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Simulation of Mono Layer Solar Cell Using COMSOL and Fabrication in Particle Controlled BAEC Clean Room

Md. Rajibul Hoque Rajib[1], Sardar Masud Rana[2,*], Md. Rakibul Hasan[2], Rashed Al Amin[1,**], Md. Shahid Iqbal[1], Md. Ruhul Kabir Anik[1], Md. Nasrul Hoque Mia[2], Mahbubul Hoq[2], Mahmudul Hasan[2]
[1]Department of EEE, Mymensingh Engineering College (University of Dhaka), Bangladesh
[2]Institute of Electronics, Atomic Energy Research Establishment, Dhaka

***Abstract*—The performance of solar photovoltaic cells depends on its design, material properties, and fabrication technology. This paper presented a comparative study of mono layer silicon solar cell simulation result designed by COMSOL Multiphysics and the fabrication result of this solar cell. With the absorption variation of light intensity; this paper compares the simulation result of J-V characteristics and the efficiency of the cell with fabricated efficiency. In software we get the efficiency of the solar cell is 27% - 28% and after fabrication of that cell the efficiency is 11% - 12% using sun simulator.**

***Keywords*—COMSOL Multiphysics, solar cell, J-V characteristics, lux meter, fabrication.**

I. INTRODUCTION

With the inexorable rise of world energy consumption and the limited, and rather quickly diminishing supply of fossil fuels[1,2], it is high time that the world begin to look for photovoltaic (PV) technology, more commonly known as solar energy. Ever since its discovery in 1839 by Edmund Becquerel[3], PV technology had been experiencing a steady development of solar cell efficiency. At present more than 85% of the industrial solar cells are fabricated based on p type silicon material. The major objectives of simulation in solar cell research are testing the validity of proposed physical structures, geometry on cell performance, and fitting of modeling output to experimental results.

The conversion efficiency of hydrogenated amorphous silicon single-junction thin-film solar cells has gradually been improved from 2.4% [4] to 10.1% [5]. The hydrogenated amorphous silicon (a-Si:H) solar cell progress has been started from the invention of first Schottky device with an efficiency of 2.4% by Kabir et al. [6]. The main factors determining the conversion efficiency are the following: the kind of semi conductive material, the incompatibility of solar radiation with the cell absorption, spectrum sensitivity of photo element and the construction of a cell [7-9].

The aim of this study is to analysis the performance of the p-type mono layer solar cell simulation efficiency and investigates a comparison with fabrication efficiency. After design and simulation of the silicon solar cell; the designed model is fabricate on the energy laboratory of BAEC, Bangladesh. For proper fabrication we use BAEC particle controlled clean room. After fabrication it can be said that, the fabrication efficiency of mono layer silicon solar cell is exceeding 12% which is much better fabrication in the present world.

II. DESIGN AND SIMULATION RESULT

The model has been built in 2D space dimension, electromagnetic wave frequency domain in COMSOL Multiphysics. The p-region is 15nm, intrinsic region is 200 nm and n-region is 27 nm decomposed in silicon wafer. The designed mono layer solar cell model shown in Fig.1.

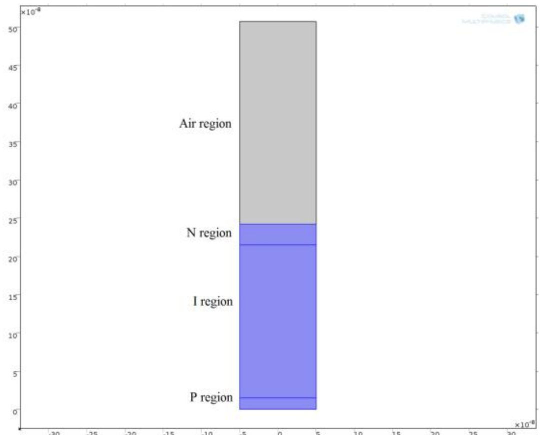

Fig. 1. Mono layer solar cell model in COMSOL

Electromagnetic wave is defined in the top of air region as light intensity. Light incident on the surface of PIN solar cell, some part is reflected and some part is refracted into the solar cell. As a result electron hole pair is generated. This contributes for creating the voltage and current in the solar cell. For different light intensity J-V characteristics curves are plotted. It is seen that short circuit current density and open circuit voltage increases with light intensity.

The intensity of sun light varies in different hours of the day. The short circuit current density J_{sc}, open circuit voltage V_{oc} and efficiency of solar cell also vary with the light intensity. Light intensity from the time 10.00 to 17.00 is measured by lux meter in Bangladesh Atomic Energy Research Establishment, Institute of Electronics. We measured highest light intensity which is 774W/m^2 at 13.00 and lowest is 284W/m^2 at 17.00. The measurement of the light intensity and change of efficiency is shown on Table. 1.

Time	Light intensity (W/m^2)	Jsc (A/m^2)	Voc (V)	Efficiency (%)
10.00	616	453.6	0.5722	28.04
11.00	648	480.9	0.5737	28.11
12.00	687	431.2	0.5708	27.97
13.00	774	541.8	0.5768	28.26
14.00	569	398.3	0.5688	27.88
15.00	442	309.4	0.5623	27.55
16.00	333	233.1	0.5550	27.19
17.00	284	198.88	0.5509	26.99

TABLE I. Light intensity, current density and efficiency of the solar cell at various times.

The efficiency graph of the solar cell at different time is shown on Fig. 2.

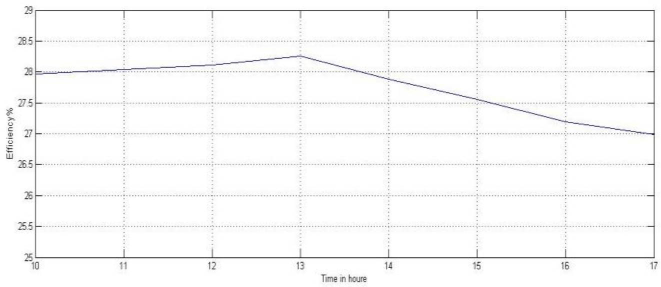

Fig. 2. Variation of efficiency at different times

The values of light intensity are putting in the model. For different light intensity different J-V curves are simulated. From the J-V curves Jsc and Voc are measured. With a Fill Factor 0.7 efficiency are calculated. We observed that efficiency increases with light intensity. Highest efficiency is 28.26% at the highest light intensity 774W/m^2.

The J-V characteristics graph at different day time of the solar cell is shown on Fig. 3.

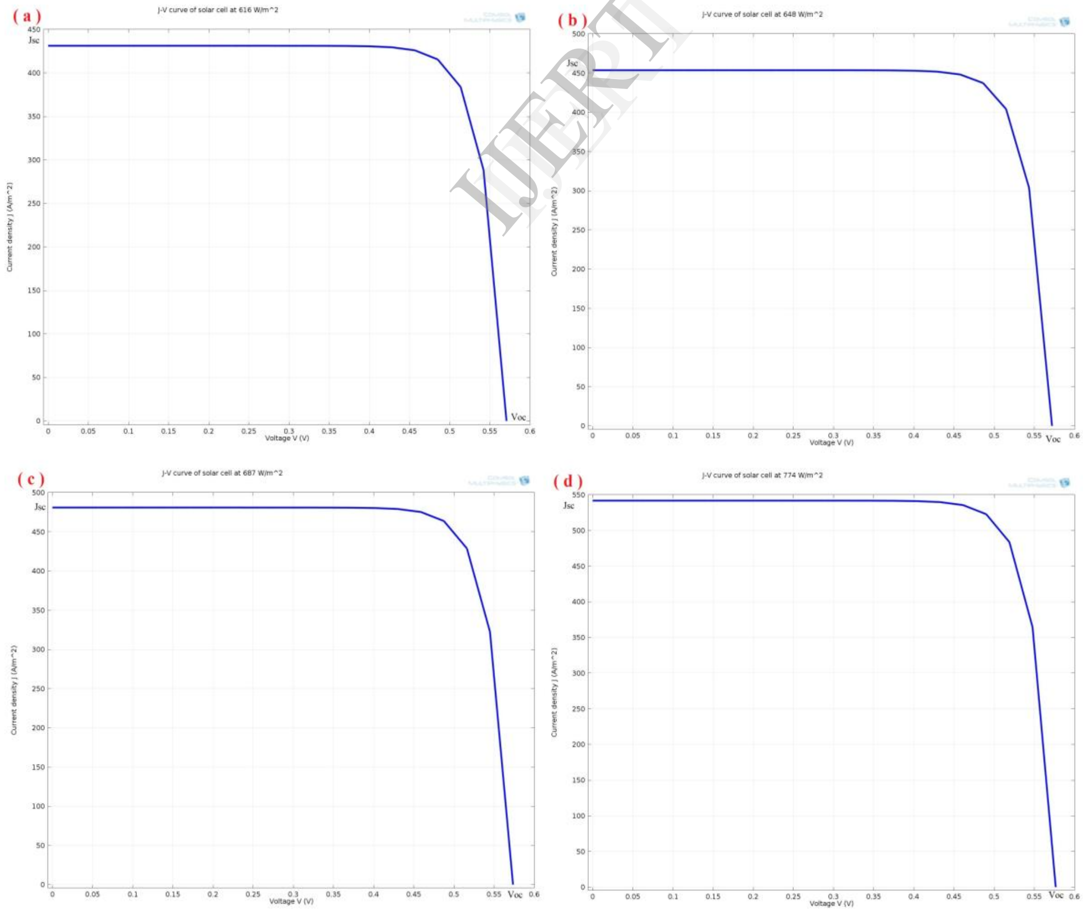

Fig. 3. J-V characteristics graph at, **(a)** 10:00 AM **(b)** 11:00 AM **(c)** 12:00 PM **(d)** 01:00 PM

Another J-V characteristics graph at different day time of the solar cell is shown on Fig. 4.

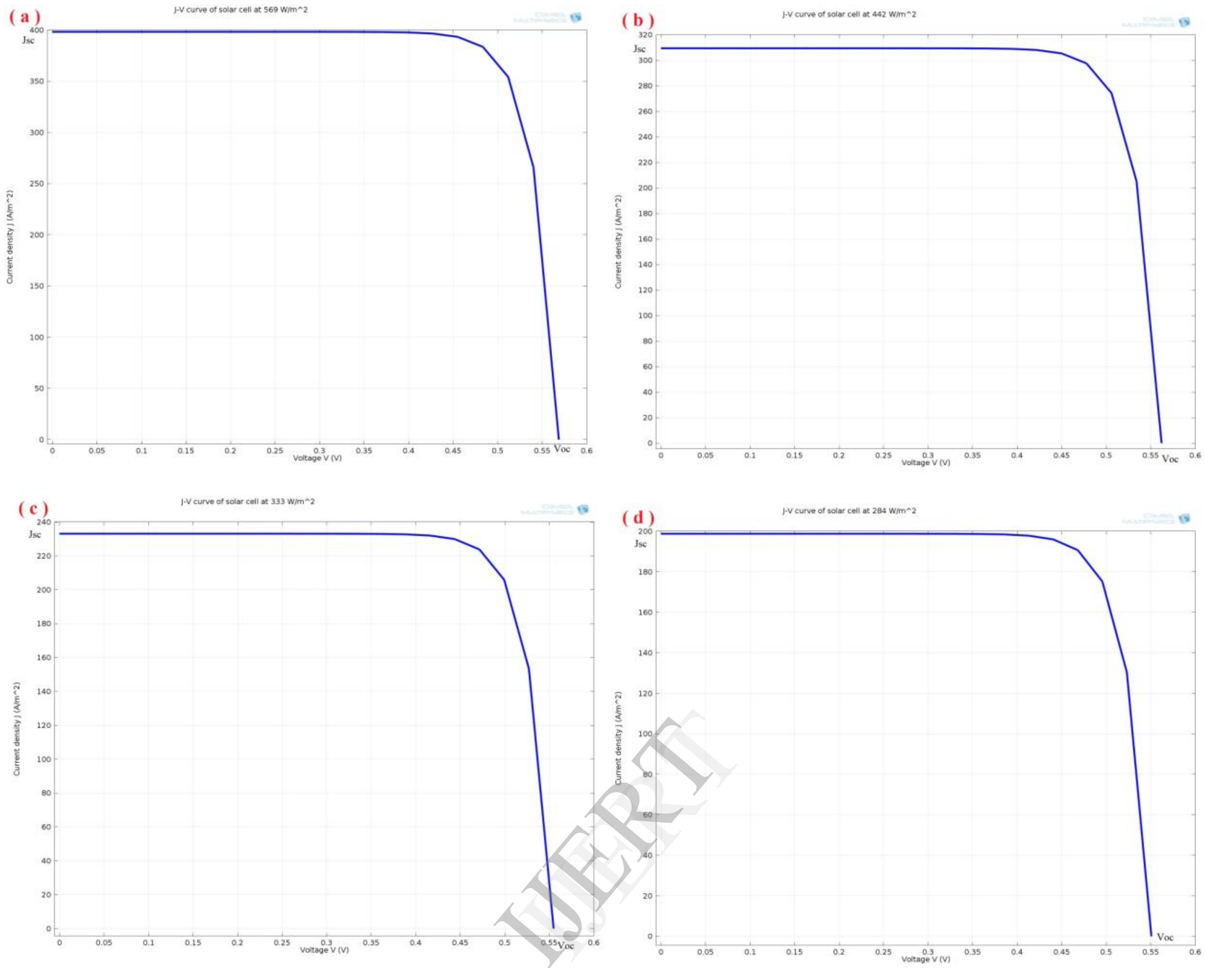

Fig. 4. J-V characteristics graph at, **(a)** 02:00 PM **(b)** 03:00 PM **(c)** 04:00 PM **(d)** 05:00 PM

Electron density of the solar cell is shown on Fig. 5.

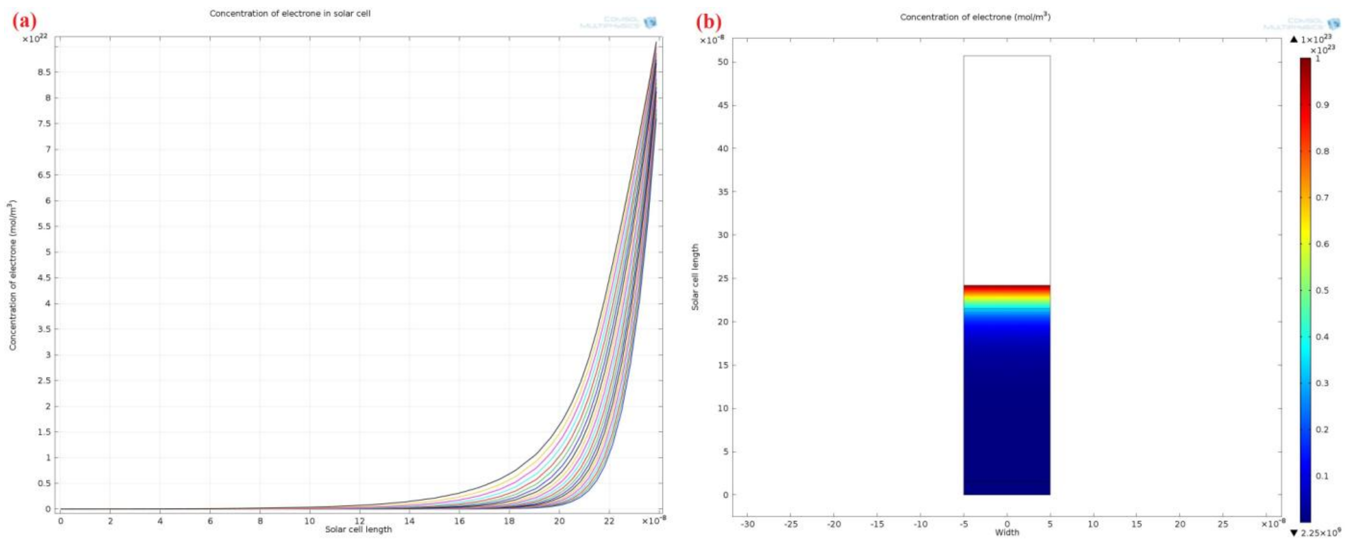

Fig. 5. **(a)** Electron density and (**b)** Electron density surface of the solar cell.

Hole density of the solar cell is shown on Fig. 6.

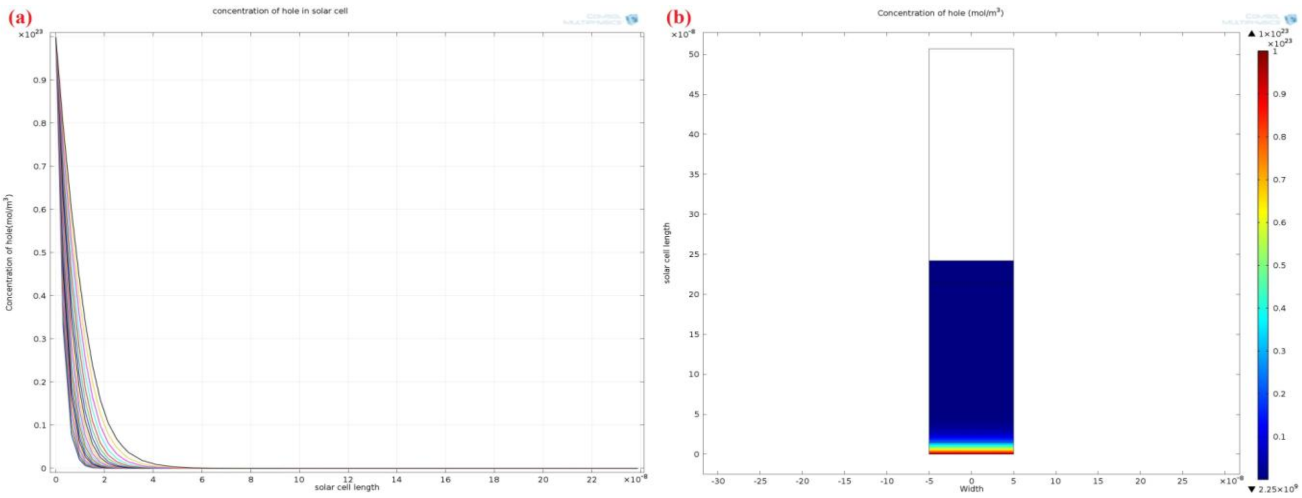

Fig. 6. **(a)** Hole density and (**b)** Hole density surface of the solar cell.

Generation rate of the solar cell is shown on Fig. 7.

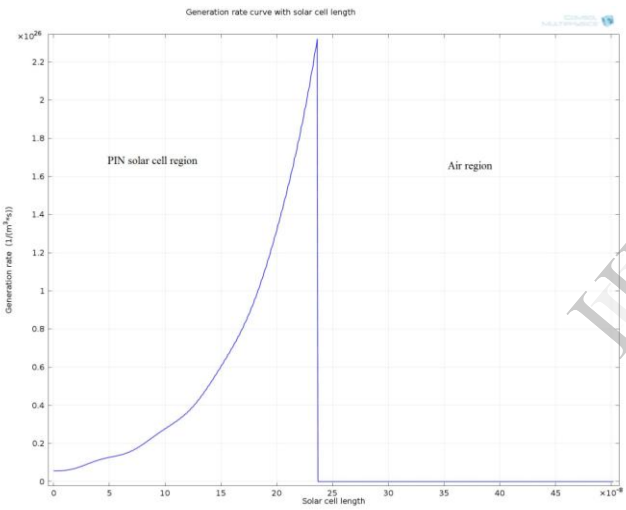

Fig. 7. Generation rate of the solar cell.

Space charge density is shown on Fig. 7

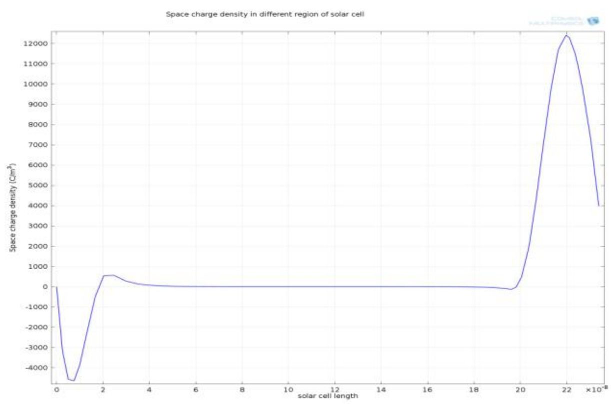

Fig. 8. Space charge density of the solar cell.

III. FABRICATION PROCESS AND RESULT

We have used the recipes of RCA for the fabrication of solar cell. For cleaning, saw damage removal process (10% NaOH with DI water) and hydrophobic process with the ratio of (1ml Hydrofluoric acid with 50ml DI water) process has been done. For texturing solution is made with potassium hydroxide, Iso-2-propanol and DI water with corresponding ratio 1gram, 5ml and 125ml. Surface reflectance measurement is done once after the saw removal process and then after the texturing process and finally the result of these two are compared to the reflectance of a standard mirror.

Next, the edge isolation process is done using a screen printing machine and a diffusion barrier paste is used to isolate the edge. The mask screen both top and bottom, squeezer, spatula and the work holder carriage is cleaned very well using the IPA solution. After the screen printing is done the wafers are dried for 10 minutes in a preheated oven at 200°C.

For diffusion or doping process the wafers are kept on a tray made of a glass for diffusion process. When the diffusion machine reached 600°C then the tray containing the wafers are transferred to the diffusion chamber. Nitrogen gas is turned on for 10 minutes and then temperature is increased to 875°C keeping the Nitrogen gas on. After 875°C is reached nitrogen gas is turned off and Oxygen and $POCl_3$ (Phosphorus oxy-try-chloride) are turned on simultaneously. After 10 minutes nitrogen gas is turned on for 10 minutes and then nitrogen gas is turned off and only oxygen gas is turned on for next 10 minutes. The temperature of the chamber is reduced to 600°C from 875°C and this stage nitrogen gas is turned on again. When the temperature is falling down at 600°C nitrogen gas is turned off and wafers are ready to take out. After doping process the sheet resistance is measured. Sheet resistance of different wafer is shown on TABLE 2.

TABLE II. Sheet resistance of different wafer on the solar cell fabrication process.

Experimental wafer	Sheet resistance before cleaning	Sheet resistance after texturing	Sheet resistance after diffusion
Wafer 1	4.6 KΩ	4.3 KΩ	2.16 KΩ
Wafer 2	5 KΩ	4.4 KΩ	2.19 KΩ
Wafer 3	4.7 KΩ	4.3 KΩ	2.1 KΩ

The front contact is made by Silver paste and back contact is made by Aluminium paste. After printing, rapid thermal annealing process is done with the temperature 500°C, 600°C and 800°C respectively. The wafers are passed through a moving belt which goes inside the RTA machine. Rapid thermal annealing is important because it provides proper contact between the conductor and semiconductor. After transmission line measurement process the desire cell making process is completed.

The efficiency of the solar cell is measured by sun simulator and got 10% - 12% efficiency.

IV. CONCLUSION

The mono layer solar cell has been simulated in COSOL and finally fabricated to investigate the compares between designed and fabricated efficiency. It is seen that, the fabricated and simulated efficiency is different. Because in simulation, ideal values are taken but in fabrication we cannot get the ideal material and wafer defect, doping error and contact error may occurred in fabrication process. It gives us only 12% efficiency which is the better fabrication efficiency in the world of mono layer solar cell.

REFERENCES

[1] US Department of Energy web site, accessed 1/8/2011, http://www.eia.doe.gov/.
[2] US Department of Energy, Annual Energy Review - July 2006, Accessed 1/8/2011, http://www.eia.doe.gov/.
[3] J. Nelson. The Physics of Solar Cells. Imperial College Press, London, 2003.
[4] D. E. Carlson and C. R. Wronski, “Amorphous silicon solar cell,” Applied Physics Letters, vol. 28, no. 11, pp. 671–673, 1976.
[5] U. Kroll, C. Bucher, S. Benagli et al., “High-efficiency p-i-n a-Si:H solar cells with low boron cross-contamination prepared in a large-area single-chamber PECVD reactor,” Thin Solid Films, vol. 451-452, pp. 525–530, 2004.
[6] M. I. Kabir, Z. Ibarahim, K. Sopian, and N. Amin, “A review on progress of amorphous and microcrystalline silicon thin film solar cells,” Recent Patents on Electrical Engineering, vol. 4, no. 1, pp. 50–62, 2011.
[7] K. Nakajima, K. Ohdaira, K. Fujiwar, W. Pan, Solar cell system using a polished concave Si-crystal mirror, Solar Energy Materials and Solar Cells 72 (2005) 323-329.
[8] A. Blakers, K. Weber, V. Everett, S. Deenapanray, E. Franklin, Sliver solar cells and moduls; Centre for Sustainable Energy, Systems Australian National University,(2004).
[9] A. Goetzberger, C. Hebling, Photovoltaic materials, past, present, future, Solar Energy Matererials Solar Cells 62, (2000)