Measurement of the Life Time of the Solar Cell Using AVR Microcontroller

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Abstract : In this paper we have concentrated on the system to determine the micro second ranged lifetime of solar cell, where OCVD (open circuit voltage decay) technique is used with AVR Micro-controller. Using a contactless instrument, the photo conductance is measured in a quasi-steady-state mode during a long, slow varying light Pulse and flashing of the LED array can be changed by changing the frequencies through pulse rate. AVR micro-controller is connected with the computer and entire system is controlled by the software. Life time of the solar cell is changed by changing the value of pulse in the program. The effective lifetime (τ) of solar cell is obtained from the slope of the decay curve which can be seen in the C.R.O. But here AVR is interfaced with LCD display so that, the life time (τ) of the solar cell can be seen directly as a numerical value on the LCD. The life time (τ) is one of the most important parameter for the characterization of solar cell, used in the preparation of the power electronic devices and photovoltaic solar cell.

I. INTRODUCTION

Electrical and electronic properties of semiconductor materials are normally required to be measured as accurate as possible [1]. The concepts of carrier lifetime in semiconductor materials and average life expectancy in demography are similar. Like common creature, electrons (and holes) die after some time and average of this time is called the minority carrier life time [2]. The lifetime is quite unpredictable and difficult to control. It can vary by several orders of magnitude, from approximately 1 µs to 1 ms in common silicon solar cell materials. The highest value ever measured is 32ms, for un-doped silicon, and the lowest 10 ns, for heavily doped silicon. The lifetime indicates the quality of silicon material. This quality depends, primarily, on the growth process [2]. Besides, lifetime can change when wafers are processed at high temperature or subjected to certain treatments. It is, therefore, essential to model the carrier lifetime before going for rigorous experiments or to be ascertained about correctness of experimental results. In addition, cell's output current is also related to the life time. This is because electrons take some time to travel across the silicon wafer and they reach the *p-n* junction only if their life expectancy is long enough to complete the journey [3]. Two fundamental processes that take place in a semiconductor are hole and electron recombination and generation. The generation creates carriers, whereas the recombination annihilates them. Lifetime of minority carriers is the mean time elapsed until a carrier disappears by recombination [4]. In the electroluminescence mode the carrier injection occurs within a distance of a diffusion length from the *p-n* junction. Therefore, the determination of the minority carrier lifetime within this region is required to obtain the parameter which controls the output power of the LEDs. A number of methods have been developed in order to determine the minority carrier lifetime on semiconductor wafers and devices. Photo conductance decay (PCD) and its variants, Quasi Steady State Photo conductance(QSSPC) and Free Carrier Absorption (FCA) are the most common methods applied to lifetime measurement on wafers, whereas Reverse Recovery (RR) and Open Circuit Voltage Decay (OCVD) are the most used in experiments on PN junctions. OCVD presents a few advantages over RR method [4]. The open-circuit voltage decay (OCVD) technique was one of the earliest methods for carrier lifetime determination. It is easy to implement, interpretation of experimental data is fairly straightforward and, moreover, very good correlation with real electrical parameters of devices is expected. In this work, the OCVD Technique is implemented to measure the carrier lifetime. The system, which works attached to a computer, includes software and hardware developments. The OCVD is a simple and non-destructive technique for the determination of minority carrier lifetime in semiconductor diodes. It consists in applying a current pulse to the device under test (DUT), in order to forward biasing the junction, and then to observe the voltage decay at the junction in an open circuit condition. This decay is linear and it is product of the recombination of the excess carriers injected to the DUT by the current pulse [4]. The experimental setup consists mainly of a data acquisition system based on a AVR microcontroller (Arduino), connected to a computer, and software for the control of the entire system, data processing, storage and visualization of results [4]. Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board. The Arduino platform has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board – you can simply use a USB cable. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program [5] [6].

II. EXPRIMENTAL DETAIL

Life time of the solar cell is the most important parameter, which can be determined by different methods with different instruments. Here we have used the Open Circuit Voltage Decay (OCVD) method with the AVR microcontroller. In this experiment, different coloured LED array (white, red, blue, green), LM35 Temperature Sensor, 16x2 LCD along with AVR microcontroller is used to measure the life time of Solar Cell with different open circuit voltages V_{oc}(2V, 4V, 6V). We can also use the CRO to show the decay curve.

Figure 1 shows the block diagram of the Experimental setup. The LED array and the Solar Cell are placed in a box which is covered with an Opaque material which isolates it from outside light and makes our result more accurate.

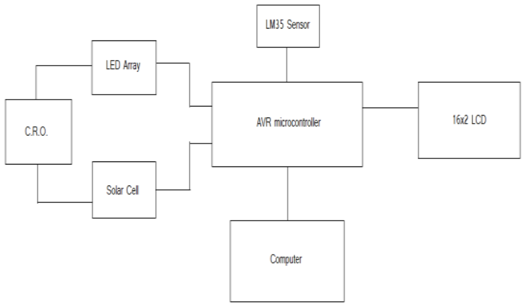

Figure1:-Block diagram of the system to determine the life time of the solar cell.

Long, slow varying light Pulse and flashing of the LED array can be changed by changing the frequencies through pulse rate with the help of the software in which the program is loaded through the AVR microcontroller. AVR microcontroller is performing by the C++ software. Through the software, frequencies can be changed from the 20 Hz to 2000 KHz, which changes the varying light pulse of the LED array. AVR microcontroller is used for generating the input and getting output. Through this microcontroller we generate the pulse rate through software and LED is blinking. After that solar cell output calculated by the AVR and displayed on the LCD screen. whole setup which can be seen in the figure 2.

Figure 2- **Set up off the whole practical to measure the life time of the Solar cell.**

III. RESULTS AND DISCUSSION

Flashing light from the LED is incident on the solar surface, electrons and holes are generated from the solar cell, whose life time is measured through the equation given below [4].

$$\tau = \frac{kT}{q} * \frac{1}{\frac{dV}{dt}}$$

Where,

τ is life time, k is Boltzmann constant, T is room temperature, q is electron charge, $\frac{dV}{dt}$ is voltage decay.

From the above condition we can quantify the life time of the solar cell. This condition is stacked in the program. The Value for the Constants, k and q is predefined. Room temperature is detected by the LM35 temperature sensor. Life time is figured and its numerical quality is shown on the LCD screen. LCD shows the Frequency in KHz, Temperature in degree and life time of the sunlight based cell in microseconds. To see the input pulse and output voltage decay curve, we can use the CRO.

Table 1, 2 and 3 shows that change in the value of the solar cell life time in microsecond for different LED array (white, blue, red, green) for 2 V, 4 V and 6 V open circuit voltage of the solar cell respectively.

Table 1:- Life time of the 2 V solar cell for Different LED

Frequency (kHz)	**Pulse Rate (µs)**	**Lifetime of Solar Cell (V_{oc} = 2 Volts) in (µs)**			
		White LED	**Blue LED**	**Red LED**	**Green LED**
0.005	200000	2657.3	3027.7	3836.8	10370
0.01	100000	1327.2	1530.5	1911.6	5193.3
0.02	50000	662.54	756.89	962.62	2596.6
0.05	20000	265.8	302.67	382.33	1037.7
0.1	10000	133.46	152.34	191.84	519.36
0.2	5000	66.37	75.9	95.77	259.68
0.5	2000	26.52	30.27	37.96	102.88
1	1000	13.36	15.16	19.12	51.94
2	500	6.79	7.57	9.63	26.48
5	200	2.72	3.07	3.82	10.7
10	100	1.37	1.57	1.9	5.35
20	50	0.69	0.81	0.95	2.67
50	20	0.27	0.31	0.36	1.04
100	10	0.14	0.17	0.18	0.53
200	5	0.07	0.08	0.09	0.26
500	2	0.03	0.03	0.04	0.1
1000	1	0.01	0.02	0.02	0.05
2000	0.5	0.01	0.01	0.01	0.03

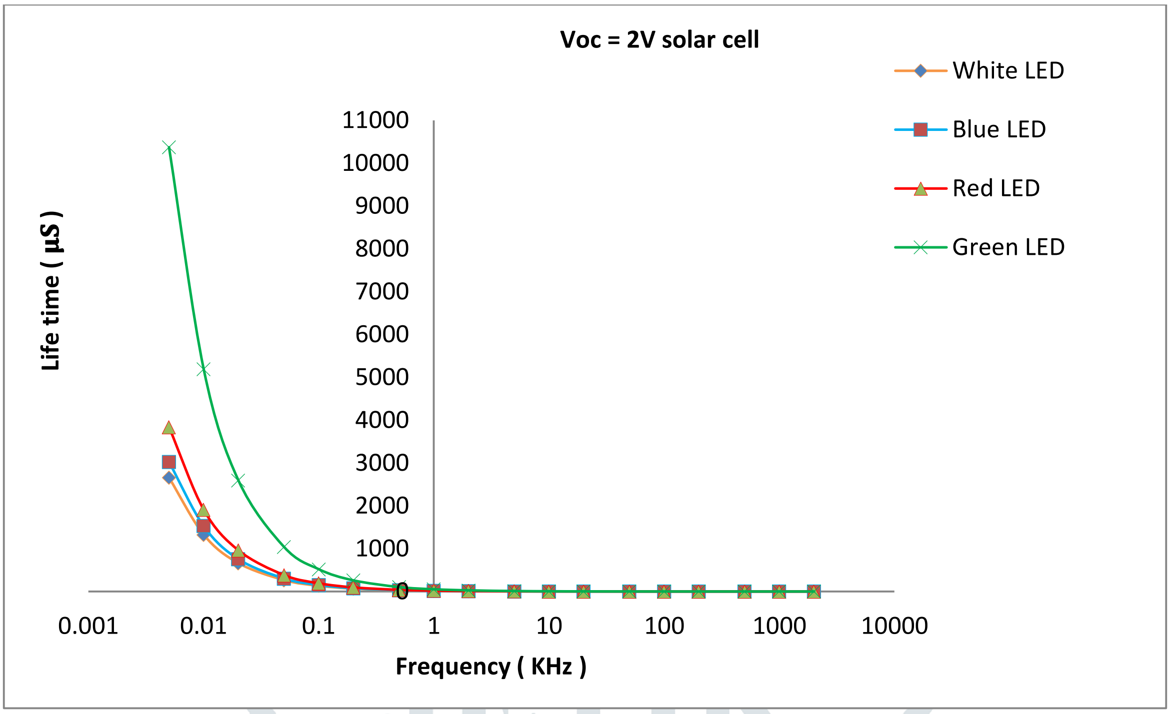

Figure 3:- 2 V Solar cell life time Vs. Frequency

Table 2:- Life time of the 4 V solar cell for Different LED

Frequency (kHz)	Pulse Rate (µs)	Lifetime of Solar Cell (V_{oc} = 4 Volts) in (µs)			
		White LED	Blue LED	Red LED	Green LED
0.005	200000	1524.1	1604.2	2212.6	7003.5
0.01	100000	763.1	803.56	1106.3	3524.6
0.02	50000	381.03	400.43	552.04	1762.3
0.05	20000	152.68	160.17	219.92	703.93
0.1	10000	76.58	80.09	109.74	352.74
0.2	5000	38.16	40.04	55.63	175.09
0.5	2000	15.34	16.02	22.15	70.61
1	1000	7.67	8.11	10.97	35.02
2	500	3.86	4.07	5.46	17.62
5	200	1.57	1.62	2.22	7.04
10	100	0.77	0.84	1.09	3.52
20	50	0.39	0.43	0.54	1.75
50	20	0.15	0.16	0.22	0.7
100	10	0.08	0.08	0.1	0.35
200	5	0.04	0.04	0.05	0.17
500	2	0.02	0.02	0.02	0.07
1000	1	0.01	0.01	0.01	0.04
2000	0.5	0	0	0.01	0.02

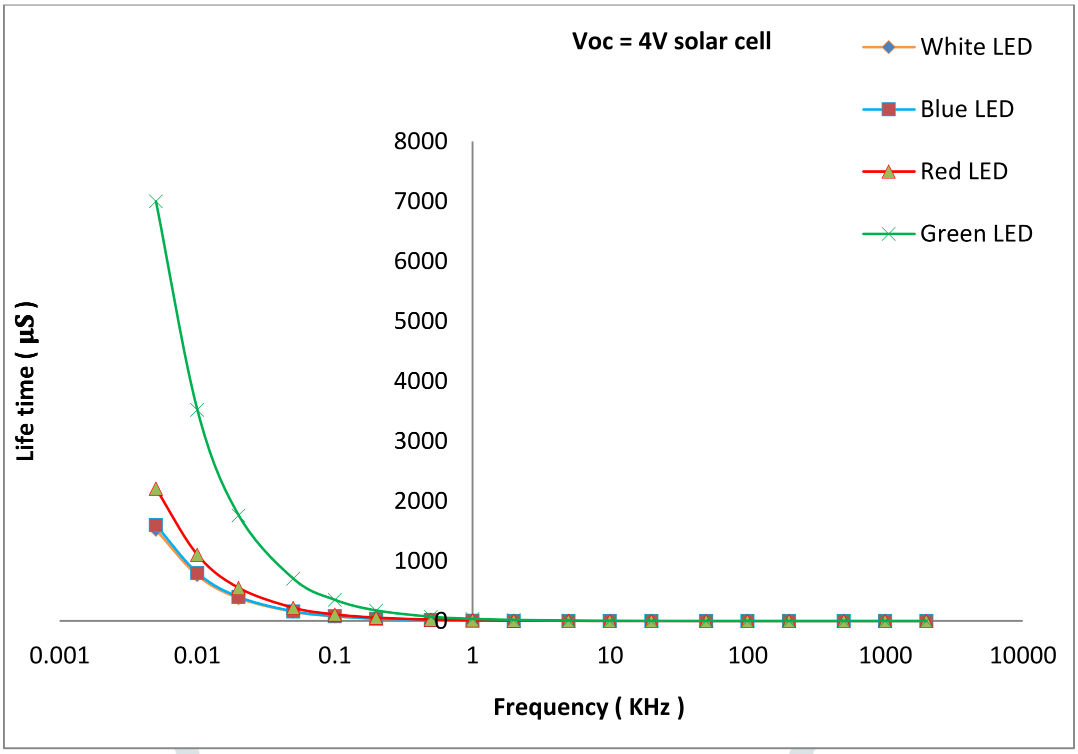

Figure 4:- 4 V Solar cell life time Vs. Frequency

Table 3:- Life time of the 6 V solar cell for Different LED

Frequency (kHz)	Pulse Rate (µs)	Lifetime of Solar Cell (V_{oc} = 6 Volts) in (µs)			
		White LED	Blue LED	Red LED	Green LED
0.005	200000	1241.2	1119.6	1509.1	5202.3
0.01	100000	621.33	561.37	746.78	2605.6
0.02	50000	310.17	278.52	371.98	1296.3
0.05	20000	136.61	111.47	152.8	517.7
0.1	10000	62.03	55.76	76.29	259.44
0.2	5000	31.15	27.91	37.55	129.63
0.5	2000	12.62	11.46	14.91	51.77
1	1000	6.41	5.73	7.53	25.89
2	500	3.26	2.89	3.73	12.94
5	200	1.33	1.27	1.61	5.15
10	100	0.71	0.62	0.76	2.59
20	50	0.36	0.32	0.39	1.29
50	20	0.12	0.11	0.14	0.52
100	10	0.07	0.06	0.07	0.26
200	5	0.03	0.03	0.04	0.13
500	2	0.01	0.01	0.02	0.05
1000	1	0.01	0.01	0.01	0.03
2000	0.5	0	0	0	0.01

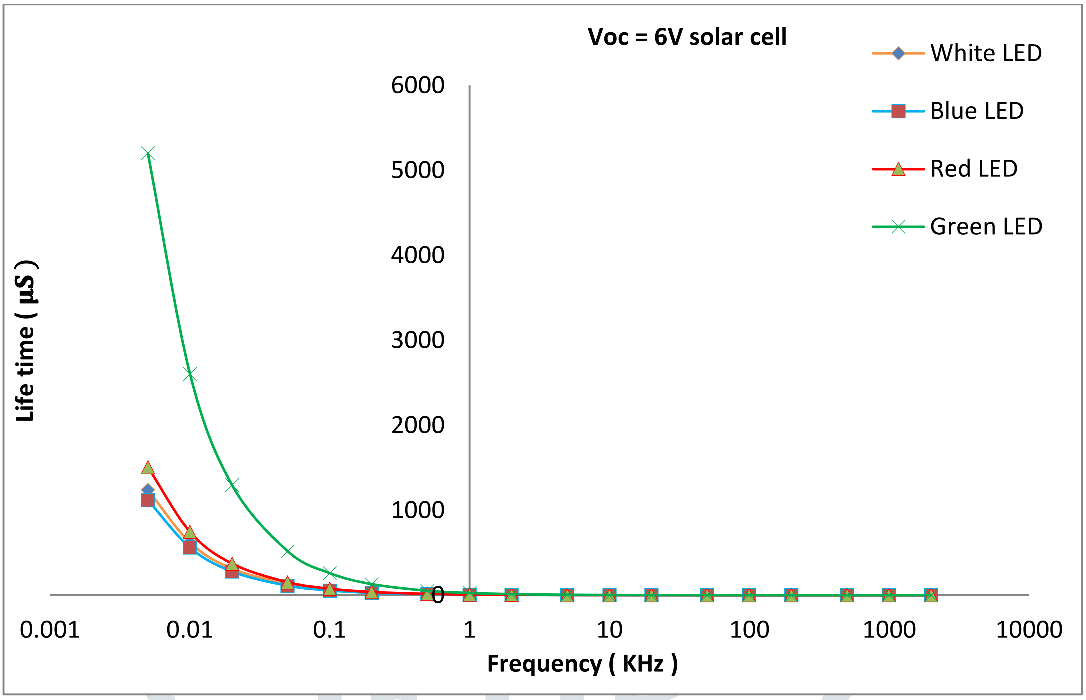

Figure 5:- 6 V Solar cell life time Vs. Frequency

Figure 3, 4 and 5 shows that major change in the solar life time for different LED array for 2 V, 4 V and 6 V open circuit voltage solar cell respectively. From the above graph it can be observed that the maximum life time for Green LED in 2v, 4v, 6v solar cell is 10370µs, 7003.5µs and 5202.3µs micro seconds because of low intensity while the maximum life time for White LED is 2657.3µs, 1524.1µs and 1241.2µs because of High Intensity. This shows that Higher the Intensity lower is the life time and Vice Versa. It also shows that at 50 KHz frequency, life time of Solar cell is less than 1 µs.

IV. CONCLUSION

Life time of the solar cell measured through the AVR microcontroller is one of best new method. When the frequency is changed the blinking rate of the LED is also changed. This gives us with decay and Transient decay curve at the OFF time of the LED. When we increase the frequency, life time of the solar cell is decreased and with the decreases in frequency, life time of the solar cell is increased which concludes that both the parameters i.e. Life time and Frequency are inversely proportional to each other. Also we conclude that if the V_{oc} increase from 2 V to 6 V, life time of the solar cell decrease. Through AVR microcontroller we can calculate solar life time for all types of the LED light. Also we can calculate the Δn excess electron concentration from the life time of the solar cell.

Figures and Tables

V. ACKNOWLEDGMENT

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