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High-k ZrO2 Enhanced Localized Surface Plasmon Resonance for Application to Thin Film Silicon Solar Cells

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Localized surface plasmon resonance (LSPR) has been explored recently as a promising approach to increase energy conversion efficiency in photovoltaic devices, particularly for thin film hydrogenated amorphous silicon (*a*-Si:H) solar cells. The LSPR is frequently excited via an electromagnetic (EM) radiation in proximate metallic nanostructures and its primary consequences are selective photon extinction and local EM enhancement which gives rise to improved photogeneration of electron-hole (*e*-*h*) pairs, and consequently increases photocurrent. In this work, high-dielectric-constant (*k*) ZrO_2 (refractive index n=2.22, dielectric constant ε=4.93 at the wavelength of 550 nm) is proposed as spacing layer to enhance the LSPR for application to the thin film silicon solar cells. Compared to excitation of the LSPR using SiO_2 (n=1.46, ε=2.13 at the wavelength of 546.1 nm) spacing layer with Au nanoparticles of the radius of 45nm, that using ZrO_2 dielectric shows the advantages of(i) ~2.5 times greater polarizability, (ii) ~3.5 times larger scattering cross-section and ~1.5 times larger absorption cross-section, (iii) 4.5% higher transmission coefficient of the same thickness and (iv) 7.8% greater transmitted electric filed intensity at the same depth. All those results are calculated by Mie theory and Fresnel equations, and simulated by finite-difference time-domain (FDTD) calculations with proper boundary conditions. Red-shifting of the LSPR wavelength using high-*k* ZrO_2 dielectric is also observed according to location of the peak and this is consistent with the other's report. Finally, our experimental results show that variation of short-circuit current density (J_{sc}) of the LSPR enhanced *a*-Si:H solar cell by using the ZrO_2 spacing layer is 45.4% higher than that using the SiO_2 spacing layer, supporting our calculation and theory.