ENERGY HARVESTING AND PASSIVE COOLING: A NEW BIPV PERSPECTIVE OPENED BY WHITE SOLAR MODULES

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ABSTRACT

CSEM has developed homogenous white and colored solar panels with conversion efficiencies from above 10% to 15%. This innovative technology is particularly attractive for the building industry as PV elements can blend into any building skin and become a virtually invisible energy source. Aside from completely new possibilities in the design and rendering of active PV façades of any shape and size, notably white PV offers another important feature as a mere side effect: through the reflection of most of the visible spectrum of light the white solar surface will be at a lower temperature than the similar black standard module and therefore improve passive cooling. First tests of outdoor monitoring have shown very promising results and could globally lead to important savings in air-conditioning costs.

Keywords: Photovoltaics, BIPV, architecture, façades

INTRODUCTION

The constant call for colors to stimulate the ambitious market of BIPV products has had no important impact so far [1]. Discussed for more than 25 years, colored photovoltaics cannot yet find its way out from a tiny niche to some broader acceptance by the building industry and most architects. Some identified key reasons are related to poor visual appearance, efficiency losses caused by adding colors to the PV unit and the small series which lead to a mismatch in the targeted price/Wp ratio. Despite many promising attempts at constructing colored PV façades [2] most producers are experiencing difficulties in securing major market shares.

CSEM is proposing a new understanding of the use of color in architecture by broadening the narrow and exclusively design-related perspective according to which colored PV was serving so far to merely embellish the building envelope as a superficial decoration. Colored PV has rather to be redefined as an important added value through its genuine technical properties. To exemplify this technical and intellectual turnaround the attention shall be drawn to the advantage of white PV.

THE MARKET SITUATION FOR COLORED PV

Most PV modules in the market are made of crystalline silicon solar cells, which are interconnected by metallic ribbons, and encapsulated either between two glasses or between a front-glass and a back-sheet. These solar cells, designed to maximize light to electricity conversion and thereby sunlight absorption are characterized by their blueish or black rendering. The overall appearance given by the combination of dark cells, metallic ribbons and very often white back-sheets, is considered by most experts in the building industry and even laypeople to be visually unaesthetic and were a barrier to a more sophisticated use of PV in the built environment. According to many stakeholders in the building industry a homogenous monochromatic colored rendering of PV is in clear demand. White as a "color" is seemingly of a particular interest: it's not only widely used in architecture and appreciated for its elegance and versatility, but also connoted with adjectives like "clean", "fresh", "classy" and figures sustainably as "modern" throughout the decades despite so many ephemeral architectural trends that passed since the worldwide rise of what is considered to become known as "modern architecture" in the Bauhaus tradition since the 1920's. But despite a clear demand all attempts to ever realize reliable and well performing white solar panels failed due to technical obstacles since it seemed fairly contradictory to the core idea of any PV technology according to which a maximum of light absorption instead of reflection is the aim.

CSEM'S WHITE PV TECHNOLOGY: CHALLENGE AND NEW PERSPECTIVES

The CSEM technology combines two different elements: a solar cell technology based on crystalline silicon able to convert solar infrared light into electricity; a selective filter which reflects and scatters the whole visible spectrum while transmitting infrared.

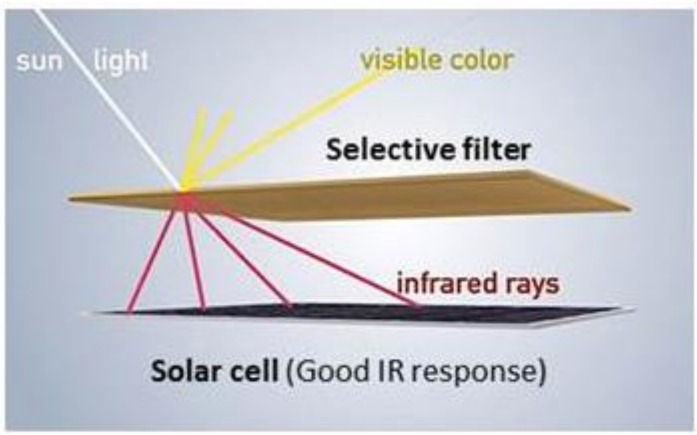

Photo 1: Principal scheme of the CSEM filter technology.

Although any PV technology based on crystalline silicon can be used to manufacture white solar modules, heterojunction crystalline silicon solar cells turned out as the preferred choice. These cells combine open circuit voltages close to 730 mV, i.e. much higher values than the ones measured by standard silicon solar cells (~630 mV), with an excellent response in the infrared part of the spectrum. Approximately 55% of the current generated under standard test conditions comes from the infrared. Thus, even without considering visible light, conversion efficiencies above 10% are possible when using this technology.

The selective filter consists of a plurality of transparent dielectric layers with different refractive indexes, stacked on top of each other, to highly reflect visible light. Moreover, in order to give a white appearance to a mirror-like surface, scattering of visible light is necessary. This effect is achieved either by growing the filter on a micro-structured surface or by placing a foil on top of it with embedded micro particles of different refractive indices. The result is a completely white and homogenous surface which turns the PV wafer structure completely invisible.

Photo 2: The first white PV prototypes developed by CSEM.

The lower temperature of white PV compared to standard dark PV surfaces is an extra advantage. The visible light being reflected reduces the temperature in the module, thus a white solar cell is expected to work at temperatures up to 50° lower than in standard black PV panels. This leads to a clear improvement of performance since in conventional PV the electrical output decreases with rising temperature at rates of 0.3-0.5% per degree Celsius.

This innovative technology can be applied either on top of an existing module or integrated into a new module during assembly. Finally, the white color provides a universal base for a wide range of other possible color variations.

Photo 3: A test module based on the same technology

Hence any new building surface could become photoactive, with typical efficiencies in the 10 to 15% range, maximizing the use of space for electricity generation. This virtually invisible energy source offers completely new architectural approaches [3].

Besides its high BIPV potential the CSEM developed optical filter can be applied in many other fields like consumable electronics (laptops), displays, security (cameras), signage, watch and car industry etc. The next steps for CSEM are to raise the efficiency of white PV modules above 13% and integrate them into new applications.

Photo 4a-d: Before and after. The CSEM technology offers virtually an endless variety to design future PV-façades (simulations).

PASSIVE COOLING BY WHITE PV

Targeted to become an industrially manufactured product within the coming year, white PV doesn't only offer a completely new architectural dimension in the so far [as] unlikely considered possibility of constructing homogenous bright white PV building exteriors of any kind by harvesting energy. It could at the same time contribute to energy savings in the building. This additional feature is provided by the color itself: since any white PV-unit reflects most of the visible light by letting through the part of the infrared spectrum important to the PV cell, it could simultaneously operate as a protective sun shield and hence passive cooling component. According to current tests conducted under lab conditions the temperature measured behind a white PV panel is at 10°C lower compared to the temperature behind a black one. This result could be of considerable interest for big cities located in warm climate zones where the "Heat Island" effect takes place but also in any rural zone suffering from hot weather conditions. From this perspective white PV meets an important trend: in most North American cities official initiatives have been launched to improve the urban and indoor climate by turning dark surfaces of the building shell into white ones. Widely known under its name “The cool roofs movement” New York City, Philadelphia, Boston and many other urban communities started to literally paint their flat roofs with ordinary white paint. At first glance a seemingly curious effort to reduce unwanted heat, the result proven by several independent scientific studies is quite impressive: such treated "white roofs" are at peak temperatures up to 12°C cooler than roofs with aluminium coating and even 17°C cooler compared to roofs covered with a typical black waterproof asphalt layer [4]. This effect clearly contributes to also lower the indoor temperature, which is even more pronounced for buildings with low quality insulation. The decrease of air conditioning output generated by white surfaces could lead according to serious estimations to very promising cost savings in the range of several billion dollars for the US alone. On a worldwide scale the figures would be even more impressive. The additional use of white PV on top of white painted roofs as a façade element could support the effect of outdoor and indoor cooling. The bi-functional solution provided by white PV is worth taking into account in areas with longer periods of peak outdoor temperatures above 30°C: white PV surfaces would hence provide both, energy harvesting on an important scale and the reduction of air conditioning costs by contributing to passively cooling down the building and the urban and rural climate simultaneously. White PV could thus help meet the requirements of any smarter energy concept by reducing the environmental impact of human civilization.

REFERENCES

1. Heinstein, P., Ballif, C., Perret-Aebi, L.-E., Building Integrated Photovoltaics (BIPV): Review, Potentials, Barriers, and Myths, Green, 3, 2, (2013), pp. 22-25.

2. Among others there are very interesting and promising approaches in the field of colored PV by some Swiss PV manufacturers and suppliers like Swissinso and glass2energy.

3. The modules based on the CSEM filter technology are commercialized by Solaxess, Neuchâtel (www.solaxess.ch).

4. See the NYC °Cool Roofs Annual Review 2012, based on studies carried out by Columbia University, NY. There has been measured a temperature decrease even up to 23°C at peak summer outdoor temperatures for NYC.