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INTEGRATED MULTIFUNCTIONAL GLAZING FOR DYNAMICAL DAYLIGHTING

Annual report 2010

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N° projet / n° contrat OFEN	103326 / 154386
Responsable OFEN du projet	Dr. Charles Filleux
Durée prévue du projet (de - à)	De 01/11/2009 à 31/10/2012
Date	15/12/10

ABSTRACT

In this project, a novel integrated concept and the development of advanced glazing for dynamical daylighting are studied. The novel glazing will combine the functions of daylighting, glare protection, overheating protection in summer and thermal insulation in winter. Novel micro-structures shall provide redirection of the incident solar radiation, thus providing for chosen angles projection of daylight deep into the room in the same manner as an anidolic mirror-based system, as well as glare protection. The solar gains will be reduced for chosen angles (e.g. for given incidence angles in summer at noon). Recently developed solar protection coatings ("M-coatings") shall provide the optimized spectral properties of the transmitted sunlight: maximized visible transmission for daylighting and carefully dosed energetic transmission for overheating protection in summer. The solar protection coatings simultaneously provide the necessary low thermal emittance in combination with a double glazing in order to ensure thermal insulation in winter. Technological progress will include the improvement of micro-structures by selective deposition of micro-mirrors, easier fabrication of micro-structures by sol-gel techniques and the powerful combination of solar protection "M-coatings" and micro-structures.

In 2010, further software tools were developed and used to asses the performance of structured glazing, both on a mesoscopic (the glass) and macroscopic scale (the room) .The mesoscopic calculations were used to understand the influence of the different parameters and the different types of structures. They also produced a bidirectional transmission distribution function (BTDF) that was then used in another software to produce predictions regarding daylighting in a room.

In the laboratory, commercially available samples were partially coated using angular evaporation. This demonstrated that it is possible to coat only selected facets on both macroscopic and microscopic scales. A custom made optical set-up for the measures of planar transmission distribution was used to measure the obtained samples.

Finally, in order to produce customized micro-structures, a collaboration with the LTC lab at EPFL was started, yielding promising initial results.

Project Goals

In this project a novel integrated concept and the development of advanced glazing for dynamical daylighting are studied. The novel glazing will combine several functions:

- Daylighting: redirection of incident radiation and projection of daylight deep into the room, thus reducing electrical lighting needs.
- Glare protection/visual comfort: angular dependent solar transmission to achieve the most effective blocking for the elevated angles of direct solar radiation during summer.
- Overheating protection in summer: The glazing should avoid overheating of the building in summer, but provide sufficient natural daylighting and acceptable solar gains in winter.
- Thermal insulation in winter: Double-glazing and the low emissivity properties of the used thin film coating provide thermal insulation in winter.

APPROACH:

STUDY EXISTING PRODUCTS AND ARCHITECTURAL REQUIREMENTS.

- **Obtain further simulation results**.
- **Fabricate novel micro-structures.**
- **Show that it is possible to partially coat the micro-structures.**
- **Measure the resulting coated micro-structure.**

Accomplished work and results.

1. Study of existing products and architectural requirements for this novel glazing.

Because this research aims at producing an integrated element for architecture, it is important to understand the needs and the existing solutions in this domain. Preventing glare is a common problem, usually solved by the use of blinds. Designers have optimised blind shapes to combine protection with comfortable light levels. The large amount of available solutions prove the interest for blinds that protect from glare but preserve a comfortable level of illumination.

The *retrolux©* blinds by *RETROSolar©* might well be the most advanced blinds with such aims (*Fig 1 a*). On a macroscopic scale, they are a very good example of what we wish to do on a microscopic scale. The number of projects for offices and public building integrating such blinds show that there is an interest.

Another approach uses static glazing with special angular properties. Laser cut panel acrylic panels for example use total internal refraction to redirect light upwards. Again, such panels are used in public buildings (schools, museums) and offices (*Fig 1 b*). They are partially transparent and often placed in the upper third of the window. A second example of static systems is the *Lumitop©* glazing by *St-Gobain©* (*Fig 1 c*).

(a) (b) (c)

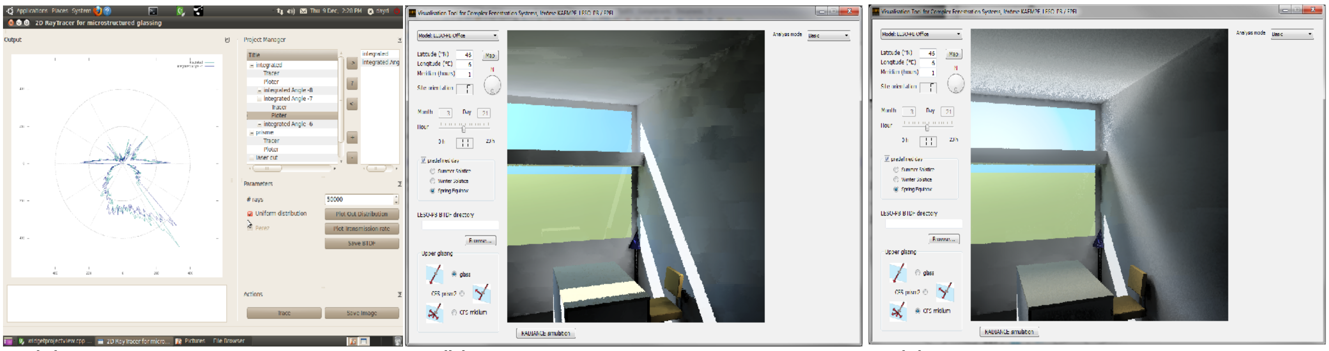
Fig 1: Examples of existing products and application domains. a) Retrolux© blinds b) Lasercut Panels in classroom c) Lumitop© example and principle.

One important conclusion is that the considered problematic differs depending on the type of building, the orientation of façades, the type of architectural element, the latitude on earth. The second important conclusion is that truly transparent devices do not currently exist bin spite of the demand.

2. Simulation results

Using the numerical modelling on a microscopic and macroscopic scale, we further defined what influence the different parameters of the structure have on the performance. It is not only important to design a structure with geometrical goals such as “redirect light upwards” or “block a certain range of angles” but also to understand quantitative architectural goals like daylight factor and glare.

For a rapid assessment, a custom 2D tracing tool was developed. It allows to visualize the path of light depending on angle and position, it calculates transmission factors and distributions depending on the incoming angle. The graphical interface makes it possible to directly compare multiple designs, vary parameters individually and rapidly identify their effect (*Fig 2 a*).



(a) *(b)* *(c)*

Fig 2: a) Angular distribution comparison of microscopic 2D tracing. b) & c) Radiance simulation comparing a clear window (b) and a glass with micro-mirrors (c) using the calculated BTDFs.

This first part also allowed to create a good approximation of the three dimensional transmission distribution. This BTDF was used in radiance for rendering of an office with a clear glass and a micro-structured glazing. It allowed a visualisation in time of the effect of such a glazing (*Fig 2 b & c*).

3. Fabrication of micro-structures

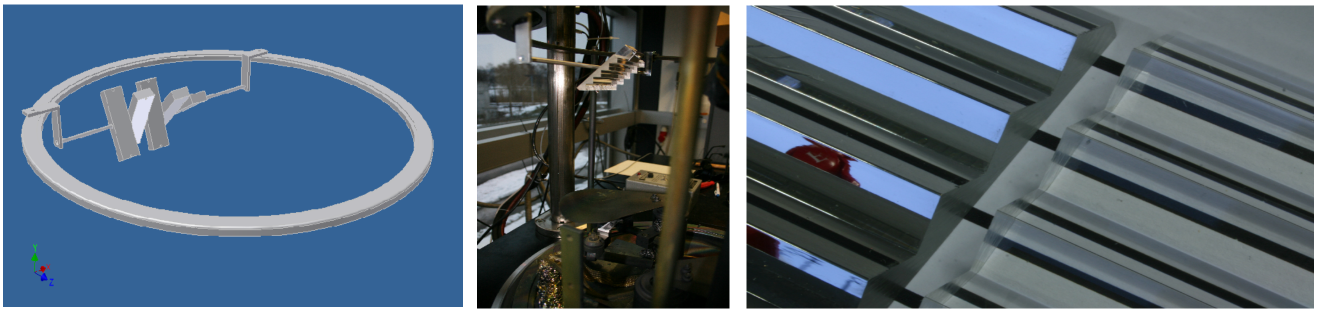
Existing structures are scarce and limited to specific applications. For example, arrays of lenses, called lenticular sheets are used for advertising (to show 2 different images depending on the viewing angle). Arrays of 45° pyramids, called prismatic films or glasses, are used for solar protection in buildings on a macroscopic scale and as brightness enhancement films in portable devices on the microscopic scale. In this project, aims and specifications are different and the required structure is defined by the simulations.

Therefore an onsite collaboration was established with the “Laboratoire de technologie des composites et polymères“ (LTC) at EPFL. The research group led by Y. Leterrier develops a replication process for nano structures using a resin and UV polymerisation. A drop of resin is deposited on the mould, a treated glass placed on top of the mould and pressure up to 5 bars is applied. A UV lamp is then turned on for 3 minutes of polymerisation. Once the resin is hardened, the glass is removed from the mould and the surface of this transparent resin retains the mould's shape.

4. Coating of micro and macro structures by physical vapour deposition (PVD)

In order to be able to deposit a coating only on a selected part of the structure, the first necessary element was to conceive a device to hold the samples at a give angle. It was designed and built with Pierre Loesch, the laboratory's mechanical engineer to fit the laboratory's Balzer PVD machine (*Fig 3 a*).

First attempts were made to coat 45° micro-prisms from 3M. Those prisms have a period of 13 to 50 µm and are made of a stack of polymers. The first evaporation was too long and the plastic suffered from the heat. Optimised parameters yielded a rapid (less than 10 seconds) and stress free process. A macroscopic 45° prism was coated to demonstrate that it is possible to coat only exposed surfaces (*Fig 3 b*). The first visual check confirmed that only one side of the prism was coated: normally those prisms duplicate objects into a left and right displaced images. The coated prism shows only one image(*Fig 3 c*).



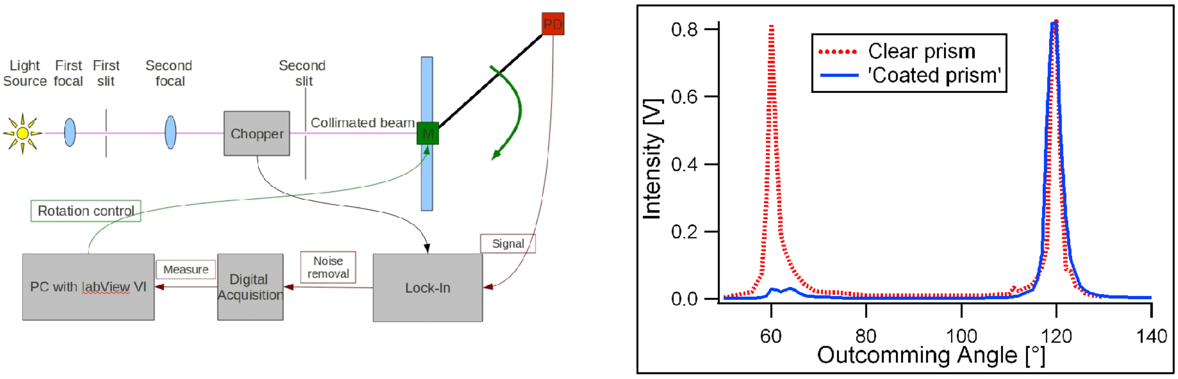
(a) (b) (c)

Fig 3: a) Angular support b) 45° prism ready to be coated. c) Coated prism: Partial coating can be observed, one facet is mirrored, the other one still “bends” light and shifts the image like an original, clear prism.

5. Measurements.

The designs of the structures and coatings are based on simulations, their accuracy has to be verified. Also it should be possible to check if the produced sample corresponds to what was designed. Comparing simulations and measures can give those answers.

Therefore, a set-up was designed for the measurement of transmitted planar distribution depending on the incident angle (*Fig 4 a*). This set-up still has to be fully automated but in manual mode, it was already possible to measure coated and uncoated micro prisms from 3M (*Fig 4 b*).



(a) (b)

Fig 4: a) Measurement set-up principle. b) Manual measure of coated and uncoated prisms.

2010 Evaluation

There are five main objectives to this project: a study of the state of the art, a simulation aspect, the fabrication and deposition task, and finally measurement of optical properties. All of these have been approached and most of them successfully reached.

1. **State of the art:** It seems that an easy to integrate and location specific glazing is of interest to architects but does not currently exist.
2. **Simulations:** Additional tools were developed and they allowed to define the shape of the first, most simple integrated mirrors. They also allowed to optimize the parameters. Architectural simulations showed clear glare elimination and daylighting capabilities.
3. **Micro-structure fabrication:** First results are very encouraging. A feasible, scalable method for production of micro structured transparent sheets was found.
4. **Coating:** Selective Coatings were successfully realised on both micro and macroscopic structures.
5. **Measurements:** The set-up was defined for automation and first manual measurements were carried out. They confirmed selective coating for microscopic structures.

Outlook for 2011

1. **Architectural integration:** More architects will be contacted to further understand their needs.
2. **Simulations:** Different shapes will be studied. The variation in coating thickness and type will be introduced and simulations will be run to study the spectral behaviour of selective coating for the thermal aspect (such as the “M-coating”).
3. **Micro-structure fabrication:** A solution to the de-moulding problem has to be found. A prototype metal mould will be fabricated on a 5 axis, on site CNC machine. In the future, photo lithography and etching at the micro technique facility of the EPFL (CMi) will be studied.
4. **Coating:** Must be tested on replicated structures. Deeper studies on the effect of the deposition angle will be done using the angular measurement of transmission.
5. **Measurements:** The full automation and complete validation of the set-up is being accomplished. Motors and data acquisition cards have been ordered. A professional company has been contacted to do a high quality reference measure.

Invited Talks

A. Schüler, *Nanostructured inorganic thin films in solar energy conversion, Part I: Vacuum deposited selective absorber coatings*, invited keynote lecture, Winter College on Optics and Energy, February 8-19, 2010, The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy

A. Schüler, *Nanostructured inorganic thin films in solar energy conversion, Part II: Sol-gel coatings for solar thermal and photovoltaic applications*, invited keynote lecture, Winter College on Optics and Energy, February 8-19, 2010, The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy

A. Schüler, *Innovatives Architekturglas für aktive Solarfassaden: Neue Möglichkeiten für gebäudeintegrierte Solarthermie und Photovoltaik*, invited plenary talk, 3. Energie-Apéro des Energie-Clusters Schweiz, Bern, March 2nd 2010

A. Schüler, *Optical and electronic properties of carbon- and nitrogen- based nanostructured inorganic thin films*, invited keynote lecture, International Conference on Metallurgical Coatings and Thin Films ICMCTF 2010, April 26-30, San Diego, USA

A. Schüler, *Semiconductor-metal transition in vanadium dioxide based thin films: towards “smart” solar energy materials,* invited plenary talk, From Solid State to BioPhysics V, June 12-19 2010, Cavtat, Croatia

Industry Contacts

- Partnership with SWISSINSO: technology transfer of magnetron sputtering and research on novel coatings for innovative solar collector glazing
- Collaboration with GLAS TRÖSCH for production of prototype glazing by industrial scale magnetron sputtering
- ASULAB (SWATCH GROUP) donated equipment for vacuum deposition of thin films, suitable for multilayer deposition

International Collaboration

- Pietro Altermatt, University of Hanover and Institut für Solarenergieforschung Hameln (ISFH)

National Collaborations

- Collaboration with Prof. Peter Oelhafen and Roland Steiner's research group at the Institute of Physics, University of Basel.
- PV laboratory at the university of Neuchatel.

ON CAMPUS:

- Research group of Dr. Yves Leterrier in Professor Jan-Anders E. Månson's laboratory LTC for structure replication.
- Access to lithographic techniques and etching for micro-structuring at EPFL-CMi
- Access to electron microscopes and to the facilities of TEM sample preparation at the Interdepartmental Center of Electron Microscopy EPFL-CIME
- Prof. Libero Zuppiroli's research group (LOMM at EPFL) provides access to their new ellipsometer
- Collaboration with Dr. Rosendo Sanjines and Henry Jotterand, Laboratory of Thin Films Physics, Prof. Laszlo Forro, Institute of Complex Matter Physics, EPFL. Experiments on magnetron sputtering and X-ray diffraction analysis.
- Synergy with Dr. Jerôme Kaempf of LESO-PB who has the competences for macro scale modelling and rendering.