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Development of n-µc-SiO:H as a back reflector and its application to Amorphous Silicon Solar Cells

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Abstract

The use of 'doped silicon oxide based microcrystalline' material as a potential candidate for cost-effective and reliable back reflector layer (BRL) for single junction and intermediate reflecting layer (IRL) for micromorph double tandem solar cells is discussed in this article. The doped µc-SiO:H layers with a refractive index close to 2 and with suitable electrical properties were fabricated by radio frequency plasma enhanced chemical vapor deposition (RF-PECVD) technique, using the conventional capacitively coupled reactors. Optoelectronic properties of these layers were controlled by varying the oxygen content within the film. The performance of these layers as BRL have been investigated by incorporating them in a single junction amorphous silicon solar cells and are compared with the conventional ZnO:Al based solar cells. It is found that the oxide based BRL shows similar performances compared to that of conventional layer. The main advantage with this technique is that it can avoid an ex situ deposition of ZnO:Al, by using doped SiO:H based material deposited in the same reactor and with the same process gases as used for thin-film silicon solar cells. Initial single junction a-Si solar cell efficiency of 8.95% (V_{oc} = 0.88 V, FF = 0.70, Current density = 14.53 mA/cm^2) is achieved by using doped SiO:H based material as a back reflector.

Key word: Back reflector layer (BRL), n-µc-SiO:H, single junction a-Si cell.

Explanatory Pages

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Motivation of this work

Thickness of the absorber layer for single junction a-Si solar cell is kept reasonably less to reduce the light induced degradation. This reduction of the absorber layer thickness has been compensated by using a back reflector to reflect back the unabsorbed light in one pass within the cell. The refractive index of the back reflector must be lower (typically n_{BR} ~ 2.0) than that of silicon (n_{Si} ~ 3.7 at 600nm). Moreover, it should be conductive enough to avoid series resistance of the device, and also be transparent enough to minimize the absorption loss. Conventionally, ZnO:Al has been used extensively as a back reflector, but for this the device needs to be taken out from the PECVD reactor and the deposition of ZnO needs to be done in another sputtering or LPCVD system. This was the motivation to develop silicon based material to replace the ZnO:Al so that the deposition of the entire structure can be done in the same reactor without breaking the vacuum, enabling reduced production cost and process complexity.

Doped silicon oxide based microcrystalline material has been developed by using radio frequency plasma enhanced chemical vapor deposition (RF-PECVD) technique. Material has been studied in detail by FTIR spectroscopy, Raman spectroscopy, Ellipsometry and conductivity and activation energy measurements. The material layer with optimized optoelectronic properties were used to fabricate the back reflector layer (BRL) for single junction solar cells [1].

Results & Discussions

Optical E_{04} value is evaluated to be ~ 2.27 eV from optical density obtained from UV-Vis spectro photometer. The absorption spectrum is shown in figure 1. Raman spectrophotometer was used to determine the crystalline fraction in the films which is ~ 38%. The Raman spectra [2] taken around the 520 cm^{-1} peak is shown in figure 2.

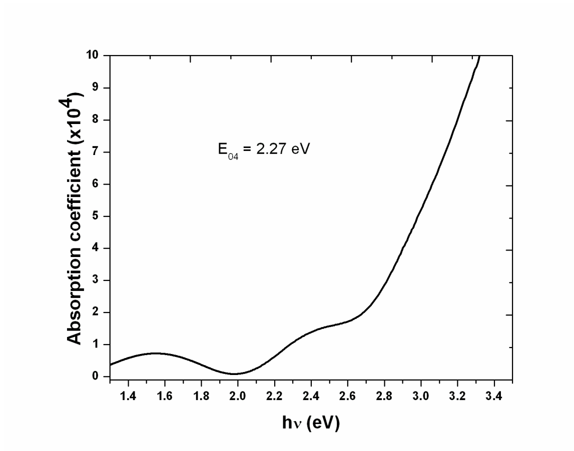


Fig. 1: Variation of absorption coefficient with energy for n-µc-SiO:H material

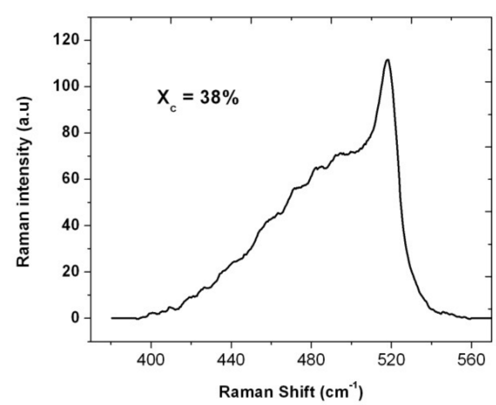


Fig. 2: Raman spectra of n-µc-SiO:H material

Refractive index of the material was calculated in different ways to confirm the exact value. Three different routes were used: reflection measurement [3], Swanepoel's method [4] and Ellipsometric measurement. Using both reflection and Swanepoel's method, we got refractive index value of ~2.2 at 600nm which is in good agreement with the Ellipsometry measurements.

The FTIR data of the oxide materials were used to determine the oxygen content in the films as well as to study the bonding configuration. Atomic percent of oxygen C(O) [5] incorporated in the film is obtained from the integrated absorption strength of IR absorption in the range of 900 - 1200 cm^{-1} [6], and it is found to be 34%. IR absorption spectrum is shown in figure 3.

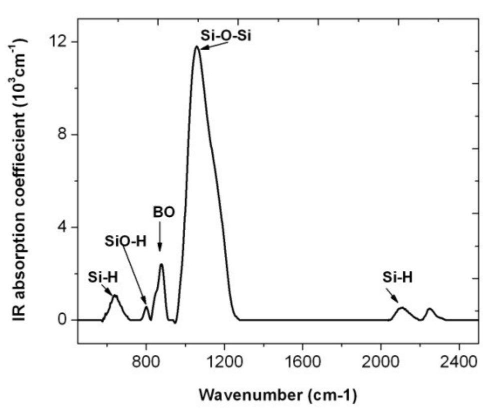
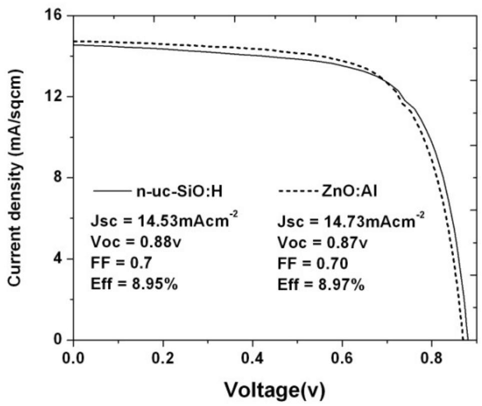


Fig.3 Full range IR absorption spectra of n-µc-SiO:H films deposited on Si wafer.

In single junction a-Si solar cells, the n-µc-SiO:H layer was used as back reflector, and the performance of this solar cell was compared with solar cells with conventional ZnO:Al back reflector. It is observed that similar performance can be obtained by using the optimized n-

μc-SiO:H layer as the back reflector instead of the conventionally used ZnO:Al. Comparison of the IV and EQE curves are given in figure 4 and figure 5, respectively.



4: Comparison of IV curve for different back reflector

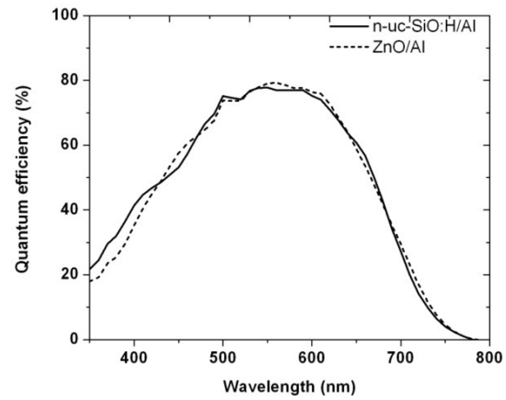


Fig. 5: Comparison of EQE curve for different back reflector

Conclusion

Silicon oxide (n-μc-SiO:H) based BRL has been successfully developed and applied to single junction a-Si solar cells. Comparable performance to the conventional ZnO:Al based back reflector has been demonstrated. This can lead to twin advantages: the ability to fabricate the solar cell structure (excluding metallization) without breaking vacuum in same PECVD reactor, and also lead to considerable reduction in cost as well as process complexity by eliminating the ZnO:Al back reflector layer.

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