Light Absorption Enhancement in Thin Film Hydrgenated Amorphus Si Solar Cells

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***Abstract*—In this paper, light absorption enhancement in thin film solar cell (SC) is reported and analyzed. The suggested design is based on a nanostructured pattern that increases the diffuse scattered component of radiation and hence the absorption through the active layer. An ion beam sputtering (IBS) approach is used to texture large areas of the glass substrate with high aspect-ratio ripples in order to increase light scattering. Then, thin film SC supported on the textured glass is simulated and analyzed using 3D finite difference time domain (FDTD) method. The suggested SC can offer an ultimate efficiency of 19.26% with short circuit current of 15.76 mA/cm^2 with an enhancement of 31.435% over the SC without texturing surface.**

Keywords— thin film solar cell; finite difference time domain; textured glasses.

I. INTRODUCTION

Recently, thin film solar cells (TF-SCs) have aroused great interest of researchers to minimize the cost of the photovoltaic devices. However, amorphous TF-SCs suffer from quite low carrier life time and short diffusion length. In order to increase light absorption in TF-SCs, light trapping techniques employing random textures or periodic grating structures can be used to increase the effective optical path length in a wide range of wavelengths. Photo-current enhancement in TF-SCs can be obtained using pseudo-periodic and random interface textures either at the front electrode or at the back reflector [1-2] since a large number of diffraction orders can be excited.

The aim of this paper is to demonstrate the feasibility of light trapping enhancement over a broad wavelength range employing nanofabrication methods based on self-organized approaches. Moreover, with the aim to meet large scale and cost effective production requirements, the potential of self-organized techniques based on ion beam sputtering (IBS) is explored.

II. AFM ANALYSIS

Figure 1 shows the AFM topography of the nanostructured glass fabricated by defocused IBS at grazing incidence (θ=82°) through a self-organized sacrificial Au nanowire stencil mask. We stress that pseudo-periodic one-dimensional nanostructures (figure 1), elongated along the in-plane ion beam direction (red arrow), can be obtained over cm^2 area. AFM analysis allows to extract the relevant morphological parameters like root mean square roughness, in the range of 140 nm, and lateral periodicity distribution, which spans from about 200 nm to more than 1000 nm. Such a broadband distribution of surface features induces interesting behavior from the optical point of view. Optical investigation was carried out by measuring total and diffuse reflectance spectra in the VIS-NIR range by means of an integrating sphere. Textured glasses show broadband reduction of reflectance and enhanced scattering properties [3, 4]: Textured glass reflects 10% less light than a flat glass and shows that almost 60% of the light is scattered away from the specular angle of reflection indicating a Haze of 60% over the VIS-NIR spectrum.

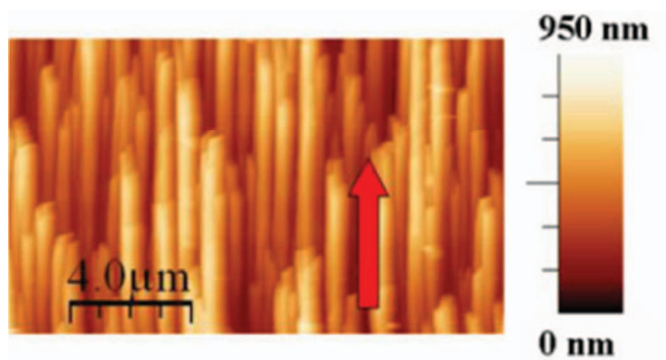

Fig. 1. AFM topography of nanostructured glass. Red arrow indicates the in-plane ion-beam direction.

III. SIMULATION METHODOLOGY

Figure 2 shows cross section of a unit cell of the suggested TF-SC which is grown on a nano-patterned glass in a superstrate configuration. The transmission, reflection, and absorption of the proposed SC are calculated using 3D-FDTD method via Lumerical software package [5]. The incident plane wave has an electric field linearly polarized along the x-axis and propagates normal to the x-y plane as shown in Fig. 2 (a). In this study, a simple sinusoidal pattern with A=150 nm and D=800 nm is used to represent the textured geometry. Due to the symmetry of the structure, the suggested design with only one periodic texturing is simulated with periodic boundary

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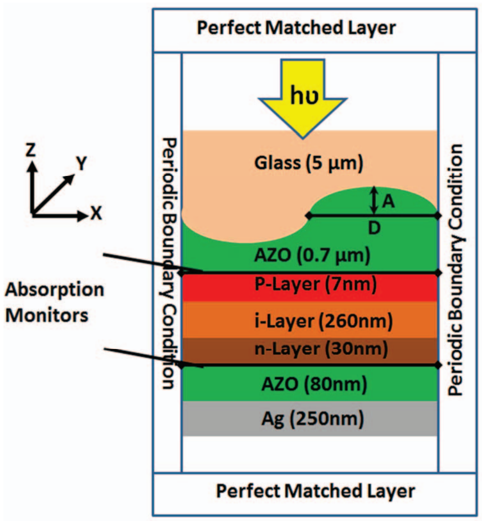
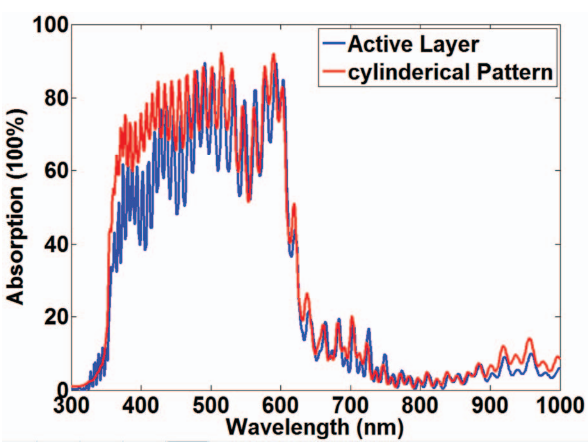
condition (BC) in x and y- directions. Additionally, a perfect matched layer (PML) boundary condition is used in z-direction to eliminate unnecessary reflections at the top and bottom boundaries of the simulated unit cell. Two frequency domain monitors are used to calculate the total reflection R(λ) and the transmission T (λ), respectively as shown in Fig. 2 (a). In order to calculate the absorption through the hydrogenated amorphous Si active layer only, other two monitors are placed above and below the active layer.



(a)



(b)

Fig. 2. (a) 2D side view of a unit cell of the proposed SC with periodic texturing, (b) Wavelength dependent absorption of the active layer of the thin film SC with and without surface texturing

The ultimate efficiency (η) can be used to evaluate the absorption capability of the proposed solar cell [6-9]. Figure 2(b) shows the wavelength dependent absorption of the active layer of the TF- SC with and without surface texturing. It may be observed from this figure that the absorption has been improved using the suggested texturing. Therefore, an ultimate efficiency of 19.26% with short circuit current of 15.76 mA/cm^2 has been achieved with an enhancement of 31.435% over the SC without textured surface. It is expected that the enhancement can be further improved when taking into account the randomness of the pseudo-periodic pattern. Additionally, the different geometrical parameters can be optimized to achieve broadband absorption enhancement using the texturing glass.

IV. Conclusion

High aspect ratio nanostructures formed by self-organized IBS process show high ability to enhance the effective optical path of photons into thin film PV devices and hence broadband absorption can be achieved. Further, the 3D-FDTD method shows that the TF-SC based on the textured glass offers an ultimate efficiency of 15.93% with short circuit current of 13 mA/cm^2 with an enhancement of 18% over the SC without textured surface. This improvement is due to light scattering at the corrugated interface which enhances the light absorption and hence the ultimate efficiency.

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