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LabVIEW Application to Characteristize Low Cost Solar Cell based on Solution Processed Quantum Dots and Nanocrystals

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***Abstract*— The demand for solar cells, which converts sunlight directly into electricity, is growing. Solar or photovoltaic (PV) cells are prepared by semiconductor material that absorbs the photons from sunlight releasing electrons, due to which an electric current flows when the cell is connected to a load. This traditional semiconductor material is replaced by solution-processed quantum dot material to lower down the overall cost of the device. This paper shows the synthesis, fabrication, and characterization of the PbSe quantum dot solar cells using LabVIEW tool.The paper describes a LabVIEW application to measure the current and voltage characteristics of quantum dot solar cell under illuminated conditions. The desired parameters of quantum dot solar cells including fill factor, efficiency, short-circuit current, open-circuit voltage are calculated. The characteristics of the quantum dot solar cell have been drawn quickly using the LabVIEW tool. All the details of the LabVIEW VIs are shown in this paper and experimental results obtained are presented.**

Keywords—Quantum dot solar cell ,PbSe, LabVIEW VI, fill factor, characterization

I. INTRODUCTION

A solar cell also called as a photovoltaic device is an electrical device that converts the energy of light directly into electricity by the effect known as photovoltaic. The electrical characteristics, such as current, voltage, or resistance of such device vary when exposed to light. Solar energy collection requires a combination of low cost and high efficiency in order to overcome balance-of-systems costs. Sun emits energy in form waves. These waves can range in length from ultraviolet, visible and infrared.When the light from sun hits the surface of the solar cell,only the light from wavelength ranging from 350 nm to 1150nm is absorbed and the photons are transferred to the active layer of the cell.The smallest possible element of this light wave is called photon. The energy of the photon is inversely proportional to its wavelength. Higher the frequency ,lower the energy.IF the energy band gap of this photon is equivalent to the band gap energy of the active material in the cell,then this photon promotes the generation on free electron in the material,thereby electricity is generated in the circuit.Now thin film solar cells are the third generation of the photovolataic technology.Its the alternative to the monocrystalline and polycyrstaline silicon solar cells.These solar cell requires very less material,easily processable,easy to fabricate and cheaper to manufacture.Theoritical efficiency in thin film solar cells is higher than that of the previous two generation cells.Thats why,lot of research is going on into this area.hte thin film solar cells uses solution processed quantum dot material as an active material to generate the electricity.In this paper ,a brief description of a quantum dot solar cell is mentioned along with the development of an application to characterize this cell. Quantum dots (QDs) are man-made nanoscale crystals transporting electrons through the device. When UV wavelength light strikes these semiconducting nanoparticles, they emit wavelength of various colors. The electronic properties of such materials are in-between between those of bulk semiconductors and of discrete molecules. A bound state of an electron hole attracted towards each other by an electrostatic coulomb force is called as an exciton.An exciton being confined in all three directions acts as an elementary excitation of condensed matter transporting energy without transporting net electric charge. Quantum dots emit three electrons per photon due to effect called multiple exciton generation (MEG), contrasting to only one for standard crystalline silicon solar cell. Theoretically, this could boost solar power efficiency from 20 % to as high as 65 %.

Theoretically,the device must absorb as much light as possible.The QDs are able to absorb the photons from the region of visible light.

The three important parameters that characterize the performance of a photovoltaic cell are the open-circuit voltage (Voc), the short circuit current (Isc), and the fill factor (FF) fill factor is being the function of Voc and Isc. Therefore, Voc and Isc are key factors for determining the cell’s power conversion efficiency. Under ideal conditions an electron flows in the external circuit when each photon hitting the cell has energy greater than the band gap. The maximum area of the I-V characteristics under illumination is the fill factor and the short circuit current and open circuit voltage.

$$FF = \frac{VmpImp}{VocIsc}$$

Where Vmp and Imp are the voltage at the operating point. The efficiency is given by[7]

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$$\eta = \frac{VocIscFF}{Pin}$$

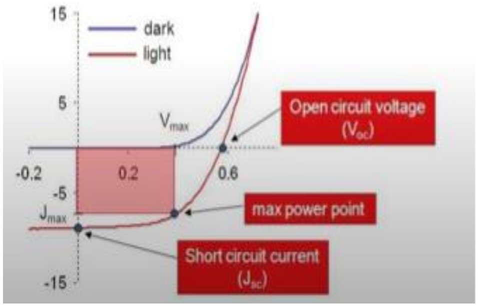

Figure 1:IV characteristics of a QD solar cell

Figure 1 shows the IV Characteristics of the QD solar cell.The Jsc is the short circuit current at zero applied bias to the device.Voc is the open circuit voltage that is the at which we have zero current.Fill factor is the area between the curve of maximum power point.Thus a high current density (Jsc) while maximizing the amount of work extracted from each absorbed photon via a large open-circuit voltage (Voc) and fill factor (FF) is produced.

To get these current at the appliaed bias voltage,the high precision source meter from keithley and Agilent is used. In order to get measure and monitor the data automatically from the device labview application have been developed which is presented in the paper.LAbVIEW tool is used as a data acquisition tool to interface and interact the high precision source meter to the supervisory computer.

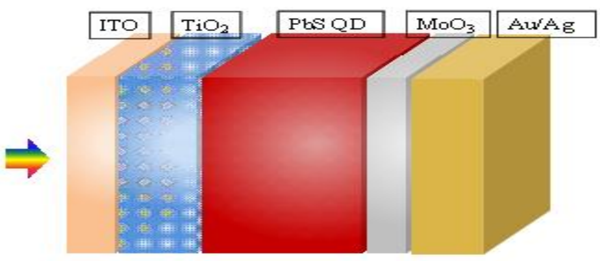

Figure 2:PbSe quantum dot solar cell structure

Figure 2 shows the device structure.It is as: transparent conducting electrode (TCE)/n-type layer/PbS QD/MoO3/Au/Ag.ITO and FTO substrates were first cleaned in soap solution followed by 10 minutes of sonication each in, distilled water, acetone and ethanol in the given order. ITO has high tempreture co-efficient which makes it a good material at even high tempreture. Finally ITO substrates were cleaned in boiling isopropanol for five minutes before film deposition. For low temperature processing of n-type TiO2 or Nb doped TiO2 layer deposition, the appropriate precursor solution were spin coated at 2500 rpm on top of ITO. The films were then annealed at 70°c for 30 minutes. The substrates were then kept aside to cool down to room temperature. Small amount of Millipore water was added to them at steady state followed by rotation at 2500 rpm for 1 minute. The substrates were then heated to150 °C for another 30 minutes. [1]

The device was fabricated using the thermal evaporation technique. The solid material is heated inside a high vacuum chamber, rising its temperature to the extent so that some vapor pressure is produced. This evaporated material now converts into a vapor stream, traversing through the chamber hits the substrate and sticks to it as a coating or film. [1]

II. METHODOLOGY

As discussed above, the three important parameters that characterize the performance of a photovoltaic cell are the open-circuit voltage (Voc), the short circuit current (Isc), and the fill factor (FF) .Fill factor is the function of Voc and Isc..So,Voc and Isc are key factors for determining the cell's power conversion efficiency. Here,we are not only concerned about the input wavelength but also the power of the input wavelengthSo we must consider two different spectrum AM0 and AM1.5.Air mass is the direct optical path length for the sunlight coming through the earth's atmosphere. Under ideal conditions an electron flows in the external circuit when each photon hitting the cell has energy greater than the band gap. The maximum area of the I-V characteristics under illumination is the fill factor and the short circuit current and open circuit voltage as discussed above.

A. Block diagram

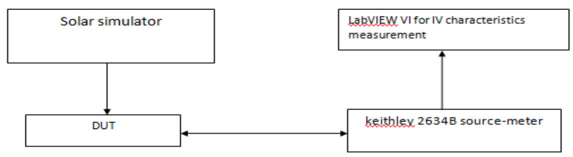

Figure 3: Block diagram of data acquisition of the quantum dot solar cell using LabVIEW

Figure 3 shows the block diagram of the data acquisition of the quantum dot solar cell using labVIEW. Class-AAA solar simulator from Peccell technologies (PEC-L01) was used to shine the illumination intensity of AM1.5. A shadow mask was used in front of the device under test(DUT) to match the illuminated area closely with the device area. Current-voltage measurement of the device was carried out with a keithley 2634B source-meter under ambient condition integrated with LabVIEW for monitoring and processing the data. Laboratory Virtual Instrument Engineering Workbench (LabVIEW) is a system-design platform and development environment for a visual programming language from National Instruments. The hardware interface and integration is made super easy with the engineering applications to acquire and visualize data sets from virtually any I/O device.Labview provides the user to develop their own programs for the data acquisition with the help of very simple graphical language.

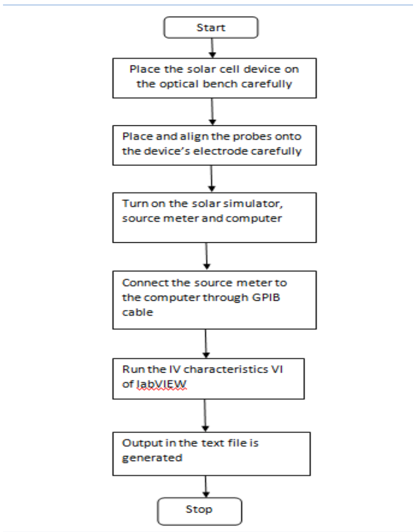

Figure 4:Flowchart of the project

Figure 4 shows the flowchart. The PbSe quantum dot is placed on the optical bench carefully and connected to the channel A or channel B of the source meter through the platinum probes which are highly precise and sensitive.

LabVIEW programs-subroutines are called virtual instruments (VIs). Each VI consists of two components: a block diagram and a front panel.

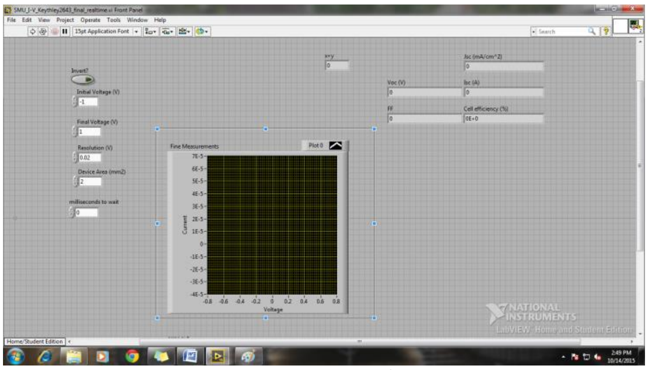

Figure 5: Front Panel of the VI

The front panel includes controls and indicators and is the user interface for the VI. Through the front panel, the user enters device parameter values for initial voltage, final voltage, resolution, and device area based on which code in block diagram runs. After successful execution of the code output i.e, the IV characteristics of the device get displayed on the graph of front panel and also get saved as a text file that can be used later.

Figure 6 below shows the block diagram of IV characteristics VI part1. The actual graphical source code of a LabVIEW program is written in a block diagram. It is used to separate the graphical source code from the user interface in a logical and simple manner. Terminals in the block diagram are the objects from the front panel.

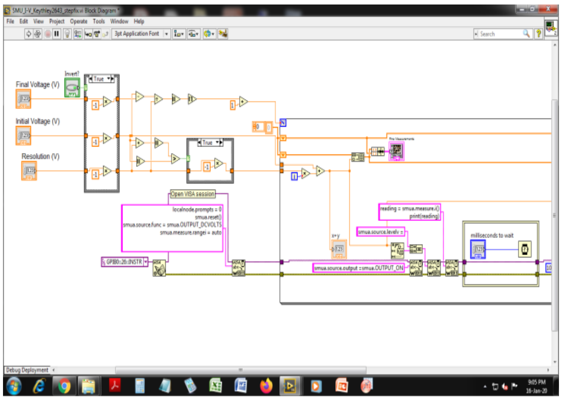

Figure 6:Block Diagram of IV Characteristics measurement VI part 1

Keithley 2634B source-meter is connected to the computer through GPIB cable at the address GPIB0::23::INSTR and keithley 2643B is connected at the address GPIB0::24::INSTR.VI starts with the opening of the VISA session for Keithley's 2634B instrument. It is the Virtual Instrument Software Architecture (VISA) API. NI-VISA is an API that provides a programming interface to control GPIB in NI application development environments like LabVIEW. The API is installed through the NI-VISA driver.VISA Configure Serial Port VI initializes the serial port specified by the VISA resource name to the specified settings for Keithley's 2634B precision source meter. The program enters into for loop and iterates in steps until the difference between final voltage and initial voltage is zero. The program enters into the loop.For each iteration it communicates with Keithley 2634B Source Meter, the first write VI of LabVIEW fetches the current as of the output from the source meter and stores it into the buffer. The second write VI reads the voltage provided by the mathematical logic for the loop.

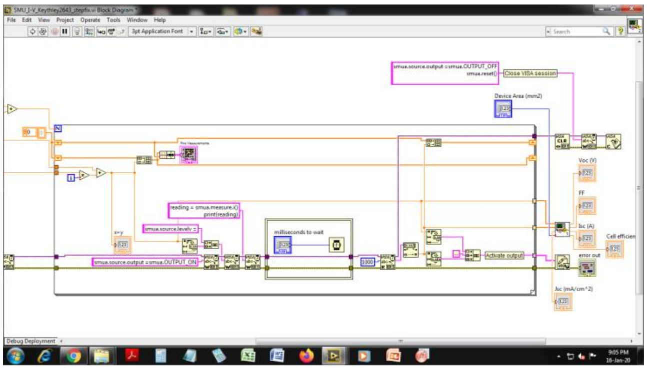

Figure 7: Block Diagram of IV Characteristics measurement VI part 2

Figure 7 shows block diagram of IV characteristics measurement VI part 2. After a waiting period is over read VISA reads the buffers and plot graph of current against voltage. When the execution exits from the loop, it enters into the SC_Parameter_Calculator sub-VI's for the calculation of maximum power point values (Vm , Im and Pm) and its curve, fill factor (FF), cell efficiency (η), current density (Jsc), open-circuit voltage (Voc), short-circuit current (Isc) and displays the results on the front panel of the VI.

III. RESULTS

The IV measurement of NB doped TiO_2 depleted heterojunction quantum dot solar cell were taken.

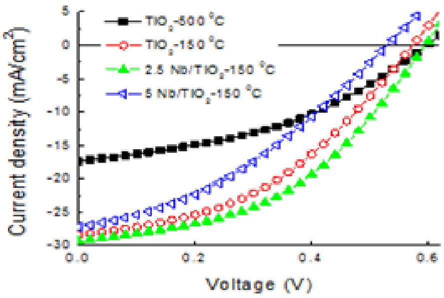

Figure 8:IV characteristics of the Nb doped TiO2 at varied temperature

Figure 8 shows IV characteristics measured through LabVIEW VI and then simulated in SCAPS software. It shows that Rectification ratio and current density under forward bias have increased appreciably in presence of light , though the reverse bias current remained almost invariant.

PV devices based on TiO-150 °C, 2.5Nb/TiO2-150 °C and 5Nb/TiO2-150 °C show approximately 10^4 times increase in forward bias current and rectification ratio. The electron extraction efficiency of the developed TiO2 and Nb doped TiO2 layers are found to improve significantly upon solar light soaking.

IV. CONCLUSION

The paper describes the synthesis, fabrication and the labview application to measure the IV characteristics of the Nb doped TiO2 depleted heterojunction quantum dot solar cells. The LabVIEW software is applied in this work as data acquisition system to interface and interact with Keithley 2634B Source Meter.A graphical user interface (front panel) is designed for the easy and smart way to interact with the instruments for the user The developed labview program offers the user easy,smart and fast method to take the measurements and focus more on the research activities.

The efficiency of the developed quantum dot solar cell is as good as the traditional semiconductor solar cells.As the device is fabricated with the simple laboratory techniques,low cost solar cell is developed.

V. ACKNOWLEDGMENTS

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