ENVIRONMENTAL SOUNDNESS OF MICRO MIRROR BASED ACTIVE WINDOWS

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Summary

In active windows micro mirror arrays between the layers of conventional glazing allow a fast and only partial blind of selected areas of a window. Glare can be effectively avoided while daylight use is kept to a maximum. In contrast to external sun blinds active windows are supposed to be maintenance-free and thus applicable also in high-rise buildings. An analysis of the environmental soundness of active windows is challenging as active windows are not yet in a commercial stage and the energy demand over the use stage depends on a variety of factors such as control strategy, building design and local climate requiring an illumination and energetic simulation. An important advantage is the lower material demand which in case of aluminum is lower by several orders in the final product compared to typical external sun blinds making a contribution to dematerialization.

Keywords: daylight use, active window, environmental, life cycle assessment

1 Introduction

The European Commission has identified sustainable construction as a promising emerging market and declared it as one of six lead markets [1], [2] with the integration of renewables and building automation as important areas. Today's passive role of windows as a thermal isolator allowing the transmission of visible light is extended by active functions such as electricity production, light source, glare protection or heat production. Here we refer to an active window as a window whose daylight transmission can be flexibly changed [7]. One option is to place micro mirrors between the panes of a conventional double-glazed window [3], [7], [8] and changing the pitch of the mirrors by applying a voltage [8]. While in open position at 90 degrees, a nearly undisturbed view is possible (the single micro mirrors cannot be seen with naked eye) (**Fig. 1**), an angle between 45 and 90 degrees results in a more or less intensely tinted window. In closed position the window is opaque. Segments of a few square centimeters of micro mirror arrays can be controlled independently allowing a tailored glare protection while maximizing daylight use. Further system advantages are the fast opening and closing time in the range of milliseconds, a rather maintenance free operation and their protected position between the glass planes [8]. One of factors critical for the later success of this innovative concept is its environmental soundness.

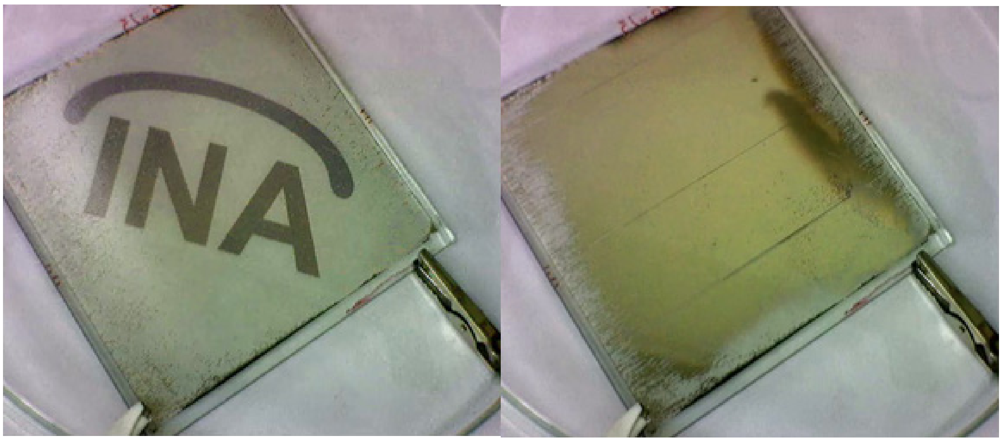

Fig. 1 *Micro mirror demonstrator: Left side: open position (without voltage applied). Right side: closed position (voltage applied) [8]*

2 Environmental soundness of micro mirrors in active windows

A sound environmental assessment of a product requires a standardized framework as provided by life cycle assessment (LCA) taking the entire life cycle and all possible relevant environmental impacts into account [4]. An LCA of micro mirrors in active windows is challenging for a number of reasons. Several assumptions have to be made introducing uncertainties in all life cycle stages [5].

The micro mirrors are produced using Micro Electro Mechanical System (MEMS) technology, a special kind of micro system technology [8]. To minimize production costs state-of-the art production processes from the glass, solar and TFT display industry are adopted as far as possible [7]. Overall, three main production steps can be distinguished: i) deposition of several thin films including an electrode and a mirror layer on the float glass pane, ii) structuring of the mirror shapes and the grid on these layers, and iii) release of the micro mirrors from the substrate to an upstanding position without any voltage applied [8]. Production processes but also materials used are permanently checked for improvement, in particular in the up-scaling process. Indium tin oxide (ITO), for example, was originally used in an early stage for the transparent electrode layer and is now replaced which likely reduced the primary energy demand as ITO is known to make a major contribution to the embedded energy and direct process energy of solar cells [9].

Other uncertainties refer to the use stage. To prove the claim that active windows may reduce the total primary energy demand for artificial lighting, heating and cooling compared to conventional external sun blinds requires a detailed simulation of both illumination (**Fig. 2**) and energy demand. Assumptions need to be made regarding for example the building design, building use, local climate, control strategy for the external sun blinds and the active windows, e.g. the preferred trade-off between daylight use, glare protection and cooling demand, etc.

Finally, little is known about the end of life stage including the recycling route of the active windows.

Addressing these large uncertainties in the different life cycle stages requires an elaborated scenario-based approach with scenarios for among other things production processes and materials used, types of building design including window areas and orientation, local climate, control strategies as well as recycling processes and rates.

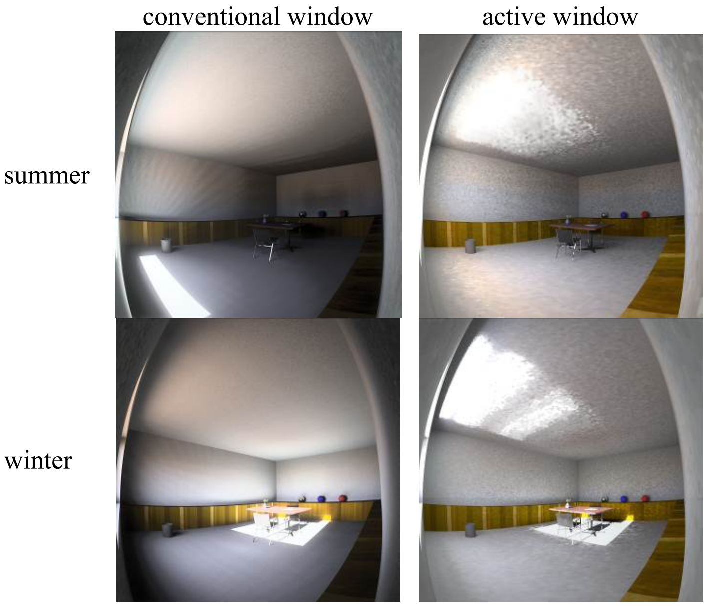

Fig. 2 *Illumination simulation: left side: conventional window; right side: active window [8]*

When comparing active windows with electrically driven external sun blinds, environmental advantages can be expected from the lower aluminum demand in the final product of about 1 g per m² active window compared to 1.5 kg per m² for aluminum slats used in external sun blinds and the lower energy demand for actuating the micro mirrors. On the other hand, the production process of active windows requires photoresists and thus a more thorough eco- and human-toxicological assessment. Little can be said so far about possible energy efficiency gains during the use stage. As the micro mirrors are between the layers of conventional glazing leading to a supposedly higher degree of heat trapping and as transparency is lower, detailed simulation analyses are planned to assess the total primary energy consumption for heating, cooling and lighting for different buildings under different climates and use scenarios.

3 Conclusions

Active windows with micro mirror arrays allow a fast and partial blind of selected areas of a window avoiding glare effectively while keeping daylight use to a maximum and reducing cooling demand. An analysis of the environmental soundness of active windows is challenging for several reasons. As an emerging technology, production processes and material use is subject to changes. An important advantage compared to external slat blinds is the lower material demand. The primary energy demand during the use stage compared to external sun blinds is considered as highly important for the overall environmental advantageousness but requires elaborated illumination and energy simulations and a large number of assumptions. Further analyses accounting for such uncertainties and further environmental aspects and impact categories are necessary in order get a more complete picture. Such analyses will also account for the fact that active windows have a wider range of application than external sun blinds, e.g. in high-rise buildings or areas with high wind speed.

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