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PERFORMANCE ENHANCEMENT IN ULTRATHIN CIGS SOLAR CELLS USING PLASMONIC NANOPARTICLES – A FINITE DIFFERENCE TIME DOMAIN ANALYSIS APPROACH

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The plasmonic effect in photovoltaics is gaining attention because of its optical absorption enhancement properties in solar cells. Plasmonic structures exhibit wavelength-selective photon scattering based on their shape, size, and the surrounding dielectric medium. Plasmonic enhancement is achieved through the collective oscillations of the free-electron cloud in metallic materials when the size is smaller than the wavelength of the incident radiation. This study explores the application of plasmonic gold (Au) nanoparticles (NPs) in CuInGaSe₂ (CIGS) solar cells using the finite-difference time-domain (FDTD) analysis method for simulation. The study was carried out using ANSYS LUMERICAL to simulate optoelectronic properties, solving Poisson's and continuity equations coupled with Maxwell's equations. Au (NPs) exhibit different resonance frequencies in semiconductor materials, making them suitable for selective wavelength-absorption enhancement. The results demonstrate that the unabsorbed light in the base CIGS was effectively captured in the devices with embedded Au NPs. In particular, when 20 nm diameter spherical Au particles were incorporated into CIGS solar cells, they achieve a higher efficiency increase of 4% compared to CIGS solar cells without plasmonic nanoparticles. This study highlights the effective utilization of plasmonic nanoparticles for efficient light absorption, which enables thickness reduction of high-efficiency thin-film solar cells.

Keywords: CIGS, FEM simulation, Gold Nanoparticles, Plasmonics, Thin film solar cells