MON-Cell Designer: An interactive Computer Program for Quantum Well Solar Cell Designers

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Abstract
In this paper the authors place forth the current research being undertaken at Monash University regarding Quantum well solar cells (QWSC). Currently the Solar Energy Applications Research Group (SEARG) is undertaking the development of an interactive computer program which is intended to be a researchers design tool (in a similar fashion as PSPICE is for electronics). The program is to be an optimisation toolbox and aid in achieving better efficient designs. The program is based on previous work undertaken by the research group and its implementation into computer algorithms. It is to be a C/C++ based program and Windows interactive. Presently, the program is limited to certain functions but it is hoped that future developments will be rapid. Currently the program can be used to optimise a design through optical and photo-carrier means.

INTRODUCTION

Professor Keith Barnham of Imperial College, London, developed the Quantum well solar cell (QWSC) in the 1990s. This remarkable device has shown great potential in achieving high efficiency beyond the 30% and 50% (under concentration) [1]. Since then the QWSC has been researched by a number of institutes and progress has been extensive. Many have developed QWSCs with efficiencies in excess of 25% [2].

For the past two years the SEARG research group at Monash University has been computationally modeling the Quantum well solar cell. The main focus on the work has been modeling of the optical and photo-carrier aspects of this revolutionary cell. It is hoped that through better understandings developed through mathematical and computational modeling an optimised design can be achieved and hopefully a cell with better performance achieved.

The development of the previous mathematical models [3-8] has led to a step closer in achieving the final goal. It has also lead to the development of MON-Cell designer. This is an interactive computer program, which can be used by researchers to design a QWSC. The program was developed through the correlation of the previously recognized work. Similar programs exist including University of New South Wales' PC1D and Sandia Labs' I-V tracer however these do not target QWSCs.

The program was designed to computationally model and determine the effects design parameters such as molar concentration, doping concentration, operating temperature, cell dimension and electric field have on the refractive index of the QWSC. Through this, determination of the cells reflective losses is achieved and the introduction of an antireflection coating is also possible.

Along side the "optical model", algorithms based on previous work has allowed for the development of a "photo-carrier model". The program presently can determine the radiative recombination lifetimes of an electron-hole pair within the respective quantum wells (conduction/valence) of the QWSC. Further research has also included the determination of the effects design parameters such as molar concentration, doping levels and operating temperature has on the Auger, Radiative and Shockley, Read, Hall (SRH) lifetimes in alloys.

In order to determine the design's performance the current density versus voltage (J-V) curve and associated efficiency is determined using an existing model [9-11]. Although limited to the above features it is hoped that development and further improvement of the computer program though the request of fellow researchers will be undertaken.
SOFTWARE BASE

With all the relevant mathematical models set up, Microsoft's Visual C/C++ (MVC) package was utilized to develop a beta version of the proposed Windows interactive program. The rationale behind the selection of this package was due to the ease of use, with extensive examples and online tutorials. The process of development for the program involved three sections. The first was the incorporation of a graphical user interface (GUI) to emulate the windows type environment such as tabs, buttons, edit boxes, etc. This process was achieved through the use of 'drag and drop' method similar to packages such as IRONCAD and PSPICE where a toolbox window containing the necessary parts/components was selected. From this, MVC was able to establish, in the language level, the necessary functions for modification. Further manipulation of the GUI could then be later accomplished by accessing these functions.

The second section was the translation of the mathematical models generated for QWSC. Coding for determining the refractive index, reflectivity, current density and radiative recombination was achieved by using C/C++ math library. Memory size and complex mathematical operations were some of the issues considered during coding. Finally, for the third section, this involved interfacing the GUI with the QWSC model. The determination of inputs and respective outputs had to be debugged. Likewise, data manipulation, transfers, storage and the overall operation of the program were scrutinized to make sure that certain processes did not stall, or to cause the program from crashing. Finally, the authors took into consideration the aesthetic aspect of the GUI design. It was important to avoid difficult to understand prompts or make the graphical output too small, but rather to allow intuitive learning and to produce an interface which is like most Windows applications which is familiar and easy to use.

COMPUTER PROGRAM

This version of the QWSC interactive program allows the user to model conditions, which may not be easily generated under normal testing environments. Four possible graphical results can be generated to reveal the performance under these tests. Furthermore, a dialog window containing information such as cell efficiency, fill factor, short circuit current and open circuit voltage allow convenient access for users. It is hoped that for future work, the ability to introduce multiple models will allow for easy comparison as well as a database option from which the user can access results for the different testing conditions considered. Indeed one could also incorporate the optimization algorithm to increase the usefulness of this program, which will benefit cell designers greatly.

Below are the display windows generated for certain test conditions. It has the capability to display more results, but currently, open-circuit voltage, short-circuit current, maximum voltage and current, fill factor and cell efficiency are shown:

![Figure 1: Display window generated to reveal results of solar cell operation](image-url)
Below is the main window where the user can input a range of inputs such as the molar concentrations, doping concentrations, lengths, etc, to calculate the performance of the QWSC:

![Main interactive window of the QWSC simulator](image)

Figure 2: Main interactive window of the QWSC simulator where the user can simulate different operating conditions

There is a graphic which represents symbolically the P, i and N layers, these graphics are filled in when the user adds any of the three components — it is also used to indicate to the user which layers are ready and contains the necessary data for calculation. For ease of use, the units have been conveniently converted to common dimensional sizes such as nanometres and centimetres. There is an ‘Add’ and ‘Clear’ button, which allows the user to at anytime alter data if necessary. The ‘Specs.’ button opens the window shown in Figure 1 and the ‘Execute’ button generates the relevant graphical results (shown in Figure 3).

For future developments, the project database can be incorporated to allow easy access to other results that can be used for comparison purposes. Furthermore, a button can be added to activate an ‘optimization’ operation so that the user can determine from a set of data, a realistic performance value for efficiency.

Though not shown, the user has the capability to ‘save’ and ‘open’ files, which contain results that has been or previously generated. Therefore reinserting data information once again is not necessary. It is hoped that a ‘print’ function will also be incorporated in a later version to obtain hard copies of results generated which can then be used for reporting purposes.

Below are the sets of graphical results generated once all inputs have been inserted:
Figure 3: The graphical output plotting the results, in this case, the JV curve

The graphs have been developed to display the necessary characteristics for comparison purposes; the axes have been labelled and factored to allow accurate reading. The tab buttons allows the user to literally scroll through the four results generated as shown. Thus the initial steps to developing a more sophisticated program is well under way with most of the backbone of this project completed.

CONCLUSIONS

From preliminary results, the QWSC interactive windows program beta version show great promise as a designer's tool in the development of solar cells in this area. The results generated do reflect those obtained theoretically. The GUI has been aesthetically designed to minimize messy calculations but rather, it attempts to produce accurate and visually useful results. It is hoped that future advances will culminate in a commercially available product, which will allow users to continue further research in this revolutionary field.

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