ABSTRACT

Recently, high efficiency ($>20\%$) silicon p-n junction passivated emitter solar cell has been demonstrated using the V-groove/serrated emitter structure. In this V-groove solar cell, the p-n junction boundaries are parallel to the oblique $\langle 111 \rangle$ front surface. Naturally, the motions of the charge carriers are two-dimensional about the junction boundaries. Thus, a 1-D device model is inadequate for the theoretical study of such type of cell structures. A 2-D device model is needed for the analysis of this cell structure. To the best of our knowledge, there has been no theoretical modelling and analysis of this structure so far.

In this investigation, a 2-D modelling and analysis of the V-groove/serrated silicon solar cells has been done using the double Fourier transform technique. A 2-D ray-tracing model has been developed to compute the 2-D optical generation rates for the V-groove solar cells. A 2-D analytical model formula for these structures has been also developed using the double Fourier transform technique on the basis of the generation rate data computed by using the ray-tracing model. This model formula has been the key of success for the present 2-D device modelling and analysis, for it became possible to apply the technique of separation of variables with this model

formula only to solve the relevant 2-D minority carrier transport equations with appropriate boundary conditions for the V-groove solar cells. The developments of these 2-D ray-tracing model for optical generation rate and the 2-D device modelling and analysis of the V-groove solar cells may be considered as the significant contributions of the present investigation.

A bandgap narrowing (BGN) model has been also developed in which the position-dependant dielectric function and the Fermi-Dirac Statistics have been incorporated. This BGN model exhibits excellent agreement with the existing experimental results for n-type and p-type silicon and germanium.

In the present work, there has been useful modelling on the Fermi-Dirac integrals (FDI) of half-integer orders between -3/2 and 11/2 for the range $-4.0 \leq \eta_r \leq 20.0$ (η_r is the reduced Fermi energy) with an RMS error less than 1.0, the tolerable limit. The BGN and FDI models have been incorporated in the present 2-D device modelling and analysis. It appears from our simulation results that more investigation is yet needed on BGN, because none of the existing models can account for the experimentally found very high open circuit voltage ($\sim$680 mV).

In addition, there have been accurate and useful modelling on the photon-flux densities and the 1-D optical generation rates (for silicon over the range of distance, 0 to 1000 μm) for AM0, AM1, AM1.5 and AM2 spectra. These modelling have been very much useful for the computation of point-by-point generation rate in course of the development of the 2-D ray-tracing model.

The most of the algorithms and methods discussed in the thesis have been implemented in a solar cell analysis code named KISCAMEL, developed by the author, currently running on the HP-9000, series 500 computer system. Comparisons between the simulation results and the existing experimental results have been made in this thesis. Agreement between the simulation results from KISCAMEL on the V-groove solar cells and the experimental results has been found satisfactory. Thus, the present 2-D device modelling and analysis of the V-groove/serrated solar cells has been a successful initial step on the subject.