1

RADIATION-SELECTIVE ABSORBER COATING FOR HIGH TEMPERATURE APPLICATIONS

THE TASK

The sun is the largest renewable energy source. However, an efficient conversion of solar energy into heat demands that specific optical parameters have to be fulfilled by the solar absorber surface. For high optical efficiency, absorption in the solar spectrum (280 nm - 2500 nm) has to be maximal, while thermal emission has to be low (Fig. 2).

Spectral distribution and emission performance of a surface depend on its temperature and the absorption characteristics. For low thermal emission, according to Kirchhoff's Law, absorption has to be low at the same wavelength. The change in the absorption characteristics, as is needed for solar applications, is achieved by so-called radiation-selective absorbers, which can only be produced in vacuum processes for high temperature applications (> 400 °C).

OUR SOLUTION

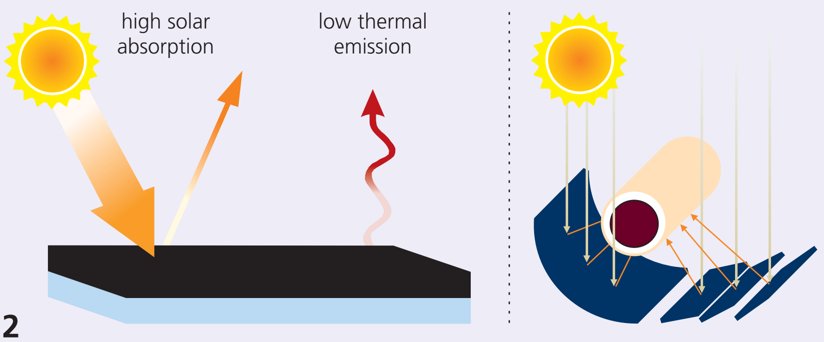
At Fraunhofer IWS Dresden, an approach based on the employment of innovative materials and low-cost processing techniques was developed. A solar absorber more effective than the current state-of-the-art was built and a patent for it was filed.

The basic structure of the newly developed film system is as follows: it consists of a highly reflecting metal film in the infrared wavelength range and a highly absorbing CNT thin film in the solar spectrum. For better adhesion of the films and improved abrasive resistance of the system, the CNT thin film is mechanically reinforced by means of an optically transparent silicon oxide film (Fig. 3).

Carbon nanotubes (CNT) have, due to their one-dimensional structure, specific optical properties, which can be intentionally used for the fabrication of radiation-selective film systems. For this purpose, it is possible to customize the optical properties of these innovative CNT-based solar absorbers for the corresponding technical range of application or the required temperature. Thanks to their excellent thermal resistance, the CNTs are also suitable for use in high temperature applications.

The coating techniques, which are required to fabricate such a solar absorber, are inexpensive, easily scalable, and may be flexibly retrofitted to suit numerous substrate materials and geometries (Fig. 3).

Principal sketch of a radiation-selective surface, as well as concentration of solar radiation with line concentrators (parabolic through collector technology and Fresnel collector)



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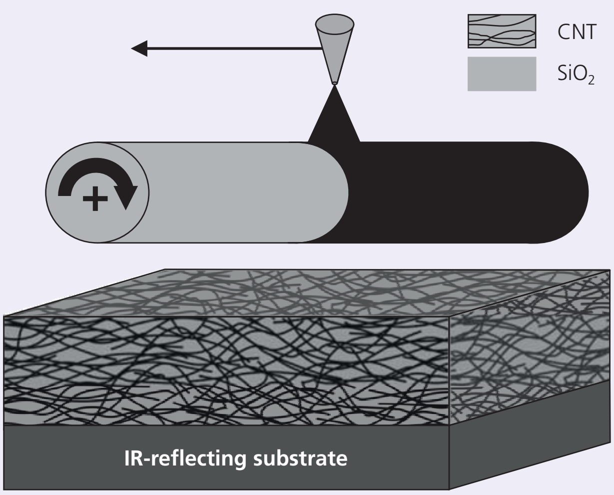
RESULTS

The absorption mechanisms occurring in CNTs are based on interactions of the electromagnetic radiation with the π plasmon and interband transitions, the so-called van Hove singularities (vHS). Radiation selectivity of the CNT film can be intentionally adjusted by the wide background absorption of the π plasmon (peak maximum in the UV range) and the specific absorption bands of the vHS, by variation of the CNT diameter and the CNT film thickness (Fig. 4).

Based on analyses of various CNT materials, several radiation-selective film systems were built and analyzed. The best results are shown in Figure 5 in comparison with commercially available products.

Thermogravimetric measurements carried out on single-walled carbon nanotubes (SWCNT) films in an oxygen-containing atmosphere demonstrated a temperature resistance of 584 °C, and in an inert nitrogen atmosphere as much as 850 °C.

Simple atomization technology to apply the radiation-selective CNT absorber films and dip-coating of the SiO_2 protective film



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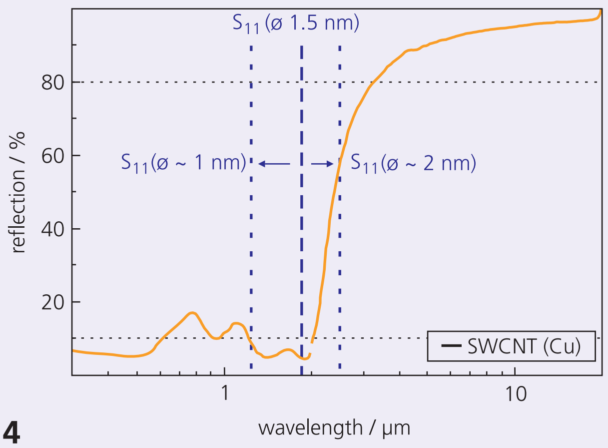
Influence of various CNT diameters on the S_{11}-vHS absorption bands in the reflecting spectrum



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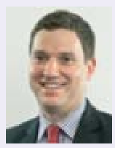
Optical properties of CNT-based radiation-selective film systems in comparison with state-of-the-art

	solar absorption	thermal emission	
	α_{dir}	$\varepsilon_{100\,°C}$	$\varepsilon_{400\,°C}$
MWCNT on Cu	0.92	0.09	0.22
SWCNT on Cu	0.90	0.05	0.11
black chromium	0.96	0.19	-
Cermet	0.94	0.08	0.13

5

1 *Receiver tube with CNT-based absorber tube*

CONTACT



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