OPTICAL THERMAL INSULATION VIA SOLAR-ENERGY HARVESTING PHOTOTHERMAL NANO COATINGS

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Key Words: Solar Energy, Green Window, Photothermal, Thermal Energy Loss, Nano Coating.

The current technological advancement has enabled glass-based building facades with double- or triple-glazed transparent panels. However, the conventional glazing technologies cannot effectively reduce building thermal energy loss especially for large area transparent building skin. According to a report by the U.S. Department of Energy, building heating, ventilation, and air conditioning (HVAC) accounted for 14.0 % of primary energy consumption in the United States. Heat loss through windows in cold weather consumes about 3.9 quads, which is estimated to encompass 28.7 % of total HVAC energy consumption. [1] We have developed a novel concept of Optical Thermal Insulation (OTI) without any intervening medium (Fig. 1). Instead of applying a thermal insulator, a transparent photothermal (PT) film can selectively absorb photons near the UV and NIR regions and efficiently convert them to heat, therefore raising the window surface temperature (via free energy). As the inner surface temperature is raised relative to room temperature, the heat transfer at the window inner surface can be effectively reduced via the so-called OTI, especially in winter. It must be noted that the PT films are spectral selective with high absorptions near UV and IR, while allowing high visible transmittance, therefore transparent and ideal for façade engineering. Based on this concept, a so-called “Green Window” has been designed for single-pane applications that meet the U-factor specifications of Department of Energy for colder regions of the United Sates. The “Green Window” is composed of chlorophyll (Chl) retrieved from natural greens (by which the name “Green Window” is derived). [2] A thin film window coating of naturally occurring chlorophyll exhibits strong near UV and NIR absorptions and pronounced photothermal effect, while remaining highly transparent (Fig. 2). Upon collecting solar light, considerable heat is created, effectively raising the window surface temperature, leading to a reduced U-factor less than 1.7 W m^{-2} K^{-1}, even below the values of double-panes. Based on these experimental results, we demonstrate of a new concept of “optical thermal insulation” that lifts the dependence on insulating materials making single-pane window highly possible. Fig. 2 shows the change in temperature (ΔTg) induced by simulated solar light as a function of time for the multilayer samples of chlorophyll. Consistently, thicker films (each layer is ~ 2 mm) gave greater ΔTg as expected. Conversely, the thicker films exhibit lower visible transmittance (VT). As shown in this figure, the temperature plateaus can be observed after 2 min.-irradiation by solar simulator. Fig. 2b shows $\Delta T_{g,max}$ vs. VT for thin films of different layers (a maximum of 6 layers). $\Delta T_{g,max}$ vs. VT displays a linear relationship extending to the point where no Chl film was applied (highest VT).

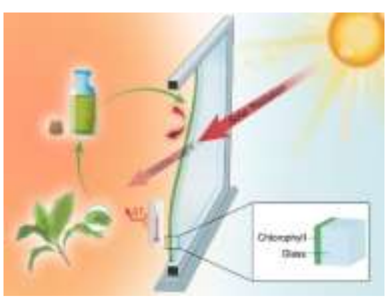

Figure 1 –Chlorophyll-coated “Green Window” for “optical thermal insulation.”

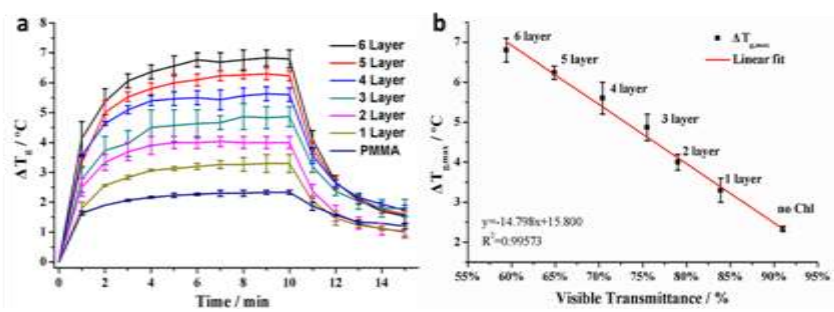

Figure 2 (a) ΔTg vs. Time for Chl-coated glass. (b) ΔTg vs. VT for Chl-coated glass

References:
[1] ARPA-E, "Single-Pan Highly Insulating Efficient Lucid Designs (SHIELD) Program Overview," https://arpa-e.energy.gov/sites/default/files/documents/files/SHIELD_ProgramOverview.pdf
[2] Yuan Zhao, Andrew Dunn, Donglu Shi, MRS Communications: Volume 9, Issue 2, pp. 675-681 (2019)