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I-V Characterization of Dye Sensitized Solar Cell Using Cost Effective Automated Load Variable Method

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ABSTRACT

In the literature, two methods are available for measuring I-V Characteristics of DSSC. One of the methods employs Source Measuring Unit (SMU) and the other conventional variable load method. SMU method is costlier and the conventional variable load method is operated manually and this may not be accurate. Here, we have reported an automatic and accurate variable load method to determine I-V characteristics of DSSC. The method uses ATMEL 8-bit microcontroller (ATmega16), which is configured to obtain variable load through twenty four relays. The microcontroller is programmed for a preset quasi-static time interval of 50ms to connect the relays on to different resistors. Built in ADC converts analog voltages across each load resistor to ten bit digital values and these values are sent to the host PC using a serial port. In turn, the PC converts the digital vales of voltages into analog voltages (V). With known values of resistances and measured values of voltages (V), the Current (I) are calculated. From the plot of I-V curve the fill factor and efficiency of the DSSC are determined and are found to be 0.57 and 4.8% respectively. The DSSC has been fabricated using TiO2 nanocrystal electrode, sensitized by N-719 dye and Platinum coated counter electrode. The I-V characteristics are determined under simulated AM 1.5 solar conditions at 1000 W/m2.

KEYWORDS: : Variable load, ATmega16, Dye-sensitized solar cell, I-V characterization

1. Introduction

The dye sensitized solar cell (DSSC) is a promising third generation solar cell, as DSSC is made of pollutant free and abundantly available low cost materials compared to other inorganic solar cells. DSSC can also be fabricated easily. It has attracted researchers all over the world since the Gratzel and co-workers have reported the high solar to electricity energy conversion efficiency using Ruthenium complex dyes such as N3, N719 dyes etc. [1, 2]. I-V Characterization of DSSC is important since the efficiency of the cell is estimated using the I-V curve. In the literature, two methods are available for measuring I-V Characteristics of DSSC. One of the methods employs Source Measuring Unit (SMU) and the other conventional variable load method. The SMU method is costlier and the conventional variable load method is manually operated [3-6]. Keeping these facts in view, we have designed an automatic and accurate method of variable load using ATmega16 [7]. The DSSC, used for the study, has been fabricated using TiO_2 nanocrystal electrode, sensitized by N-719 dye and Platinum coated counter electrode. N-719 dye is modified ruthenium complex dye to increase device voltage and is highly studied high performance dye [8]. The I-V characteristics of DSSC are determined under simulated AM 1.5 solar conditions at 1000 W/m^2.

2. Fabrication of DSSC

Ruthenium complex dye N-719, P-25 TiO_2 nano powder, di-methyl propyl imid azoliumiodide (DMPII), Tert butyl pyridine and Chloroplatnic acid were procured from sigma Aldrich. Pilkington NSG TEC15 FTO glasses were purchased from Solaranix and chemicals such as Triton X-100, Lithium Iodide, Iodine and Polyethylene glycol were purchased from HiMedia laboratory. The solvents *viz.* Ethanol, acetonitrile, acetone and acetyl acetone are of A.R grade and Milli Q water was used to construct DSSC.

The TiO_2 film is coated on FTO glass plate using doctor blading technique. The film is then heated for 30 minutes at 500°C temperature. The glass plate is allowed to cool down to 80°C. At this temperature it is immersed in 5mM solution of N-719 dye, prepared in dry ethanol for a period of 24 hours.

Electrolyte is prepared with 100mM Lithium Iodide (LiI), 50mM of Iodine (I_2), 500mM tert-Butyl pyridine (TBP), and 600mM di methyl propyl imid azolium iodide (DMPII) in acetonitrile (ACN) solvent.

In order to prepare platinum coated counter electrode, 50micro liter of chloroplatanic acid is placed on conducting side of FTO glass plate and heated for 30 minutes at 550°C.

DSSC is assembled by sandwiching TiO_2 coated photo electrode and platinum coated counter electrode, facing one another with binder clips. Electrolyte is then injected between them using a syringe of 1ml till the TiO_2 layer gets wetted. Crocodile pins from each of the electrodes are used to make a connection to external circuit to determine I-V characteristics. While fabricating DSSC the sealing is not performed on the cell.

3. Results and Discussions:

Fabricated DSSC is now subjected for simulated solar irradiance. Simulated solar irradiance is obtained from 12V, 100w Philips halogen lamp of the type 6834. The incident radiation is calibrated to A.M.1.5 solar conditions at 1000W/m^2 intensity. In order to measure I-V characteristics from DSSC, ATMEL 8 bit microcontroller (ATmega16) electronic circuit is designed to achieve variable load technique. This electronic block diagram is shown in fig 1. Variable load is obtained through twenty three different suitable values of resistors. In order to achieve electronic connections in succession to each resistor twenty three electronic relays are connected. The twenty forth relay is left open to measure the Open circuit voltage (Voc).

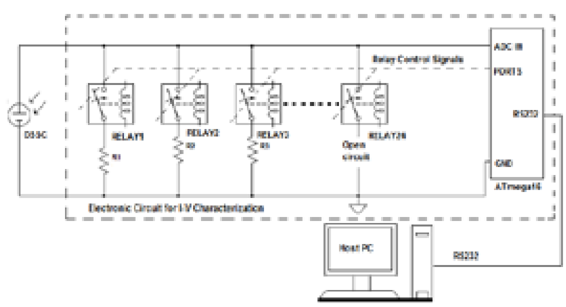


Figure 1: Block diagram to measure I-V characteristic of DSSC.

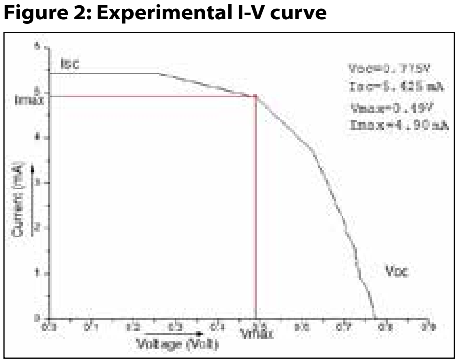
The 8 bit ATMEL (ATmega16) microcontroller is programmed for a preset quasi-static time interval of 50ms to connect the relays on to different resistors. That is at every 50 ms different resistors are connected in succession to the output of DSSC. Built in ADC converts analog voltages to ten bit digital values across each load resistor and these values are sent to the host PC using a serial port. The total scan time of variable voltages is 1.2 seconds. The resolution of ADC is set to 5mV. ADC values are temporarily stored in the microcontroller memory till the completion of scanning. Once the scanning is over, 24 ADC values are sent to host PC through RS232 to convert it into analog voltages. The Termite Software tool is used at the PC side to get the analog voltage values. With known values of resistances (R) and measured voltages (V) from the PC .and the Current (I) are calculated. All these values are shown in Table 1.

Table 1: Experimental data

Resistance (R) in Ω	Voltage (V)	Current(mA)	Power(mW)
47	0.255	5.42	1.38
100	0.49	4.90	2.40
147	0.59	4.01	2.36
169	0.625	3.69	2.31
220	0.66	3.00	1.98
267	0.68	2.54	1.73
330	0.7	2.12	1.48
363	0.705	1.94	1.37
410	0.715	1.74	1.25
470	0.725	1.54	1.12
525	0.725	1.38	1.00
592	0.73	1.23	0.90
603	0.725	1.20	0.87
690	0.735	1.06	0.78
800	0.735	0.91	0.68
1000	0.75	0.75	0.56
1220	0.755	0.61	0.47
1330	0.76	0.57	0.43
1470	0.76	0.51	0.39
2200	0.765	0.34	0.27
4700	0.77	0.16	0.13
10000	0.77	0.08	0.06
33000	0.775	0.02	0.02
Open circuit	0.775	0.0	0

From the experimental values of Voltages (V) at different resistors and the calculated values of current (I) the I-V Curve is plotted and is shown in Fig.2. Using the values of V and I power values are determined and are shown in Table 1.

Figure 2: Experimental I-V curve



Maximum power point (P_{max}) is found amongst the various power values which is 2.4 mW. Corresponding to this $P_{max,}$ current maximum (I_{max}) and voltage maximum (V_{max}) are determined which are 4.9mA and 0.49 V respectively. From the plot of I-V curve, open circuit voltage (V_{oc}) and short circuit current (I_{sc}) are determined and are 0.775 V and 5.425 mA respectively. All these values are shown in the Fig 2. Using the values V_{max}, I_{max}, V_{OC} and I_{SC} the fill factor (FF) is determined according to equation 1. In order to determine efficiency (η) according to equation 2, the value of intensity of the light incident (I_{in}) on the active area of the cell and area (A) of the cell are necessary. The value of I_{in} is taken as 1000 W/ m^2 [3] and the active area A of the cell is chosen to be $0.5cm^2$.

$$FF = \frac{V_{max} \times I_{max}}{V_{oc} \times I_{sc}} \text{ --------------- (1)}$$

$$\eta = \left[\frac{V_{oc} \times I_{sc} \times FF}{I_{in} \times A}\right] \times 100 \text{ ------- (2)}$$

Thus, the estimated values of Fill factor (FF) and efficiency (η) are found to be 0.57 and 4.8% respectively. From our experimental observation it may be inferred that, instead of conventional variable load technique automatic method of variable load can easily be implemented which may provide accurate results.

4. Conclusion:

In this paper, we have reported an automatic and accurate variable load method to determine I-V characteristics of DSSC. The DSSC, used for the study, has been fabricated using TiO_2 nanocrystal electrode, sensitized by N-719 dye and Platinum coated counter electrode. The method uses ATMEL 8-bit microcontroller (ATmega16), which is configured to obtain variable load through twenty four relays. The microcontroller is programmed for a preset quasi-static time interval of 50ms to connect the relays on to different resistors. The values I and V were obtained from DSSC when it is exposed to AM 1.5 solar conditions at 1000 W/ m^2. Values of I and V are determined using our experimental set up. The parameters such as open circuit-voltage (V_{oc}), short-circuit current (I_{sc}), current maximum (I_{max}), voltage maximum (V_{max}) are determined from the plot of I-V curve. Using these experimental values and equations of Fill factor and efficiency, fill factor and efficiency of fabricated DSSC are determined.

The values of Fill factor (FF) and efficiency (η) are found to be 0.57 and 4.8% respectively. Here, we claim that no report is available using the method adopted by us. The method adopted by us is the simple, automated variable load technique. Thus, it may be inferred that, instead of conventional variable load technique automatic method of variable load can easily be implemented which may provide accurate results.

Further, our objective was not to improve the efficiency of DSSC, but to design automated variable load technique for I-V characterization of DSSC. However in order to improve the efficiency of fabricated DSSC, further research is under progress.

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