	Exploitation of industrial partners	BSII
T6.3	Catalogue of best practices	CIEMAT
T6.4	Contribution to standards	CIEMAT
WP7	**Project management and coordination**	**DLR**
T7.1	Administrative coordination	DLR
T7.2	GA, SC and EAB coordination	DLR
T7.3	Operative management	DLR
T7.4	Management of Intelectual Property	DLR

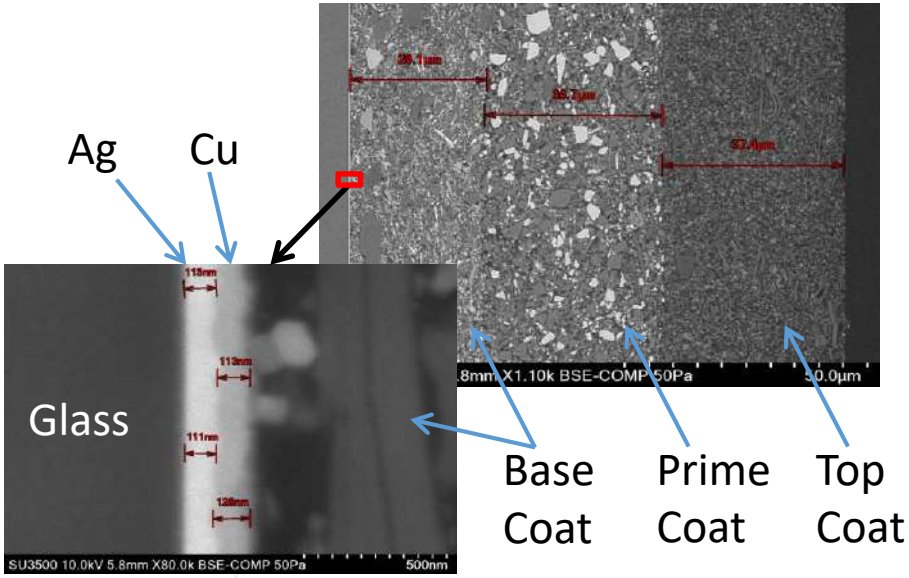
Main progress beyond the sate of the art achieved in RP 1

1) Primary mirror

1.5 percentage points higher reflectance achieved with ultra-thin glass mirrors compared to state of the art 4mm silvered-glass mirror technology

State of the art

- 4 mm glass / Ag / Cu / Base / Prime / Top coat
- ρ = 94.5 %
- 10 kg/m²
- ~15 €/m²



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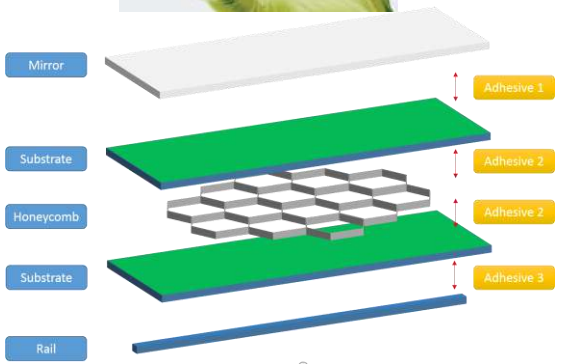
- 200µm glass + standard mirror coating
- ρ = 96.0 %
- 1.7 kg/m²
- Price to be determined

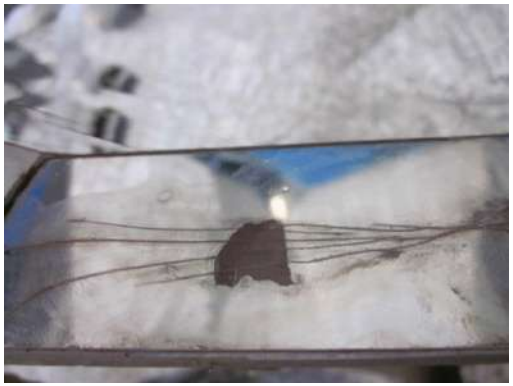


2) Secondary Reflector

Secondary reflectors with reflectance of 92% are stable in damp-heat test for 2 months and 16 days at 400°C in the oven.

State of the art

- Silvered-glass mirrors with water cooling
- Operating temperature: 85°C
- ρ = 94.5%
- High temperature mirror prototypes: stability of 1 month at 350°C in the oven



Edge corrosion and glass breakage of water cooled secondary reflector after 14 months in operation at PSA

RAISELIFE materials

- PECVP / HIPIMS coated silver mirrors without cooling
- Operating temperature: 400°C
- ρ = 92 %
- PECVD mirrors stable in damp-heat test for 2 months and 16 days at 400°C in the oven.

Mirrors with and without PECVD coating after 2 weeks in damp heat test

3) Increased absorber coating properties (ST)

Improvement of optical coating efficiency and coating lifetime for solar tower absorbers operating up to 650°C

State of the art

- Pyromark 2500 silicone based high temperature paint
- α=96%, ε=87% (650°C), η_{sel}=0.82 (250kW/m²)
- $\Delta\alpha$=2 pp/a in operation in Solar One with peak fluxes of 300kW/m²
- $\Delta\alpha$=3 pp after furnace aging at 750°C for 300h on Inc625

Pyromark used in Solar One and Two in 1981

RAISELIFE materials

- **Inorganic paint coating** (w/o aluminide slurry): α=96%, ε=70% , η_{sel}=0.84 (250kW/m²) stable for 1000h at 750°C on Inc-617, 2000h at 650°C on VM12 and T91, 2000h at 570°C on T22, 100 dish cycles on VM12 (peak flux 350kW/m²), 20 short term solar cycles with flux of 700kW/m². Stability in environmental NSS, Condensation, Humidity Freeze and Damp Heat test proven.

- **Selective coating**: α=95%; ε=22%, η_{sel}=0.91 stable for 2000 h at 600°C on T91, 100 dish cycles on VM12 (peak flux 250kW/m²). Stable in environmental tests except failure after 480h in NSS test.

Ho: Characterization of Pyromark 2500 Paint for High-Temperature Solar Receivers, 2014

4) Increased absorber coating properties (LFC)

Improvement of abrasion resistance of anti-reflective coatings and selective absorber coating efficiency for Line Focusing Collectors operating up to 400°C

State of the art

- In air:
  α=92%, ε=13% (250°C)
  Stable up to 400°C
- In vacuum:
  α=96%, ε=7.3% (400°C)
  Stable up to 600°C
  τ = 0.97

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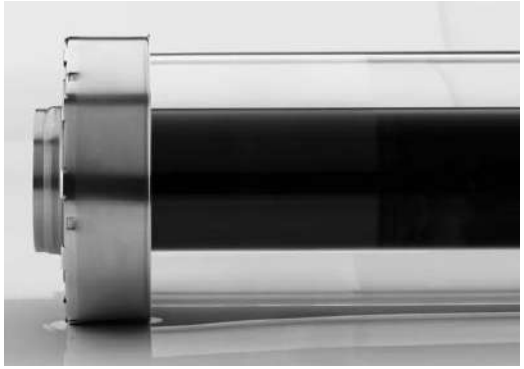
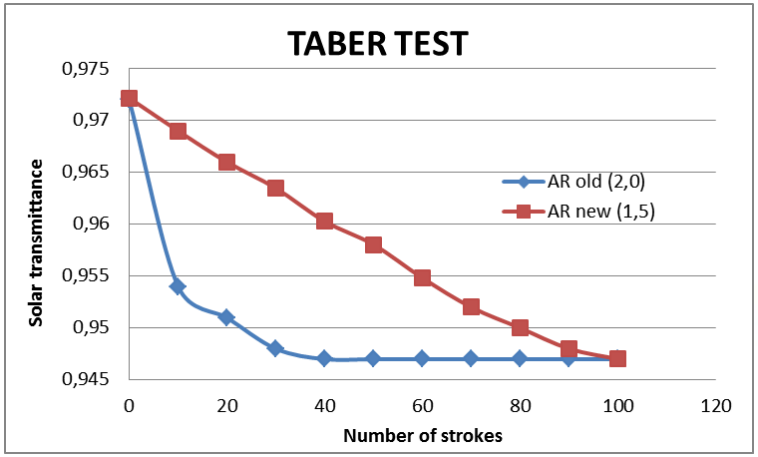
- In air
  α=0.955; ε=0.05 (250°C) coated flat aluminum
  α=0.955; ε=0.09 (250°C) chromium plated steel
  Stable up to 400°C
- In vacuum
  τ = 0.972 with increased abrasion resistance by factor 2.5 compared to the commercial coatings



Schott Receiver tube

[Archimede, Schott product sheet data]



5) Improved corrosion resistance in molten salt

Improvement of corrosion resistance of steels in solar salt (60wt.% $NaNO_3$+ 40wt.% KNO_3)by ferritic steel and using coatings.

State of the art

- Use of nickel base alloys (Haynes230/Inc-617) for high temperature parts of molten salt receiver (530-600°C)
- Use of T91 for low temperature sections of receiver (<530°C)

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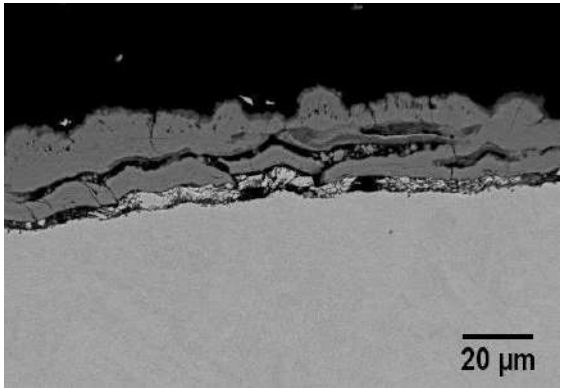
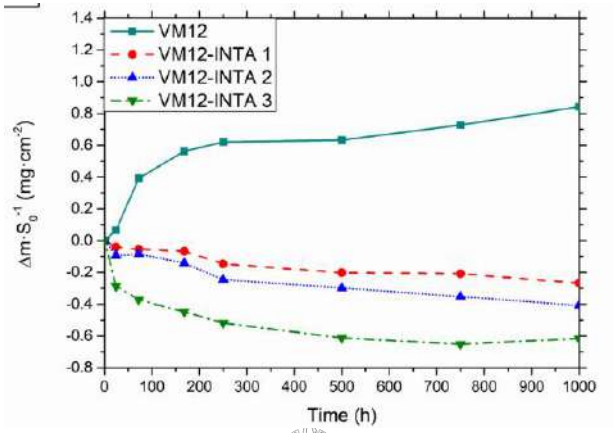
- Ferritic steel **VM12** from Vallourec tends to show improved corrosion resistance than T91: mass loss is 10µm for VM12 compared to 22µm of T91 after 1000h in contact with solar salt at 580°C.
- Diffusion **coatings for corrosion protection** of T91 and VM12 were developed. No significant mass loss was detected on coated samples in contact with solar salt at 560 and 580°C for 1000h.



VM12 after 1000h at 580°C in solar salt



6) Material lifetime assessment and economic benefit

Testing protocols for lifetime assessment and simulations to determine the economic benefit in terms of LCOE of the new materials are developed.

State of the art

- *Reflectors:*
  AEN/CTN 206/SC117: Reflector Panels for Concentrating Solar Technologies
- *Secondary reflectors:*
  no testing standard available
- *Absorbers (ST):*
  ISO 13573 Corrosion of metals and alloys (no solar/environmental testing)
- *Absorbers (LFC):*
  AEN/CTN 206/SC117: General requirements and test methods for solar receivers (only for evacuated receivers)
- *Molten salt corrosion:*
  ISO 17245 Immersion testing in molten salt under static conditions

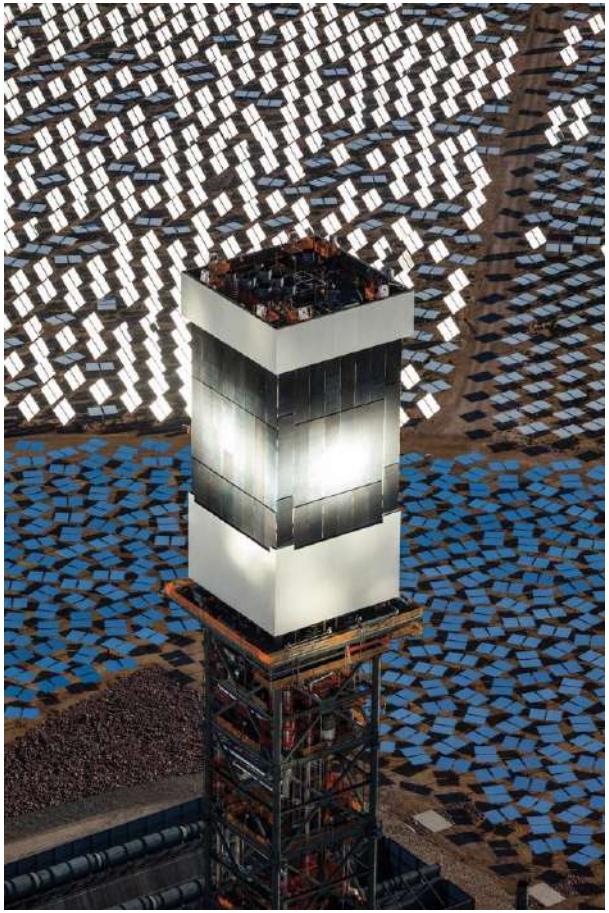
RAISELIFE methods

- *Reflectors:*
  Improvement of standard by introducing combined accelerated stress testing with the aim to reproduce outdoor degradation
- *Secondary reflectors:*
  develop environmental and solar test program
- *Absorbers (ST):*
  Solar field testing program developed + environmental test program for reflectors
- *Absorbers (LFC):*
  Solar field testing + environmental tests for non-evacuated receivers
- *Molten salt corrosion:*
  cyclic corrosion tests

Thank you for your attention!

Florian.Sutter@dlr.de

Tel.: +34 950 277684



The research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 686008, project RAISELIFE.