SIMULATION STUDIES ON CRYSTALLINE SILICON BASED BACK HETEROJUNCTION SOLAR CELLS

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Introduction

- C-Si based point contact back heterojunction (BHJ) solar cell is a combination of front heterojunction cell, and back junction cell.
- BHJ solar cell is designed by combining the advantages of the front heterojunction cell and back junction cell1.
- Absence of front grids, interdigitated point contact structure at the rear side (from back junction cell); low processing temperature around 250°C, passivation by intrinsic a-Si:H on both sides of c-Si (from front heterojunction cell) was combined to form BHJ cell.
- In the BHJ solar cell structure:
- P-type a-Si:H emitter as well as both collection grids (for p-type and n-type contacts) is placed on the non-illuminating rear side of the c-Si wafer, with the collection grids forming an interdigitated pattern.
- This design eliminates reflective and shadowing losses, and also the trade-off between reflection and series resistance, thus allowing for sufficient contact metal, and thus reducing resistive losses.
- Back surface field was formed at the rear side of the wafer by using n-type a-Si:H.
- Also, in the BHJ structure, photovoltaic junction lies on the rear side of the wafer.
- The grid less front surface in the BHJ cell enhances light incident area and hence enhances Jsc as well as fill factor.
- As compared to front heterojunction structure, a TCO layer and a-Si:H emitter layer on the front side are not required in the e BHJ structure.
- Therefore, TCO absorption loss and emitter absorption loss in the short wavelength region can be avoided. This improves IQE of the cell in the short wavelength region.
- Point contact structure in this cell provides additional advantages over a line-contact structure. This includes increased cell output voltage because of a reduced emitter component of the dark current.
- Furthermore, when contacts are reduced to points, built-in electric field at the backside can trap charge carriers and yield high collection efficiency when lightly doped or undoped c-Si wafers are used for fabrication.

Simulation details

- Schematic cross section and rear side geometry of the BHJ cell is shown in Figs 1 and 2 respectively.

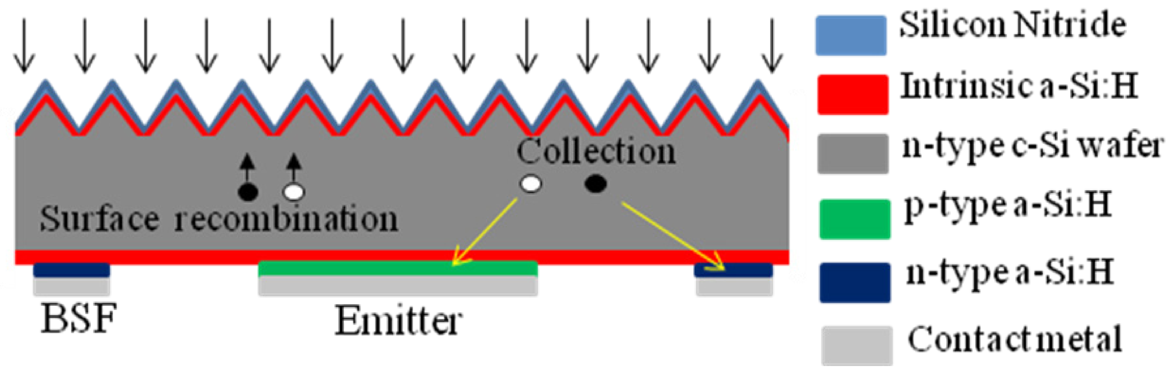

Fig. 1 Schematic cross-section of BHJ solar cell.

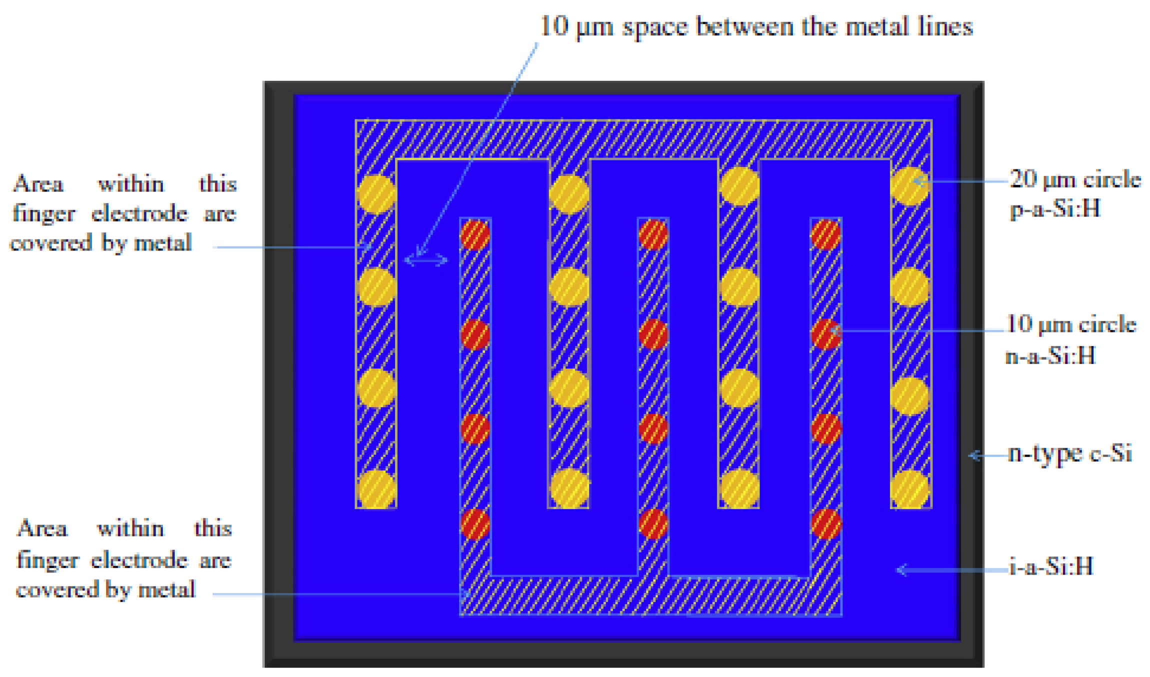

Fig. 2 Illustration of rear side geometry of the back heterojunction (a-Si:H/c-Si) solar cell. Here, p-type a-Si:H and n-type a-Si:H doped areas are shown as colored circles having diameter of 20 μm and 10 μm respectively[2].

- For our study we utilized Silvaco Atlas tools to study carrier generation-recombination, mid-gap traps, and photogeneration rate (by ray tracing) in BHJ cell structures[3].
- Tracing algorithm, i.e. ray-tracing program, has been used to trace individual light rays through the cell until they leave the solar cell or absorbed.
- Light-trapping was not considered in our simulation studies since no texturing was considered, and we used all material layers to study electrical properties in different regions of the device.
- Simulations were performed by solving Poisson's equation and continuity equations for electrons and holes simultaneously.
- Drift–diffusion model was used to solve continuity equations for electrons and holes.
- Shockley–Read–Hall (SRH) recombination model, i.e. trap-assisted recombination model, used in the study is a function of impurity concentration and describes the recombination in presence of defects (or traps) within the forbidden gap of the semiconductor.
- Heterojunction effects were activated using different band gap parameter, electron affinity, density-of-states (DOS), and mobility in different materials.

Results and Conclusion

- Figure 3 shows the dark and light I-V characteristics for the cell with an emitter (p-a-Si:H) band gap of 1.72 eV, for which the best cell performance is obtained.
- As can be seen, the forward biased dark I-V curve resembles the I-V curve for a forward biased diode, and the current results from the sum of both drift and diffusion currents.
- Under illumination, the I-V curve is shifted downwards due to the photogenerated current (Fig.3).

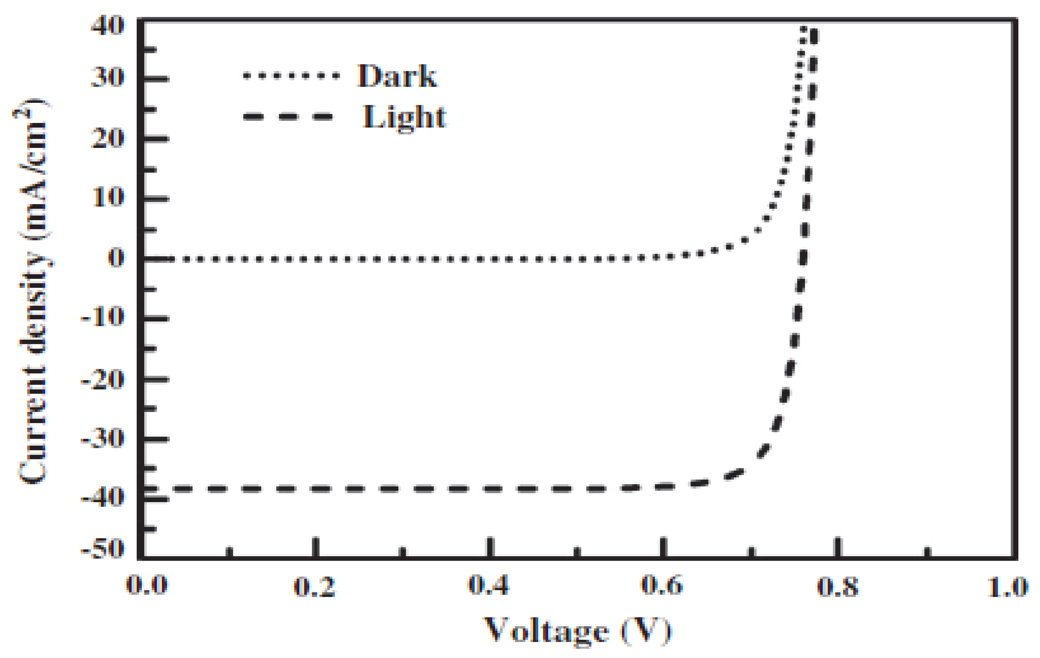

Fig.3 Dark and light I-V curves under forward bias.

- An efficiency of 24.49% (Fig. 3) has been obtained with a V_{oc} of 760 V, J_{sc} of 38.29 mA/cm2, and FF of 84.2.
- Further improvement in efficiency has been obtained by using texturization in the structure (Fig. 1).
  - In this case, an efficiency as high as 26.6% was obtained with 761 mV Voc, 41 mA/cm2 Jsc, and 84.5% FF for a small pyramid structure with 2 μm height and 4 μm base width.
- An experimental efficiency of 25.56% has been reported4. In our simulation study, an efficiency of 26.6% has been obtained.
- In conclusion, the operation of a c-Si based BHJ solar cell has been investigated. The solar cell demonstrates the potential for a very high efficiency.

References

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