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Construction of portable and flexible solar panel using light harvesting system

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Abstract:*Today harvesting and using solar energy serves as a very good addition to the existing energy resources. Various kinds of solar panels are available in markets. But most of them are made up of metals and are rigid. Construction of these panels is also very tedious. Solar panel constructed here is novel since the polymer used renders it flexibility and portability.The base of this work revolves around the natural phenomenon that electron excited in biological light harvesting system, i.e. Photosystem embedded in thylakoid is finally accepted by NADP out of the thylakoid membrane.Leveraging this phenomenon,we replace this NADP by the artificial electron acceptor.Thus electron flowing through ETC will get accepted by this conducting polymer and complete the electrical circuit to generate electrical energy.One more important feature of this solar panel is, it is very easy to construct and dispose after use. Along with being flexible and portable, it is also cost effective. In future, such a solar panel can be used ubiquitously and with ease.*

Keywords: *Solar panel, Biological light* harvesting *system, 2,6-Dichlorophenolindophenol(DCPIP),Flexibility*

I. Introduction

Solar panels use light energy (Photon) from the sun to generate electricity using photovoltaic effect. The majority of available solar panels uses suitable metallic base as a light harvesting system which make them rigid or semi flexible. Each of them is based on quite different concepts and each has its unique advantages. Use of metals increases cost of these solar panels. Hence cost and critical ways of their construction limit their use and popularity. Considering all the facts we are developing most efficient solar panel, which will try to overcome all these limitations.[1]

We can modify the technology with natural components like biological light systems and pigments from microorganisms to generate energy. Thyllakoids as the light harvesting system would be promising in developing newer technologies.[2]

The base of this work revolves around the natural phenomenon that electron excited in phototsystem is finally accepted by NADP out of the thylakoid membrane.Leveraging this phenomenon, we replace final electron acceptor of the electron transport system (PSI & PS II) with conducting polymer. Thus electron flowing through ETC will get accepted by this conducting polymer and complete the electrical circuit to generate electrical energy. To study this phenomenon we can use DCPIP a redox dye. DCPIP will accept electron from thylakoids and will get reduced. Reduction of DCPIP can be monitored to check for activity of thylakoids.[2,6,9]

II. Materials & Methods

Isolation of thylakoids

Thylakoids were obtained by homogenizing 40 g of fresh, deveined, market spinach (Spinacia oleracea) in 200 ml of Grinding Buffer with a chilled kitchen blender at 5^0C.

About 35 ml of the dark green filtrate was placed in a 40 ml centrifuge tube and centrifuged at 10,000 RPM for 7 minutes at 4^0C. The dark green filtrate was resuspended into 20 ml of Washing Buffer with a small paint brush. The resulting dark suspension was centrifuged at 7993 rpm for 20 seconds to remove the crude cell debris and more dense organelles such as nuclei. The supernatant fluid was centrifuged at 10,000 rpm for 20 minutes. The resulting pellet was resuspended in 40 ml of Washing Buffer and centrifuged again at 10,000 rpm for 20 minutes. This f1inal pellet was resuspended in 5 ml of Washing Buffer and centrifuged again at 10,000 rpm, the pellet was finally resuspended in appropriate amount of Washing Buffer.[w1]

Activity testing of thylakoids

Under physiological conditions, thylakoids transport electrons from water to $NADP^+$ forming NADPH. During the isolation of the thylakoids all of the naturally occurring $NADP^+$/NADPH activity along with the enzymes of the Calvin Cycle were washed away. Thus, it is not possible to measure the physiological electron transport reaction. However, we can add artificial electron acceptors and easily measure light induced electron transport. A convenient electron acceptor is dichlorophenolindophenol (DCPIP).Being a redox dye

DCPIP easily accepts electron and get reduced itself . DCPIP is blue in its oxidized form and turns colorless when it gets reduced. Illuminated thylakoids can readily reduce DCPIP rendering a blue solution colorless. Following procedure was carried out in subdued lighting (overhead lights off).

a. Blank

2.5 ml of Washing Buffer was taken in a large caveat. To this, 2.4 mL of distilled water was added, followed by 100 µL of extracted thylakoid suspension. Absorbance was adjusted to zero at 620 nm, and set it to zero as blank.

a. Measuring the DCPIP Reduction

DCPIP reduction measurement was carried out in a poorly lit room (bear minimum light). The experiment was performed in triplicates. Thus cuvettes were labeled as A, B, C. In these, 2.5 ml of Washing Buffer was added. 200 µL of DCPIP solution (500 µM) was introduced, followed by 2.3 ml of D/W. To this 100 µL of thylakoid suspension was added. Immediately cuvettes were placed in the spectrophotometer and absorbance measured at 620 nm. The cuvette were removed, placed in a strong light beam for 10 seconds and returned to the spectrophotometer for another reading.

Again absorbance was measured at 620nm.Perform illumination for 10 seconds until 620nm approaches 0.05.

The activity of thylakoids depends on the time taken by DCPIP to reduce its optical density to 0.05.[W1]

Stabilization of thylakoids

To use these thylakoids for construction of solar panels and to store these panels over a period of time (for one month at least), stability study was carried out.The matrix was designed by mixing active thylakoids and the polymer in ratio 1:2.These thylakoids were kept at room temperature and their activity was tested using DCPIP method for a period of the month over a time interval of 2 days.[3,4]

Fabrication of Solar Panel

A. Polymer matrix used to construct solar panel:

For fabrication of solar panel polyvinyl alcohol, which is proving as an efficient thylakoid stabilizer is used as solvent while titanium dioxide is used as a semiconductor of electricity . Composition of polymer matrix used to construct solar panel involved:

50ml Polyvinyl alcohol(20%) + 5gm Acryl amide +3gm Bisacryl amide + 5ml Triethanol amine + 5gmTiO_2, coated on glass and transparency and kept at RT for two days.[2,7,8,5]

B. Construction of final solar panel

For construction of solar panels, transparency was taken as a base. Copper wires were stuck on one surface at the ends. Then the final matrix was poured on the transparency and spread into a thin layer. The panel designed was then dried at RT for over three days. On drying the fabricated sheet was removed from transparency, thus giving a flexible and active solar panel. This panel was then exposed to light and then checked for current generation using a multimeter.

Checking for shelf life of a solar panel

Constructed panel was kept at room temperature and checked for its efficiency of current generation after time intervals for over a month.

III. Results

Isolation of thylakoids and testing for their activity:

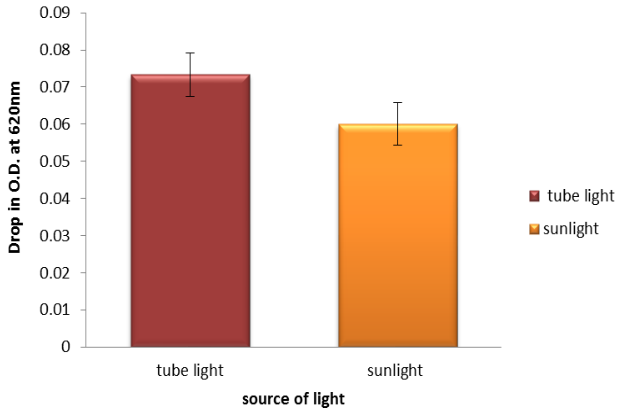
Thylakoids were isolated and their activity studied using DCPIP method. Table 1 explains drop in O.D. after exposure to light.

Tubes	Initial O.D. 620nm	Final O.D.at 620nm (after exposure to tube light for 10secs)
Blank	0.00	0.00
A	0.07	0.03
B	0.07	0.03
C	0.07	0.03

Table 1 **-** Activity of thylakoids

Comparative study of effect of natural and artificial light

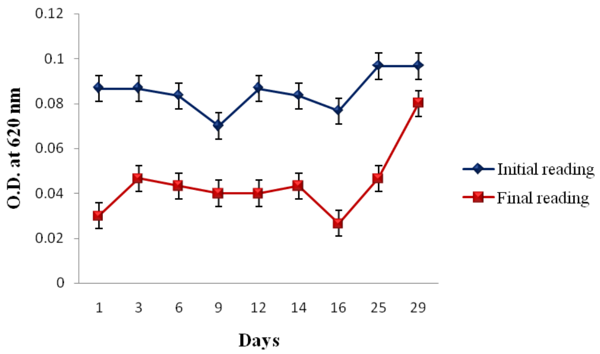
The effect of natural light and artificial light on the activity of thylakoids was compared by studying reduction of DCPIP



Graph No. 1 Comparative studies of effect of different light source

Stability testing of thylakoids

Thylakoids were kept at RT for a month in Polyvinyl alcohol. The polymer is selected on the basis of its ability to form a shell like structure around protein bodies like thylakoids, mitochondria and electricity conducting property.Graph no. 2 shows result that polyvinyl alcohol efficiently stabilize thylakoids over a period of month.



Graph 2 Activity of thylakoids at RT in PVA

Fabrication of solar panel

A panel was successfully created on a template (transparency sheet) using the polymer matrix with thyllakoids incorporated in it. After drying, polymer was pulled off from the template, forming a flexible and portable film. The film was tested for current generation. A current of around -441 µAmp and 10 mV potential difference was generated Figure 2.(b) shows control for solar panel i.e. a panel without thylakoids which is showing zero current generation .This means current generation by constructed solar panel is result of electron excitation taking place in thylakoids as polymer without thylakoid showing zero electron motive force.

Figure 1 flexibility of constructed panel

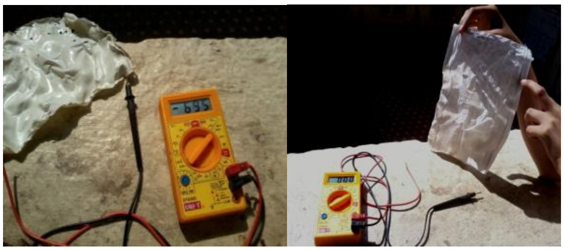


Figure no. 2 a) current generation by constructed solar panel b) Control: solar panel without thylakoids

Shelf life study of solar panel:

Day	Current generation by solar panel over a time period in µAmp
1	-403
3	-341
6	-360
9	-331
12	-414
15	-689
30	-695

Table 2 Shelf life testing of solar panel

Dried panel was kept at Room Temperature for a month and current generation was tested after time interval and was found that constructed solar panel generate current over a month under normal conditions (as in table no.2). The constructed panel was found to be stable over month.

IV. Discussion

Isolation of thylakoids and testing for their activity

Thylakoids isolated from spinach were tested for their activity using DCPIP assay. In table1 we can see that there is a drop in O.D. after exposure to light is because of a reduction of DCPIP by electrons excited in thylakoids, which suggests thylakoids are active.

Comparative study of effect of natural and artificial light

This study was done to check the effect of different light sources on activity of thyllakoids. In this comparative study, we used tubelight and sunlight as a different source of light and it was seen that decrease of O.D. in both the cases are approximately same. This means there is no significant effect of changing light source on thylakoids excitation.This study justifies further studies based on tubelight as a light source.

Stability testing of thylakoids

Thylakoids were kept at Room temperature for a month in Polyvinyl alcohol and tested for their activity over a period of 30 days .Testing was done with time interval of two days. From graph 2 it is clear that Polyvinyl alcohol efficiently stabilize thylakoids for 30 days.So we used Polyvinyl alcohol as solvent for our polymer matrix

Fabrication and construction of solar panel

A flexible and portable solar panel was constructed giving -441 µAmp current generation and 10 mV potential difference. To confirm that this current generation is because of thylakoid activity and not because of any other electron motive force generating factor. We checked, the current generation of control panel, which is film of polymer matrix without thylakoids and which was giving zero current generation. This confirms our theory is working.

Shelf life study of solar panel

Dried panel was kept at Room Temperature for a month and current generation was tested after time interval and was found that constructed solar panel is stable over a month under normal conditions.

V. Conclusion

Solar panel constructed over here is succeeding in overcoming many limitations. It is made up of biological system instead of metal as a principal component.It is very easy to construct and maintain It is portable and flexible It is very cost effective and easy to dispose hence can be employed in daily use.This panel has stability over a month

VI. Future Prospects

The solar panel in the study has been constructed on a smaller scale and is in primary stage. The output obtained being in microampere. Further improvement can be done by combining superconducting nanoparticles with the light harvesting system. Such solar panels can then be used as portable chargers for watches and mobile batteries. These can be taken around in a moving vehicle comfortably. More novel panels can be generated leveraging the pigment systems in various other life forms like bacteria and algae. Artificial dyes can also be used to create these flexible and portable solar panels.

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