Smart Windows for Passive Control of Solar Radiation as a Function of External Ambient Temperature

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ABSTRACT

The ecological goal of "smart windows" is to exploit solar energy resources to meet the energy needs of a building. In this context, KiloLambda developed a novel energy-saving technology, named Dynamic Heat Reduction (DHR), which is a dynamic layer that changes its transparency according to the outside temperature, using the sunlight benefits on a cold day, and reducing the sunlight on a hot day. Being a passive solution, it enables a cost/effective solution without the need for additional CapEx/Opex associated with the installation and operation of active technologies such as electrochromic systems.

KiloLambda surpassed the traditional techniques of light power control by developing nano-technology based optical power control capabilities in a passive (no electrical power) manner and applying them to everyday applications.

Keywords: thermochromic, thermotropic, smart window, solar control

1 INTRODUCTION

A well-known fact is that nearly half of the energy consumed throughout the developed world is used for heating, cooling and lighting of buildings. Buildings are huge energy consumers, since their functions like cooling, heating, lighting and ventilation require large amounts of energy, approximately 30–40% of consumed energy worldwide. Due to the continuing population growth, and as a consequence, of the consumed energy, mitigation measures of energy consumption are urgently needed. In this direction, a European Directive (2010/31/EU) for nearly zero-energy buildings after 2020 has been issued [1].

Windows are a key factor in building energy consumption, because thermal energy is transferred through their transparent surface. During summer, windows allow heat to pass into the building and during winter, heat escapes. It is estimated that windows are responsible for 40% of the total building energy losses. Concerning heat transfer, it would be ideal for a window to adapt its thermal properties to the outdoors environmental conditions. Windows, like essential architectural elements, should provide the essential functionality to make the resident or the worker feel comfortable and reduce glare while permitting building's lighting. Therefore, windows functionality in the modern architecture moves forward toward "smart windows".

The ecological goal of "smart windows" is to exploit solar energy resources to meet the energy needs of a building. "Smart" glazing can be divided into two major categories: passively switching (photochromic, thermochromic and thermotropic) and electrically activated types. For the electronically switchable technologies, costs are in the range of several hundred $US/m^2. As to photochromic glass, it is not yet produced in sufficient quantities and sizes presently, neither is the cost low enough (about 500 $US/m^2) to allow its wide use in buildings or cars and its durability is much lower than needed today for glazing (>10 years of lifetime). Thermochromic and Thermotropic (passive) based fenestration is not yet commercially widespread due to its costly implementation. Lower installation and life-cycle costs, as presented in this paper, can make such a technology more popular.

2 DYNAMIC HEAT REDUCTION DHR

KiloLambda has developed a novel process (patent pending [2]), using inclusions of nano-crystals in a transparent polymeric matrix. At a pre-designed temperature this novel composition is transparent, whereas a temperature change creates a refractive index variation in the nano-crystals and the matrix, making it a scattering media, scattering off the excess solar light. This proposed technology – DHR – Dynamic Heat Reduction, a novel energy-saving technology, is a dynamic layer, which changes its transparency according to the outside temperature, using the sunlight benefits on a cold day, and reducing the sunlight on a hot day. The DHR is a passive coating/film triggered only by the solar radiation and ambient temperature. It reflects a desirable level of solar heat, while allowing enough solar lighting. Being a passive solution, it enables a cost/effective solution without the need for additional CapEx/Opex associated with the installation and operation of active technologies such as electrochromic systems.

2.1 Demonstration of DHR

Figure 1 shows (a) a photo taken of DHR prototype window-device, produced in KiloLambda's laboratory according to KiloLambda's proprietary novel technology, at room temperature, in the transparent "Off" state and part (b) shows a photo taken of the same DHR device at a temperature of ~80°C in the translucent "On" state.

a. 

b. 

Figure. 1. a passive DHR (Dynamic Heat Reduction) prototype device. (a) "Off" state, (b) "On" state

2.2 Experimental Results

Figure 2 shows direct-transmission spectral measurements performed on a demonstrated device at 24°C and at 80°C. Note that transmission was acquired with two different spectrometers, one for the visible light and one for the infrared part of the spectrum, hence the discontinuities between 850 and 950 nm and the slight offset observed for the 24°C measurement. As can be seen, at room temperature (24°C) the device shows high transmittance, both in the visible and in the infrared part of the spectrum, while at a high temperature, where it turns scattering and translucent, the transmission of light and heat is drastically reduced.

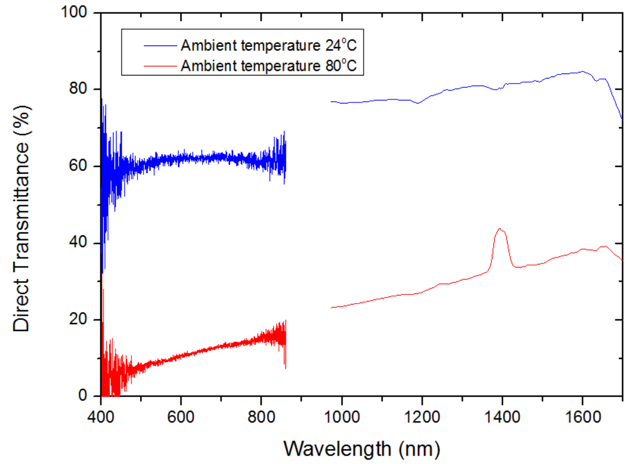

Figure. 2. Direct-transmission spectral measurements

A demonstration of the technology's ability for tuning the "Off" state temperature, i.e. the temperature at which it is transparent, via mixing ratio of two optical transparent adhesives, A and B, that have different refractive indices is shown in figure 3; Material (a) has a higher RI value and material (b) has a lower RI value than that of the embedded nano-particles at room temperature. By changing the mixing ratio between (a) and (b) the transparency temperature was shifted from a peak at ~30°C to a peak at ~10°C. In this manner the "Off" state temperature can be tailored per application, for example in case of windows dedicated to different geographical locations or windows that are exposed or not exposed to direct sunlight that may add to the ambient temperature. The "Off" state can be seen to span along 20°C before the transparency is gradually reduced as the window turns translucent.

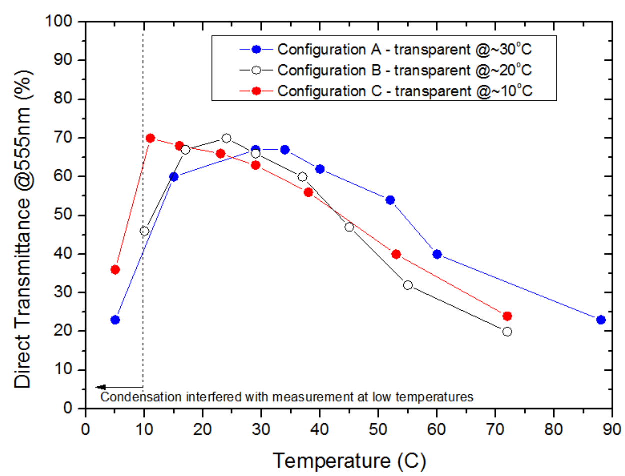

Figure. 3. Direct transmission curves as a function of ambient temperatures, the configurations A,B and C are different matrix mixtures, in which the ratios between component (a) and (b) were changed

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3 SUMMARY AND CONCLUSIONS

Within this paper we introduced our novel technology of Dynamic Heat Reduction DHR coating/layer/film. DHR is a proprietary solution for dynamic, yet self-adaptive control, over the amount of light and heat penetrating through a building or automotive glazing. The ambient temperature, at which this customizable layer is activated, as well as its transmittance characteristics, can be fine-tuned to the specific application. The exact characteristics are designed by the KiloLambda lab according to the parameters requested by the architect, engineer or glass manufacturer, responsible for supplying the energy saving solution best suited to the building project.

The dynamic light and heat attenuating layer can be applied by the glass manufacturer during the production process. It can also be applied using adhesive film, something which makes it excellent for retrofitting existing windows.

DHR is not limited to window type, size or shape. This places it in the enviable position of being able to help building, real estate renovation and automobile firms advance the cause of green energy in their respective industries.

KiloLambda surpassed the traditional techniques of light power control by developing nano-technology based optical power control [3, 4, 5] capabilities and applying them to everyday applications. KiloLambda's technology controls optical power for all wavelengths and does so in a totally passive (no electrical power) manner, as opposed to conventional solutions of limiting or blocking specific wavelengths using active methods. The company is now applying its breakthrough technologies in the advanced development of next-generation non-linear optical components, devices and films, to control and regulate optical power, passively.

4 REFERENCES

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