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Flat plate collectors with thermochromic absorber coatings to reduce loads during stagnation

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Abstract

Thermochromic absorber coatings, which switch their emissivity for thermal radiation depending on temperature, are developed to reduce the stagnation temperature of solar thermal collectors: In the operating range of the collector, the surface exhibits a low emissivity ($\varepsilon = 10\%$). At higher temperatures, the emissivity is increased by a multiple ($\varepsilon = 35\%$). Thus, the collector heat losses raise and the stagnation temperature is reduced. Efficiency measurements on a prototype collector employing this thermochromic absorber show, that below the switching temperature the efficiency is nearly identical to that of a conventional collector with a highly selective absorber plate. Due to the increased emissivity in the switched state of the coating, the stagnation temperature is lowered by more than 30 K. System simulations exhibit, that the performance of the system is not significantly affected: in a combined system for space heating and domestic hot water preparation the conventional energy demand of the gas boiler is increased by 1.5% to 4.5% using the thermochromic collector instead of a standard collector. In contrast, the duration when formation of vapour in the collector circuit occurs, is reduced by 70% to 75%. By further optimizing thermochromic collectors, the formation of vapour in the solar circuit could be completely prevented during stagnation. This would allow the use of lower cost materials in the solar circuit and reduce the cost of installation and maintenance of the solar circuit significantly.

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Keywords: thermochromic absorber coating; flat plate collector; stagnation temperature; system simulation; overheating protection

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1. Intoduction

Thermochromic absorber coatings have the particular feature, that their emissivity for thermal radiation is highly dependent on temperature: In the operating range of the collector below a predetermined switching temperature, the surface exhibits a low emissivity, comparable to that of commercially available highly selective absorbers ($\varepsilon \approx 6\%$). Above this switching temperature the emissivity increases by a multiple. Thus, the radiation heat transfer between absorber and glass cover increases significantly, the collector heat losses as well and the stagnation temperature is reduced.

The application of thermochromic absorber coatings enables a significant reduction of the temperature loads during stagnation on the collector and the solar circuit. Less temperature resistant materials can be employed to reduce costs of the collector and the entire solar thermal system. In addition, the avoidance of vapour formation in the solar circuit improves the operational safety of the system.

2. Development of thermochromic absorber coatings

In cooperation with partners from industry and research, suitable absorber coatings have been developed in several stages, extensively characterized and subjected to stress tests. A flat plate collector prototype was manufactured with absorber sheets that achieved the optical properties of conventional absorber coatings in the operating range ($\alpha \approx 92\%$, $\varepsilon \approx 10\%$). Above the switching temperature, the emissivity increases to $\varepsilon \approx 35\%$. The coating-process was transferred from laboratory to an industrial scale successfully. The industrially produced large area coatings using the production site of Viessmann reach a high homogeneity regarding their optical properties. The optical properties shown in Figure 1 are measured data from an absorber plate, that was produced in typical collector size (approx. 2 x 1 m²).

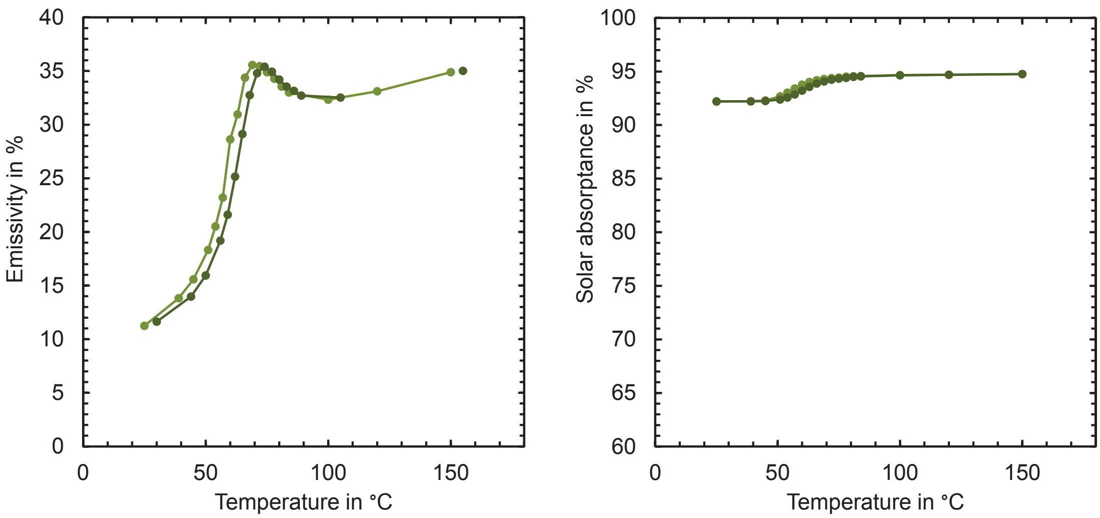

Fig. 1 Emissivity (left diagram) and solar absorptance depending on the surface-temperature for an industrially produced thermochromic coating in collector size (determined on the basis of spectral reflectance data measured at ISFH using Equinox 55 FTIR-spectrometer from Bruker equipped with a heating stage)

The switching-process of the thermochromic coating affects the emissivity within a temperature range from 55°C to 75°C. As both diagrams of Figure 1 indicate, there is a hysteresis in the thermochromic transition. The curve measured with increasing temperature is shifted by approximately +4 K against the one measured with decreasing temperature. The solar absorptance is affected by the thermochromic effect as well, but to a relatively small extent: It is increased from 92% to 94.5%, theoretically leading to higher temperature loads. However, this effect is