# Secondary reflectors tested at high temperatures and high radiation intensities

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## 1. Introduction

Concentrated solar power (CSP) systems generate solar power by using mirrors or lenses (primary concentrators or reflectors) to concentrate a large area of sunlight, or solar thermal energy, onto a smaller area (the receiver). A secondary concentrator reflects the sunlight coming from the primary concentrators onto the absorbing receiver. They ensure the gathering and redirecting, and in some applications further concentration and focusing, of the solar beams towards the absorber. A good overview of the available different secondary reflector material systems and different CSP configurations is given in [1].

A secondary reflector which is installed adjacent to the solar tower or linear Fresnel collector receiver can improve the optical efficiency of the system considerably as well as reducing its cost by [2]:

- Reducing the amount of flux which is spilled-off the target
- Improving the flux distribution uniformity
- Decreasing heat losses and CAPEX (capital expenditure) by reducing the receiver size

The main challenge for such a mirror is its high operation temperature. For the solar power tower, the high temperatures evolve mainly due to the amount of irradiance that is being absorbed by the mirror, and to a lesser extent due to convective heat exchange with its surrounding. One possible approach is to water-cool the mirror. However, this solution will mean an investment increase, technical challenges, and cause a plant shut-down in case of any failure of the cooling system.

A different approach avoiding water-cooling was to develop a protected silver coated secondary mirror which could retain its optical and mechanical properties up to 350 °C. The developed mirrors are based on a sputtered silver layer and several adhesion and barrier layers on a highly polished steel substrate. This is in contrast to products that have been previously on the market which are aluminum or glass based.

## 2. Experimental

The protected silver layer systems were sputter deposited using the Fraunhofer ISE horizontal pilot line on polished 1 mm 1.4301 steel substrates. As a benchmark for the reflector durability the reflectors were exposed to a dry oven at 400 ˚C and 450 ˚C. The aim was to maximize the reflectance of the film system whilst maintaining stability at these set temperatures. This is a critical issue as the protective layers above the reflective silver layers will reduce the reflectance of the film system, although are essential for temperature durability.

The operation of the reflectors is anticipated to not exceed 350 ˚C with an active air-cooling rather than a water-cooled system. The reflectors were tested at higher temperatures to achieve an accelerated exposure.

Reflectance measurements were done with a Vertex 80 spectrometer (Bruker, Ettlingen, Germany) with an integrated sphere. The solar hemispherical reflectance is the percentage of the direct and diffuse AM1.5 solar radiance reflected from the coating system. The reflectance was monitored as a function of time and temperature in oven.

The optimized coating system was then coated onto a prototype reflector designed at DLR. The structured channel will be air-cooled by a fan. This system is to be tested at the Synlight facility at DLR Jülich. Synlight is the world's largest research facility for the generation of artificial sunlight. Here the prototype will be exposed to radiation intensities of up to 350 kW/m$^2$. This represents the absolute maximum radiation intensity that a secondary reflector would see under specific focusing strategies on a solar power tower configuration. A schematic of the DLR designed test set-up is shown in figure 1.

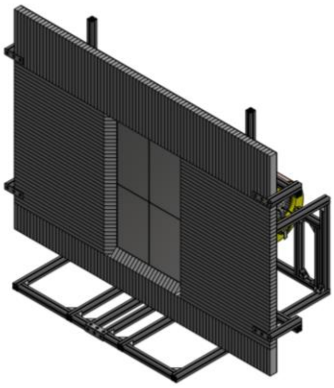

Fig. 1: Schematic of the secondary reflector prototype test-stand for Synlight.

## 3. Results

The laboratory results of the reflectance measured after exposure to the dry oven have already been measured. A protective ceramic top layer was chosen with a graded refractive index to maximize the reflectance of the film system and the high temperature durability. Figure 2 shows the solar hemispherical reflectance as a function of time in oven. After the first 24 h anneal at 400 ˚C (second point in the graph) the reflectance of the system increases to just below 93. 5 %. This increases slightly on exposure to higher temperatures. Grain growth and oxidation of the ceramic layers are responsible for the increase in reflectance with temperature. These layers are stable for up to the measured 3000 h at 450 ˚C.

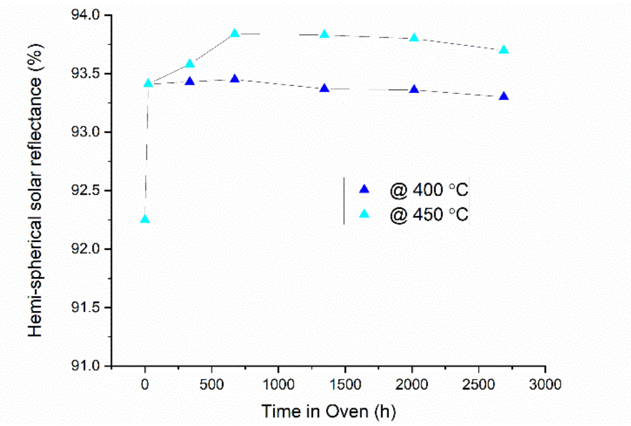


Fig. 2: Reflectance against exposure in oven for an optimized protected silver coating on steel.

The secondary reflector prototype is under construction and is due to be tested in the Synlight test facility in July 2021. The results from this will be presented at the conference.

## References


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[2] P. Schöttl, T. Zoschke, C. Frantz, Y. Gilon, A. Heimsath, T. Fluri, In Performance Assessment of a Secondary Concentrator for Solar Tower External Receivers. In Proceedings of the 24th Solar Paces Conference, Casablanca, Morocco, 2–5 October 2018.