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An Approach to Increase the Efficiency of Printed Solar Cell Using Convex Lens

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Abstract: This has been proved with conventional solar cell that the efficiency is increasing and besides that the material consumption i.e. silicon has been greatly reduced. Thus along with the increment in efficiency, the cost of conventional solar cell was greatly reduced. Here, the work is done to increase the efficiency of a printed solar cell without changing its actual printed structure or any other material. The idea for this work came from the use of Holographic planar concentrator on conventional Silicon based solar cell. Thus we proceeded with that idea by making the use of convex lens (light converging lens) to concentrate the light source on to the specific point of known dimension. We used standard xenon light source. The experiment started with the measuring of current and voltage of standard solar cell to check whether the set-up is working or not and after that measurements with printed samples were done. The results we got from conducting this experiment were positive i.e. the efficiency in terms of current and voltages was increased. The readings were taken by cutting samples from a single cell because the printed solar are not homogenous and shows different values of current and voltages over a single cell as compared to conventional solar cell due to the presence of number of variables in printing process.

Keywords: Holographic planar, conventional solar cell, standard xenon light.

I. INTRODUCTION

Solar cell or Photovoltaic cell (or PV cell for short), is the device that converts the radiation of the sun to electricity. Actually, a group of solar cells, the so-called “organic cells”, started by borrowing the idea from leaves. Solar cells based on organic semiconductors have become a promising alternative to inorganic photovoltaics due to their low weight, low cost, easy processing, and flexibility, when compared to traditional silicon solar cells. Besides material research, much has been done for increasing sunlight concentration, carrier collection, and cell stability. Moreover, researches have gone beyond the inorganic world. Despite their low efficiency, the organic polymers have attracted much interest. Efforts have been made to improve organic solar performance using new materials, novel structures, and new techniques for mass production. Photovoltaic (PV) device collect energy from the sun and convert solar radiation energy into electrical energy. When sunlight falls on a PV cell, the photons of the absorbed sunlight dislodge the electrons from the atoms of the cell. The free electron then move through the cell, creating and filling in holes in the cell. It is the movement of electrons and holes that generates electricity. This physical process is known as photovoltaic effect.Thin film solar cell is developing very rapidly. But its power output is very low and increasing its power output is a challenge. Efforts can be done in the field of materials used, ink formulations, change in chemistry of solar cell.

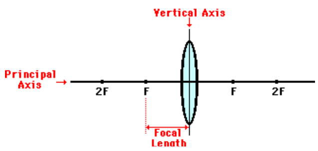

Fig:1 Anatomy of convex mirror

So setup was designed with a xenon light source and convex lens with different focal length. We took one piece of solar cell and prepared a mask and punched a hole in mask. Then mask was mounted on solar cell and readings were taken with different lenses.

II. SOLAR CELL

Bulky and on photovoltaics with a power conversion efficiency of above 10% and a lifetime of 25 years have become the benchmark in the photovoltaic industry. However, there are plenty of scopes for disposable and inexpensive photovoltaics with moderate efficiency and shorter lifetime of less than a year. The photovoltaics that we used are printed on paper substrates and are prepared by just three simple roll-to-roll printing steps under ambient conditions. A paper substrate has several advantages, since it is inexpensive, eco-friendly, bio-degradable, easily recyclable, mechanically flexible and compatible with well-established printing processes.

Despite being the most promising source of green energy, the contribution of photovoltaics to the current energy market is negligible. The major obstacles of all present approaches for photovoltaic are high production and material costs. Organic photovoltaics based on bulk heterojunction (BHJ) of a polymer/fullerene blend have the potential to overcome the existing obstacles.

In the last ten years extensive research has been done to increase the efficiency of polymer/fullerene-based solar cells and significant work is going on to improve its stability. However, nothing substantial has been done to reduce the total costs of polymer/fullerene photovoltaics.

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Our printed paper photovoltaics reduce not only production costs but also material costs.

Fig:2 Printed solar cell

In a conventional BHJ photovoltaic cell, a composite of conjugating polymer (donor) and fullerene (acceptor) is sandwiched between an opaque metallic and a transparent electrode. The conjugated polymer harvests light and the generated excitons are dissociated at the donor-acceptor interface. The generated electrons and holes are collected at the cathode and anode respectively. A naturally oxidized zinc film on conventional image printing paper acts as cathode. Transparent and conducting poly(3,4-ethylenedioxythiopene):poly(styrenesulfonate) (PEDOT:PSS), deposited by flexographic printing, works as anode. The photoactive layer is a blend of poly(3-hexylthiopene-2,5-diyl) (P3HT) and [6,6]-phenyl C61 butyric acid methyl ester (PCBM), deposited by gravure printing. Despite the high substrate roughness, our printed paper photovoltaic cells show a power conversion efficiency of 1.3% under an illumination level of 60 mW/cm^2 and yield open-circuit voltage and short-circuit current density of 0.59 V and 3.6 A/cm^2, respectively.

Lower power conversion efficiency and shorter life cycle of our simple printed paper photovoltaic cells provide the opportunity for a positive energy balance perhaps V. comparable to chlorophyll-based processes in leaves with typical efficiencies of 4-7% and a lifetime below one year. This technology could lead to a basic power source for futuristic printed electronic devices.

III. DESCRIPTION OF TASK

A. Basic Idea

Maintain constant efficiency of printed solar cell at lower angle or increase its efficiency at 90 angles is basic idea behind our concept. According to that we start working. We searched for light concentrating prism sheet. But due to unavailability of prism sheet within given time span we decided to do experiment with the set of convex lenses.

B. Selection of lens

To selected exact lens we checked range of all convex lenses from the given lens of set. For that checking focal length and focal area is a basic criterion for selecting particular lens. After checking all range of lenses we selected 40, 50, and 60 focal length lens.

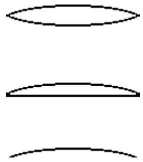

Fig: 3 convex lens

C. Focal area and Focal point of lens

The area where the light rays are converged is called the focal area. Now with convex lenses, the sides are continuously curved allowing the light to be focused into a point rather than a larger area. This would be called the focal point.

D. Setup to simulate results of prism

The designed setup reflected working condition of solar cell with prism. We draw a path for light source so that light source can move in constant path for all samples and all lenses. Different angles were measured with solar cell for exact measurements and exact concentration of light over the sample.

Then we arrange one rod on which we can fix solar cell and lens with its focal length distance. All the measurements were done at night to avoid environmental conditions i.e. sunlight. Prepared mask covered whole solar cell and only limited area is opened which takes exact focus of lens because of this same area for measurement (with and without lens) are taken into account.

IV. RESULTS & OBSERVATIONS

We cut approximately 4.5 * 3.5 size solar cell from printed solar cell. Then we placed solar cell over clamp, cut size of solar cell is placed over clamp with the help of transparent adhesive tape. Then mask is pasted over solar cell according to focus of lens. Make sure that whole solar cell is properly covered by masking material. Solar cell is pasted over rod for measurement. First readings are taken without lens. Then lens is placed in front of solar cell which focuses on masked area. Focal length of lens is noted down. Then measurements are taken with lens then same procedure is followed at different angle. Angles are decided approximately according to focus of lens over cell. We measured five different samples of solar cell. But before measuring solar cell sample of printed solar cells are tested under high intensity light condition to check its uniformity and efficiency.

Table: 1 Comparison of measurements of current & voltage of first sample with different angles, lens & without lens

SAMPLE 1	Without lens		Lens 40		Lens 50		Lens 60	
Angles(˚)	I(μA)	V(mV)	I(μA)	V(mV)	I(μA)	V(mV)	I(μA)	V(mV)
90	0.5	27	4.3	124	2.8	102	2.5	90.1
77	0.4	22.4	3.6	112	2.4	97.8	1.3	51.3
68	0.2	17.4	2.3	97	1.1	67.4	0.5	41.7
59	0.1	9.2	1.4	64.9	0.9	43.8	0.2	19.7

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Table: 2 Comparison of measurements of current & voltage of second sample with different angles, lens & without lens

SAMPLE 2	Without lens		Lens 40		Lens 50		Lens 60	
Angles(˚)	I(µA)	V(mV)	I(µA)	V(mV)	I(µA)	V(mV)	I(µA)	V(mV)
90	1.8	100	11.6	220	9.6	186	5.2	158
77	1.2	85	8.4	195	5.1	171	4.5	152
68	1.1	72.5	6.2	182	4.6	158.3	3.9	138
59	0.9	68	5.3	122	3.8	139	2.1	111.7

Table: 3 Comparison of measurements of current & voltage of third sample with different angles, lens & without lens

SAMPLE 3	Without lens		Lens 40		Lens 50		Lens 60	
Angles(˚)	I(µA)	V(mV)	I(µA)	V(mV)	I(µA)	V(mV)	I(µA)	V(mV)
90	0.9	53	5.4	132	2.9	109	2.3	93
77	0.8	49	4.7	128	2.3	103.6	1.7	89
68	0.6	42	3.9	119	1.7	89.4	0.9	78
59	0.3	35	2.8	98.5	1.2	79.5	0.5	48.8

Table: 4 Comparison of measurements of current & voltage of fourth sample with different angles, lens & without lens

SAMPLE 4	Without lens		Lens 40		Lens 50		Lens 60	
Angles(˚)	I(µA)	V(mV)	I(µA)	V(mV)	I(µA)	V(mV)	I(µA)	V(mV)
90	0.3	48	1.9	92.6	1.6	89.3	1.2	73.2
77	0.2	39	1.7	87.9	1.4	83.7	1.1	69.5
68	0.1	33	1.5	83.2	1.3	75.2	0.9	64
59	0.1	26.3	1.2	72.6	0.9	72.1	0.6	46

Table: 5 Comparison of measurements of current & voltage of fifth sample with different angles, lens & without lens

SAMPLE 5	Without lens		Lens 40		Lens 50		Lens 60	
Angles(˚)	I(µA)	V(mV)	I(µA)	V(mV)	I(µA)	V(mV)	I(µA)	V(mV)
90	1.6	110	12.1	211.1	9.8	192	4.6	149.2
77	1.2	84.3	9.2	194.2	5.4	183	3.6	139
68	1	77.4	6.8	188	4.7	164	2.9	121
59	0.7	59.8	4.4	129	3.3	152	1.9	99

V. CONCLUSION

As we had the task in this research work to increase the efficiency of printed solar cell whose efficiency has been reported 1.3% which was further getting reduced at lower angles of sunlight. In any case, whether it is printed or conventional solar cell, we can't go beyond the efficiency of materials used in the device. We have worked to maintain the efficiency at higher values i.e. obtained at angle of 90˚, and also we have succeeded in that by making the use of some sort of light concentrator which in our case is convex lens. As we can see in the observation table that the efficiency of printed solar cell is increasing with the use of convex lens compared to the readings of without lens. To get the better results with flexible solar cells we need a prism sheet that behave in the same manner as the convex lens do. Definitely we can't get the same results as we got by using convex lens because the material used in lens is glass has very high refractive index. The need for paper based solar cell is flexible prism otherwise it would be of no use to go for R2R manufacturing. We can get higher efficiency at lower angles by using prism sheet instead of convex lens but the increase would not be same as we got from convex lens because the refractive index of plastic sheet is very less as compared to glass. But it can be concluded that if a prism sheet (which will behave in the same manner as convex lens do) is placed over a printed solar cell that can be helpful to a great extent to increase the efficiency of the device.

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