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ENHANCED LIGHT TRAPPING ON THIN-FILM SOLAR CELLS FROM SCATTERING NANO PARTICLE ARRAYS

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ABSTRACT

Thin-film solar cells focus on lowering the amount of material used as well as increasing the energy production. Inexpensive fabrication methods and effective light trapping are requisite for Thin Film solar cells to attain cost-competitiveness. The very optimistic reason is that the efficiency of a solar cell depends on both the quality of its semiconductor active layer, as well as on the presence of other dielectric and metallic structural components which improve light trapping and exploit plasmonicenhancement. Thin-film polycrystalline silicon is an attractive material for use in solar cells due to ideal band gap and its relative abundance. This paper keep in focus two main objectives, a highly scalable and inexpensive HWCVD deposition method that produces high quality material at minimal cost and the Evaluation of light trapping mechanisms employing FDTD simulations to determine the optimal expected optical characteristics of a thin-film device structure and to examine the potential of surface structures that will increase photon absorption in Thin-films.

Keywords: HWCVD, FDTD, Photon, Thin-film, Polycrystalline, plasmon.

1. INRTODUCTION

ThinFilim solar cells have aroused significant interest due to the reduction in the usage of materials and production of cost modules, a substantial amount of researches have been focused on lightweight and mechanically flexible thin-filmsolar cells.To realize highly efficient cells at minimal cost,HWCVD has been examined as a scalable and inexpensive deposition method of fabricating high quality thin-film silicon layers. Thebiggest problem for the thin-film solar cells is that they do not absorb as much as that of bulk solar cells .Methods for trapping light on thesurface, or inside the solar cells are crucial in order to make thin film solar cells viable. Surface structures were examined by modeling SOI structures with 220nm thick silicon device layers and decorating the surface with nanoparticle arrays of both metal and dielectric material. This is to gain insight into the potential for scattering structures on to the surface of a thin-film solar cell to increase the fraction of light incident and redirected laterally into the film,thus increasing the path length and absorption.
The careful examination of scattering cross section, Bloch modes,Thin-film wave guiding modes and Plasmonic near-field enhancement resulting from these surface arrays ,these observations finds significant enhancement in light capturing with these structures.

2. TECHNOLOGICAL CHALLENGES TO THINFILIM SOLAR CELLS

In this era of developing environment to be a viable alternative to the bulk-based solar cells, thin-film solar cells must offer a competitive efficiency. One of the main limitations to thin-film silicon solar cells is their inability to capture a large portion of the incident solar flux due to the indirect band gap and low absorption material .The research study focuses on light-trapping methods for these devices. This portrays several different approaches to light scattering

Physical scattering of light incident on both front and back of the cell,plasmonic near-field enhancement using metal nanoparticles and physical scattering into resonant modes of the scattering structures.

3. HOT-WIRE CHEMICAL VAPOUR DEPOSITION FOR SILICON THIN-FILIM GROWTH

HWCVD, also known as catalytic CVD (Cat-CVD), has emerged as a new technology for depositing materials at low temperatures without the use of plasma to decompose source gases. Since this technique is thermal in nature, it relies on a heated metal filament to decompose the gas species. Because there is no ion bombardment (as in PECVD), there is minimal substrate damage. HWCVD also allows for low pressures that can be used for gas phase decomposition, thereby making the technique ideal for material etching. In HWCVD, the substrate is decoupled from the deposition process; therefore, substrates can be introduced and removed from the deposition chamber without disturbing the deposition process. In addition, step coverage is excellent and uniformity can be readily optimized through adjustments of key deposition parameters.

HWCVD film growth is an attractive method for deposition of thin-film silicon for use in the manufacturing of photovoltaic devices due to efficient use of precursors,fast deposition rates, and passivation of defects due to hydrogen inclusion, while atthe same time offering scalability, low cost, and a low-temperature deposition processthat permits the use of low cost substrates This study therefore focuses on the correlation between both bulk and surface passivation with the electrical properties of the films, with the goal of maximizing the stabilized performance of HWCVDfilms for use in thin-film silicon solar cells.

A. HWCVD experimental setup

The deposition of thin films via HWCVD is accomplished by introducing gaseousprecursors into a vacuum chamber in which the gases then thermally and catalytically decompose at a resistively heated wire filament. Using silane and hydrogen as precursors, the silicon will break down to subspecies (H, Si, SiH0−3) and deposit onto the substrate. This process is accompanied by hydrogen etching of the surfaces well as H-deposition at dangling bonds, resulting in removal and redeposit ion ofspecies at the surface and bulk passivation where hydrogen is incorporated. The setup includes a cluster tool with a centralized vacuum chamber through which a robotic arm moves a substrate holder to the designated deposition chamber. The depositionchamber contains a substrate holder distanced from a wire assembly by 7cm. The wireassembly is connected to power via two electrical leads passed into the chamber andisolated with ceramic spacers; the wire is resistively heated to temperatures ranging from 1400◦C to 1700◦C as determined by an optical pyrometer.The samples were prepared with a heated RCA2 clean followed by a 30s buffered HF dip to remove, respectively, organic contaminants and the native oxide layer. The samples were then immediatelyplaced on the substrate holder and put under vacuum in the load lock of the clustertool.

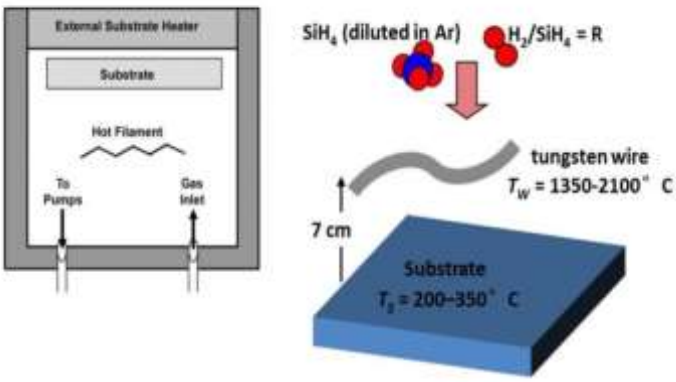

Figure 1: Schematic of vacuum chamber setup for HWCVD film growth

B. The fabrication of SOI with HWCVD emitter

The performance of HWCVD thin films for use in solar cell devices, thinfilm silicon test cells were fabricated using a 2µm c-Si device layer on oxide (SOI)structure as the base. The device design was based on the eventual use of a transparent glass superstrate and interdigitated back contacts for maximal carrier collectionwith minimal front shadowing. The fabrication steps include Sol wafer preparation followed by boron diffusion with silicon-etch through to p-type. It is then oxidized, after etching through oxide it is subjected to AG evaporation. It undergoes oxidation further and exposed to AL evaporation. By using a crystalline absorber layer and fabricating a suitably doped emitter, this control device can predict the highestexpected performance from HWCVD cells grown with the same geometry

4. LIGHT TRAPPING IN THIN FILMS

Here we focus on the light trapping techniques withmetal and dielectric nanoparticles.The results of full-field electromagnetic simulations of regular arrays of Ag nanoparticles on a thin film silicon structure exhibit tunable enhancement peaks in optical

Generation rates that vary with pitch and particle diameter. The wavelength at which these enhancement peaks are centered is controlled by the array pitch, while the amplitude and bandwidth of this peak is dictated by the diameter of the Ag nanoparticles.These models demonstrate the ability to optimize array geometry to maximize lighttrapping in the underlying thin-film silicon layer.Arrays of metal nanoparticles have demonstrated enhanced photocurrent generationdue to their plasmonic properties and increased effective scattering cross section. However, the performance of these types of devices is restricted by the losses.

due to light absorption in the metal and increased reflection at the surface from metalcoverage. An alternate technique for engineering structures that maximize light trapping in sub-micron silicon films is to exploit the scattering mechanisms of dielectricarrays on the surface of the absorbing material. The scattering properties of thesearrays are determined by the geometry and material properties of the surface features and by changing the size, pitch, and shape of these arrays, the light scattered intothe film and absorbed can be maximized

5. CONCLUSION

The HWCVD method has manifested itself as one of the most inexpensive fabrication methods, this is examined as a scalable and inexpensive deposition method of fabricating high quality thin-film silicon layers. By employing FDTD simulations to determine the optimal expected optical characteristics of the thinfilm device structure and to examine the potential of surface structures for increasing light absorption in these films. the incorporation of sub-micron surface structures on thin-film silicon has resulted in a dramatic increase in light absorption due to decreased reflectivity and increased light trapping enabled by the scattering characteristics of these surface structures. While both metal and dielectric arrays demonstrate this result, the use of periodic dielectric cylinders yielded significantly more enhancements in light absorption in the silicon film. With these observations we postulate a promising method for achieving inexpensive and highly efficient solar cells

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