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Project
Colored Solar Collectors
Capteurs solaires en couleur

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SUMMARY

The architectural integration of thermal solar collectors into buildings is often limited by their black color, and the visibility of tubes and corrugations of the absorber sheets. A certain freedom in color choice would be desirable, but the colored appearance should not cause excessive energy losses. In order to express the performance of a colored solar collector, we define a figure of merit M as the ratio of the relative luminosity A and the solar energy losses by reflection R_{sol} . It can be shown that the principal upper limit for this figure M amounts approximately to the value six, which allows strikingly low energy costs per perceived brightness. Multilayered thin film interference filters on the cover glass can produce a colored reflection, hiding the corrugated metal sheet, while transmitting the non-reflected radiation entirely to the absorber. These interference filters are designed and optimized by numerical simulation, yielding the relative luminosity A, the solar transmittance T_{sol} , the figure of merit $M = A / T_{sol}$, and the CIE color coordinates. Such coatings are deposited by vacuum processes (e.g. magnetron sputtering) or via the SolGel method. Optical measurements, such as spectrophotometry or ellipsometry, are used to determine film thicknesses and optical constants of individual layers, and to measure color coordinates and solar transmission for the multilayer stacks.

The proposed colored glazed solar collectors will be ideally suited for architectural integration into buildings, e.g. as solar active glass facades.

Research activities and Developments

(For details please see also the annual reports 2002 and 2003, and the publications mentioned below.)

1) Theoretical potential and figure of merit

A figure of merit was defined as the ratio of relative luminosity A and solar energy losses R_{sol} . For a narrow spectral band at the wavelength λ_0 it could be shown that

$$M := \frac{A}{R_{sol}} = \frac{D_{65}(\lambda_0) \cdot V(\lambda_0)}{I_{sol}(\lambda_0)} \cdot \frac{\int I_{sol}(\lambda) d\lambda}{\int D_{65}(\lambda) \cdot V(\lambda) d\lambda}$$

where $D_{65}(\lambda)$ is the CIE daylight standard, $I_{sol}(\lambda)$ the solar spectrum at air mass 1.5, and $V(\lambda)$ the photopic sensitivity curve of the human eye.

In the best case, M amounts to the factor six. For example 12% of relative luminosity, which is considerable for a colored surface, costs only 2% of Energy.

2) Computer simulations and design of multilayered interference filters

A large number of computer simulations have been performed and promising multilayer designs could have been identified. It could be shown that already for a reasonable number of layers a colored reflection in combination with a high solar transmisson can be achieved. the gained insights led to the deposition of the **International PCT Application PCT/CH03/00156 “GLAZING”**.

3) Feasibility tests of magnetron sputtering

First colored samples have been produced on the laboratory scale, based on multilayer interference stacks of silicon and titanium dioxide. It could be demonstrated for the first time that a colored reflection can be combined with reasonable values of solar transmission, and that this colored reflection from a cover glass can easily hide a dark absorber behind.

4) First experiences in Sol-Gel dip-coating

An improvised experimental set-up was used to deposit single-layered Sol-Gel coatings. Due to vibrations and presence of particles in the atmosphere the quality of the coatings was rather poor. However, the applicability of the Landau-Levich equation could be checked by studying the relation of the film thickness to the withdrawal speed.

5) Optical precision techniques for process control of magnetron sputtering

Real-time laser-reflectometry and spectroscopic ellipsometry have been applied in order to determine deposition rates, final layer thicknesses for single- and multilayered coatings, and refractive indices of the deposited thin film materials. Data taking and their analysis have been pushed to a certain degree of maturity, which guarantees the necessary control of deposition rates in multilayer deposition.

6) Establishing a Sol-Gel thin film laboratory and development of a dip-coater

The experimental infrastructure for the deposition and characterization of Sol-Gel thin films has been created. A completely new thin film laboratory has been established at LESO/EPFL. One important element is the development of a dust-protected dip-coater, which makes the development of thin film systems up to the sample size 21cm x 30cm (A4) possible. A solar simulator has been set up for the direct measurement of solar transmission.

7) Test of dip-coater and Sol-Gel experiments

The developed dip-coater could be tested in a dust-protected environment (laminar flux chapel). Individual layers of titanium dioxide have been deposited up to the sample size 21cm x 30cm (A4). Film homogenity and absence of defects caused by dust particles result in a good quality of these coatings. For the deposition of silicon dioxide thin films, the relation of the film thickness to the withdrawal speed has been studied. Tandem layers of titanium- and silicondioxide have been produced on the laboratory scale (small samples).

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Patents

A. Schüler: **International PCT Application PCT/ CH03/ 00156 "GLAZING"**, Swiss Federal Institut for Intellectual Property, Berne

Publications

Schüler, C. Roecker, J.-L. Scartezzini, J. Boudaden, I. R. Videnovic, R. S.-C. Ho, P. Oelhafen, **Interference filters for colored glazed thermal solar collectors**, *Proceedings of ISES World 2003 Conference*, 14-20 June 2003, Göteborg (Sweden).

J. Boudaden, R. S-C. Ho, P. Oelhafen, A. Schüler, C. Roecker, J. - L. Scartezzini, **Towards colored glazed thermal solar collectors**, *Proceedings of ISES World 2003 Conference*, 14-20 June 2003, Göteborg (Sweden).

P. Oelhafen, A. Schüler, **Nanostructured materials for solar energy conversion**, keynote paper, *Proceedings of the CISBAT 2003 conference*, 8 Oct. 2003, Lausanne (Switzerland)

Schüler, C. Roecker, J. Boudaden, P. Oelhafen, J. – L. Scartezzini, Coatings for colored glazed thermal solar collectors and solar active glass facades, ***Proceedings of the CISBAT 2003 conference*, 8 Oct. 2003, Lausanne (Switzerland)**