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Performances Enhancement of Thin Film a-Si:H Photovoltaic Devices by incorporating Ag Nanoparticles (Ag NPs)

Peiqing Yu[1*], Jean-Philippe Blondeau[1], Esidor Ntsoenzok[1], Caroline Andreazza[3], Timothée Pingault[1], Perrine Dutheil[2], Anne Lise Thomann[2], Amael Caillard[2], Julien Roussel[4], Elyaakoubi Mustapha[5], Jacque Meot[5], Christophe Longeaud[6], Alexandre Jaffré[6], Eric Millon[4]

[1]CEMTHI UPR3079-Site Cyclotron, CNRS, 45071 Orléans, France
[2]CRMD FRE 35201, CNRS, 45100 Orléans, France
[3]PRISME UPRES 42298, Université d'Orléans, 45072 Orléans, France
[4]Gremi UMR7344, CNRS/Université d'Orléans, 45067 Orléans, France
[5]SOLEMS, 91120 Palaiseau, France
[6]GeePs(LGEP-UMR 8507), Centrale SUPELEC-CNRS

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Thin-film a-Si:H solar cells offer the benefit of reducing material consumption and fabrication costs. Additional benefits include advantages of light-weight and possible flexible devices by roll-to-roll deposition processing. However, such thin absorbing layer reduces the photovoltaic efficiency, due to the decrease in a-Si:H layer optical path length and its poor light absorption at red and near-infrared (NIR) wavelengths. Metal NPs such as Ag can exhibit strong localized surface plasmon resonances (SPR) at UV, visible and NIR wavelengths. Their optical properties can be tuned by changing their size, shape, or by altering the local dielectric environment. They have been shown to increase the absorption in the active material and then the cell performances. However, NPs size and position in such cells need to be optimized. Our work's goal is to understand NPs influence in such cells and to perform an optimal structure by increasing the light absorbed within the cell using NPs scattering and luminescence.

Modeling based on Mie theory is first carried out with bhmie program using bulk Palik data. The SPR proprieties of an Ag sphere are calculated for various diameters and refractive medium indexes. Using simulation parameters, ultra-thin Ag layers were deposited on different SnO2 substrates by Plasma sputtering magnetron at 300°C during 1 minute. We obtained NPs with diameters include from 10-100nm, with various shapes.

UV-Visible spectroscopy displays localized SPR around 520nm and 580nm respectively for Ag layers on different SnO2 substrates. Correlated with SEM images and simulation results, these SPR allow us to assume: 1) Ag NPs were formed in air (n=1) and within Ag oxide (n=2.5) because of the oxidation during/after the deposition; 2) Ag NPs shapes play an important role to SPR in such layers.

Thin films a-Si:H solar cells with Ag NPs based on these results were prepared. Characterized with Spectral Response, the configuration in NIP junction with the Ag NPs in back contact optimizes the photovoltaic properties with a performance improvement about 14%-19%. It is the best improvement induced by NPs in such cells reported so far. This improvement observed at wavelength between 550~750nm is due to Ag NP backscattering, based on one/both of two above assumptions. Our future work focus on the confirmation of Ag oxide and Ag NPs shape influence (simulation).

Keywords: Plasmon, photovoltaic, nanoparticles, silver, modeling