Nanoscale Photothermal Effects Driven by Solar Radiation for Building Envelope Thermal Behavior Management

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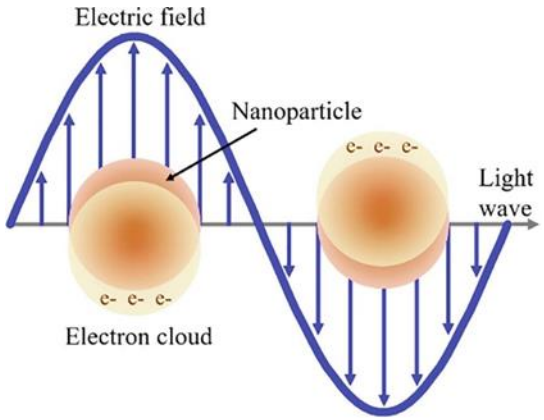
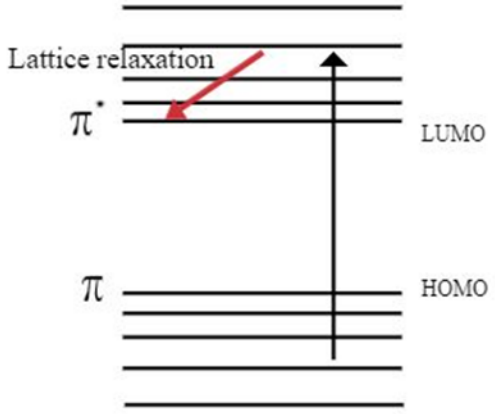
August 2023

Photothermal Effect

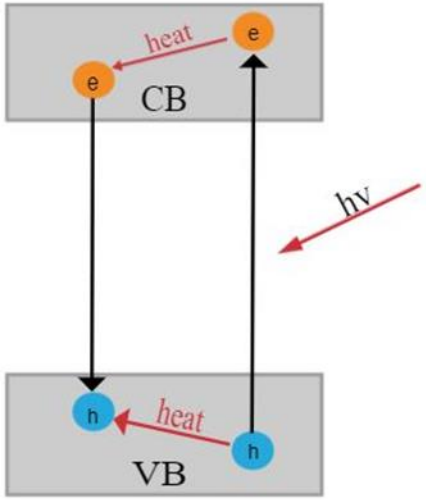
- When absorbed photon's energy is transferred to an electron and is released as heat or kinetic energy, the photothermal effect occurs
- Photothermal effect has three different mechanisms: Plasmonic localized heating, electron-hole generation and relaxation, and thermal vibration of molecules



Plasmonic localized heating



Electron-hole generation and relaxation

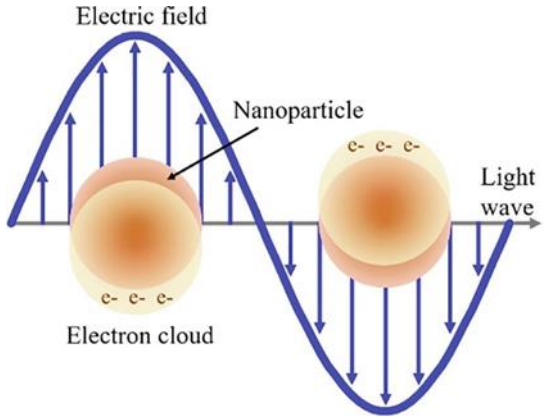


Thermal vibration of molecules

Nanoscale Photothermal Effect

❖ Plasmonic localized heating

- The frequency of the incoming light matches with the natural frequency of the electrons on the surface of the metal
- Electrons are excited, and hot electrons are produced
- Heat is produced as a result of the collective oscillation of the excited hot electrons and the incoming electromagnetic field.
- hot electrons redistribute their energy by electron-electron scattering, and heat is generated in the plasmonic element

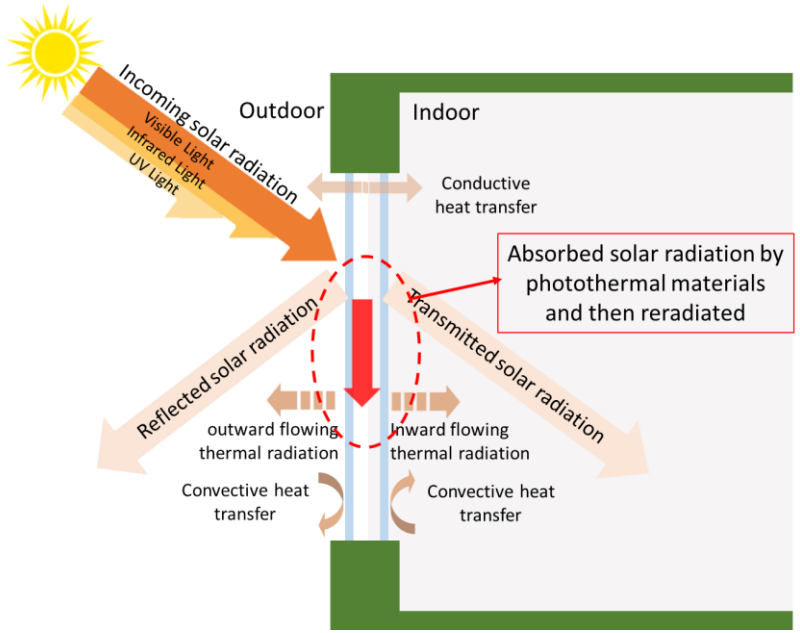


Plasmonic localized heating

Nanoscale Photothermal Effect Applications in Energy-efficient Buildings

❖Plasmonic nanoparticles coated windows

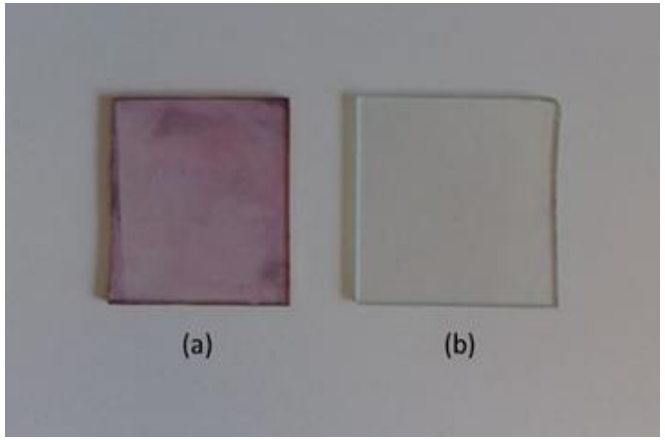
- Photothermal effect occurs by the deposited nanoparticles
- Windows surface temperature increases
- The generated heat is transferred to the inside by radiation heat transfer



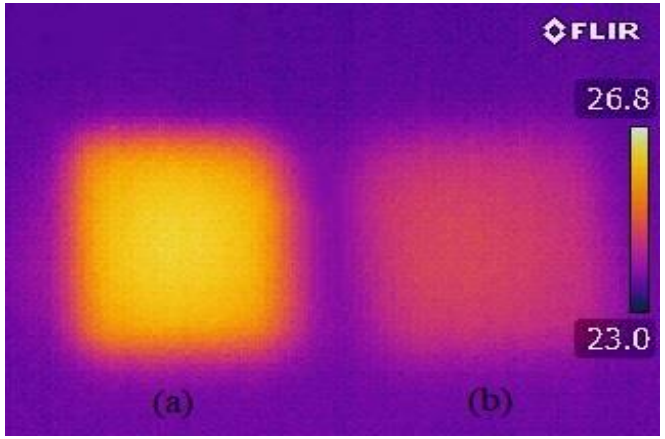
Experiments

❖Gold nanoparticle coating on glass slides

- 60 nm gold nanospheres
- Samples are exposed to light source (80 W/m^2) for 3 hrs
- 2°C temperature difference between samples in average



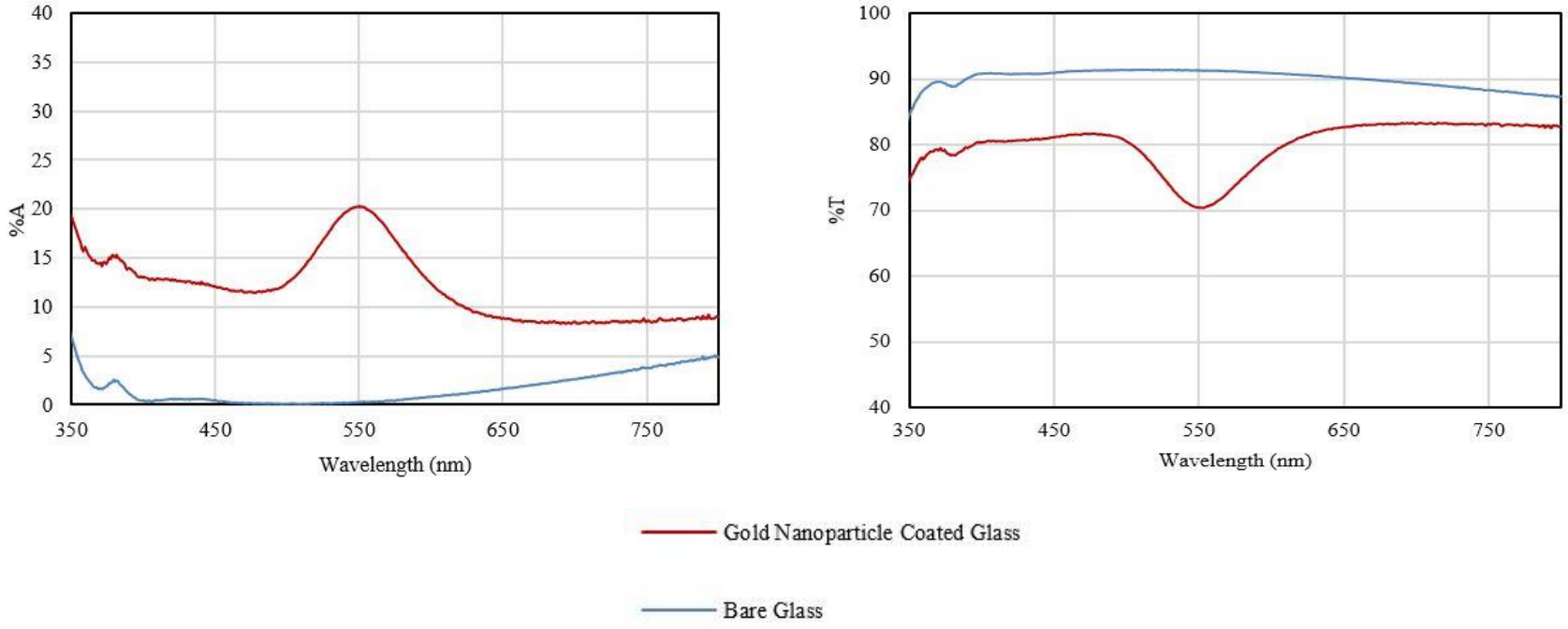
(a): Gold nanoparticle coated glass, (b): Bare glass



Thermal Image

Optical Properties

- The absorption of the glass is extremely increased by Au nanoparticle deposition
- The absorptance spectrum has a peak on the wavelength of 550 nm shows gold nanospheres with 60 nm diameter



Solar Heat Gain Coefficient (SHGC)

$$SHGC = \tau_s + N_i \alpha_s$$

- N_i is the inward-flowing fraction of the absorbed radiation, τ_s and α_s are the solar transmittance and absorptance of the window, respectively
- Previous studies showed that the solar heat gain through windows in photothermal material coated windows is about 15% more than Low-E windows and can reduce heat loss about 16% more
- In addition to changing the optical properties of the windows, plasmonic nanoparticles on windows can lead to some changes in windows thermal properties as well
- Studying the effect of plasmonic nanoparticles on the windows thermal properties is necessary in the field, which requires more theoretical and experimental research works.

Thank You!

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