Using Broadband Light-Induced Heating of Silk/Metal Nanoparticle Composite Film to Develop Silicon-Based NIR Photodetector

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Abstract

This research describes a systematic investigation of the phenomenon of white-light-induced heating in silk fibroin films embedded with gold nanoparticles (Au NPs). The Au NPs functioned to develop an ultrahigh broadband absorber, allowing white light to be used as a source for photothermal generation. With an increase of the Au content in the composite films, the absorbance was enhanced significantly around the localized surface plasmon resonance (LSMR) wavelength, while non-LSMR wavelengths were also increased dramatically. The greater amount of absorbed light increased the rate of photoheating. The optimized composite film exhibited ultrahigh absorbances of approximately 95% over the spectral range from 350 to 750 nm, with moderate absorbances (>60%) at longer wavelengths (750-1000 nm). As a result, the composite film absorbed almost all of the incident light and, accordingly, converted this optical energy to local heat. Therefore, significant temperature increases (ca. 100 °C) were readily obtained when we irradiated the composite film under a light-emitting diode or halogen lamp. Moreover, such composite films displayed linear light-to-heat responses with respect to the light intensity, as well as great photothermal stability. A broadband absorptive film coated on a simple Al/Ag Schottky diode displayed a linear, significant, stable photo-thermo-electronic effect in response to varying the light intensity.

Fabrication

Morphology

FDTD Simulation

(a) Typical thermal images of thin films (left) before and (right) after exposure to a LED. Plots of temperature change at steady state for SF films in the presence of SGNs (square) and LGNs (circles) at various (a) Au contents (halogen lamp intensity: 1300 mW/cm²) and (b) halogen lamp intensities (Au content: 25 wt %). Exposure time: 5 min.

Photo-Thermo-Electricity

(a) I-V curves for a SGN/SF film coated on Al/Ag Schottky diode before and after halogen lamp irradiation. (b) Plot of temperature change at various halogen lamp intensities for a SGN/SF film coated on Al/Ag Schottky diode. (Inset) Typical thermal image of an SGN/SF-coated Al/Ag Schottky diode exposed to a halogen lamp. (c) Current dependence obtained at various halogen lamp intensities for a SGN/SF film coated on Al/Ag Schottky diode. The reverse bias was fixed at 0.4 V. (d) Current gain for a SGN/SF coated film on Al/Ag Schottky diode.

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Reference