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RESEARCH ARTICLE

Innovative Study on Solar Energy Conversion and Storage Through Malachite Green + Ascorbic Acid + Sodium Lauryl Sulphate For Photogalvanics

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Abstract

Objective: To improve the output of photogalvanics (PG) cell. **Methods:** The specially designed H shaped PG cell was studied for better electrical outcomes. The PG cell setup consists of two electrode, digital pH meter, resistance key, carbon pot, and microammeter. The system consisting of Malachite Green (MCG), Ascorbic acid (AA), and Sodium Lauryl Sulphate (SLS) was examined in terms of photopotential (PP) and photocurrent (PC). **Findings:** The measured PC was 391.00 μA, while the observed PP was 926.00 mV. The finest and most dependable renewable energy option to help the world's population meet their energy requirements is solar energy. **Novelty:** Better results on Photo Galvanic (PG) cells are reported in the present research, helping to achieve the goal providing clean and sustainable energy. The intended electrical outcomes were obtained by using the MCG + AA + SLS, PG cell arrangement.

Keywords: Malachite Green; Photogalvanics; Sodium Lauryl Sulphate; Ascorbic acid; Photopotential

1 Introduction

Water photolysis, which occurs and photosynthesis are two examples of the photo-chemical reactions that contribute significantly to solar energy. Non-renewable energy sources have drawbacks of their own, in addition to hazardous activities and a dirty environment. Because of human usage, the fossil fuels (kerosene, coal, wood, etc.) are growing closer to being completely depleted. As a result, developing other sources is necessary. Solar energy cells are the most viable alternative energy source. PG cells are the solar cells that have been the subject of the most research.

The photogalvanic cell is an H-shaped glass tube cell containing two electrodes dipped in a multifaceted electrolyte solution of dye-reductant-surfactant-alkali [(1)]. Photogalvanic cells are photo-electrochemical devices involving ions as mobile charges moving in solution through diffusion process [(2)]. Research on enhanced electrical output by mixed surfactant [(3)] for improved results for use of various surfactants in PG cell [(4)] for PG cell, use of Alizarin Red in PG cell [(5)] for better solar results and the function of

EDTA - Azure A -SLS scientific path [6] regarding energy was investigated. The goal of the research is to increase electrical output by the use of PG cells, which will result in increased electrical output [7]. Similarly, the influence of nan particles on PG cells [8] is similarly favorable to improved results.

The investigation of glycol-NALS system for combined photosensitizer with MB system [9] for solar power conversion and storage. Positive results from micelles on PG cells [10] for cell systems and correction between photoelectrochemical and spectrophotometric study of dye – surfactant combination in photogalvanic cell [11] using a scientific approach. Photogalvanic cells provide a route for simultaneous solar power and storage [12]. Solar energy is a limitless energy resource that can be used to produce electricity forever [13]. It was suggested and required to do experiments with PG cells in sunlight conditions [14]. Innovative study for energy Source through EDTA+TB+NaLS [15] for PG system (Gangotri and Meena 2023), for solar energy conversion and storage and relevant work was done using a sustainable and green chemistry approach [16]. The enhanced study of PG cells using DSS, Tartrazine, and EDTA [17] and was followed by a study of PG cells for electrical output using the same methods with lauryl glucoside surfactant, tartrazine photosensitizer, and D-fructose reductant [18]. Given recent breakthrough findings regarding improved results in PG cells [19]. A progressive study for a viable energy source utilizing the photo-galvanic system D-Xylose+MB+Brij-35+NaLS was carried out and this study's findings were released in the journal "International journal of energy research" [20]. An innovative study using an EDTA-Alizarin cyanine green (ACG)-sodium stearate (SS) PG cell produced improved results [21]. A new approach to conducting state-of-the-art research on renewable energy sources in an eco-friendly environment with a mixed surfactant system. The results of PG cells are published in the journal "Environment science and pollution research" [22].

Throughout the solar system, a number of surfactant-dye-reducing agents (SDR) have been employed; however, none of those parties have considered the MCG-AA-SLS combination as a potential substitute for SDR in order to increase electrical generation. Consequently, development of the MCG-AA-SLS system, the present PG cell, started.

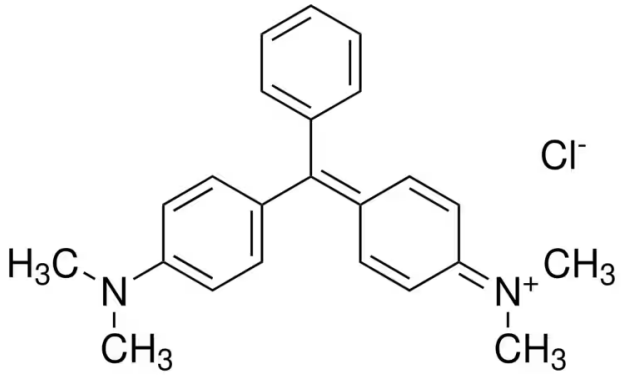

Fig 1. Structure of Malachite Green

2 Methodology

2.1. Solution preparations

To ensure that the results were necessary, distilled water (DW) was used throughout each of the experiment's methods, including ascorbic acid, MCG, and alkaline solution. To standardize the sodium hydroxide solution used in each test series, oxalic acid was added. To protect the non-reactive form of these solutions from radiation, them were constantly stored in brown colored bottles.

2.2. Methodology for setup for MCG+NaLS+AA system

Two electrodes, a digital pH meter, a key of resistance, a carbon pot, and an ammeter make up the PG cell setup. Investigations into the particularly designed H-shaped PG cell were carried out in order to achieve better electrical results. To complete the solar circuit during the experiment, the resistance key, micro-ammeter, 200 W electric bulb (with a W filament), and both ends of the electrodes were connected. The water filter was used to set up the radiation shield and light sources for the experiment. Examined were the different solar parameters in a PG cell using an MCG+SLS+AA system. The various parameters of the

PG cell were adjusted in order to investigate the primary effects of solar energy. Distilled water, alkali, and a combination of surfactant, reductant, and dye were mixed into a 25 ml solution for the PG cell. Throughout the experiment, the system's temperature was maintained at 303 K and the cell was illuminated. For improved results, the experimental setup (Figure 2) for the MCG+NaLS+AA system is given.

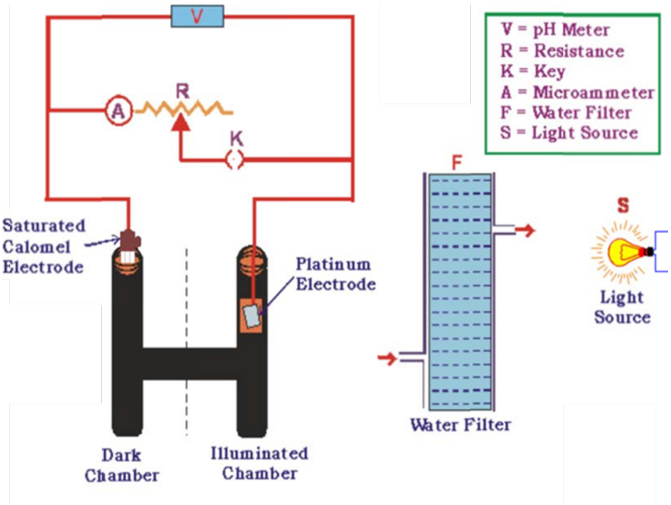

Fig 2. Methodology for PG cell

3 Results and Discussion

3.1. Variation about MCG concentration

In this study, the variation in dye concentration for MCG+SLS+AA has been examined. With an increase in MCG concentration, the electrical results in the MCG+SLS+AA system increase, peaking at MCG X 10^{-4} M, and subsequently start to fall. The dye's hydrophobic nature causes a lower nature of MCG for light absorption, so the electrical output is similarly low (MCG X 10^{-4} M). Higher concentrations of MCG molecules (MCG > 10^{-4} M) cause a significant number of them to swarm the absorbent surface. When the MCG concentration is in the center (MCG X 10^{-4} M), the best molecules are present, enabling the electromagnetic source to collide with the molecules that are closest to the electrode and initiate photochemical processes.

The Open circuit voltage (Voc), Isc, Imax, Vpp, ipp, and Ppp are measured for MCG variation on the PG system; the resulting values are 1124 mV, 586 μA, 631 μA, 576 mV, 391 μA, and 225.26 μW, respectively. All observed results are provided in Tables 1, 2, 3, 4, 5 and 6 and Figures 2, 3 and 4.

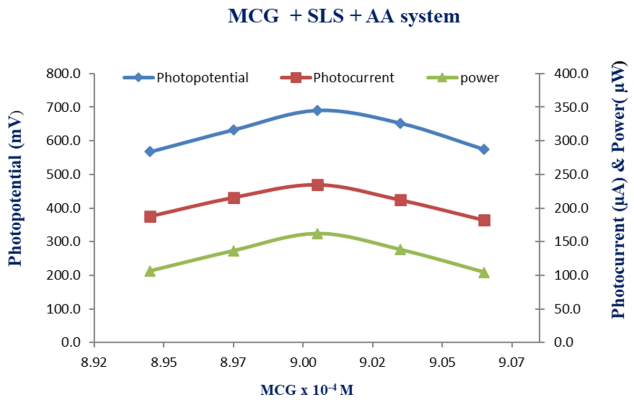

Fig 3. Variation of photopotential (PP), photocurrent (PC) and power

Table 1. Variation of MCG Concentration

Parameters	MCG Dye X 10^{-4} M concentration				
	1.0	1.2	1.4	1.6	1.8
V_{dark} (mV)	123	158	198	165	120
V_{max} (mV)	1143	1145	1167	1132	1011
V_{oc} (mV)	1117	1110	1124	1102	1002
i_{max} (μA)	310.0	521.0	631.0	414.0	212.0
i_{sc} or i_{eq} (μA)	213.0	431.0	586.0	432.0	213.0
V_{pp} (mV)	321.0	453.0	576.0	432.0	321.0
i_{pp} (μA)	202.0	234.0	391.0	235.0	217.0
P_{pp} (μW)	126.18	208.10	225.26	186.12	121.30

3.2. Variation of SLS concentrationV

The photo reactivity of SLS was investigated using electrical power using the PG cell with the MCG+SLS+AA system. It was discovered that increasing the SLS concentration will cause the outcome to rise up to a certain point before declining. At lower SLS concentrations (surfactants X 10^{-3} M), the solubilization of the molecules was reduced for photophysical activities on the surface. Because there are substantially more surfactant molecules available for photophysical processes in hydrophobic contact at higher surfactant concentrations (SLS >10^{-3} M), this could lead to a reduction in the electron carrier. The significant electrical output was measured in the intermediate range at a surfactant concentration of M X10^{-3} M SLS. In PG cells, the combination of surfactants may result in a higher-quality precipitate than the precipitate from a single surfactant.

This is caused by surfactant action at a micelle interface. The Open circuit voltage (Voc), Isc, Imax, Vpp, ipp, and Ppp are measured for MCG variation on the PG system; the resulting values are 1124 mV, 586 μA, 631 μA, 576 mV, 391 μA, and 225.26 μW, respectively. All observed results are provided in Tables 1, 2, 3, 4, 5 and 6 and Figures 2, 3 and 4.

Table 2. Variation of SLS Concentration

Parameters	SLS X 10^{-3} Mconcentration				
	0.4	0.6	0.8	1.0	1.2
V_{dark} (mV)	102	121	198	112	101
V_{max} (mV)	1102	1134	1167	1097	1023
V_{oc} (mV)	1054	1109	1124	1031	1012
i_{max} (μA)	278.0	431.0	631.0	435.0	376.0
i_{sc} or i_{eq} (μA)	460.0	512.0	586.0	443.0	321.0
V_{pp} (mV)	321.0	419.0	576.0	408.6	321.0
i_{pp} (μA)	200.0	208.0	391.0	209.0	212.0
P_{pp} (μW)	121.10	232.20	225.26	213.06	212.0

3.3. Variation of AA concentration

The current study has looked into the change in AA concentration for MCG+SLS+AA. As the concentration of AA rises, the observed consequences also do. In the MCG+SLS+AA system, as AA concentration is raised, the electrical output also gradually increases to a maximum value at AA X 10^{-3} M before declining. At lower concentrations of AA, comparatively less reductant is available for electron donation to MCG in order to produce the ionic nature. The amount of AA (AA > 10^{-3} M) that can be converted photo physically to AA to form the cationic form, which inhibits the AA molecules, is greater at these considerably higher concentrations. A suitable outcome can be achieved within an intermediate range of the reductant concentration. The reason for this is that the right amount of reductant molecules is present, creating favorable pathways for dye MCG molecules in their semi- or leuco-forms. According to the findings, the deep sleep mode only used 10 mA of current, which is frequently significantly less than what the machine is currently using. The Open circuit voltage (Voc), Isc, Imax, Vpp, ipp, and Ppp are measured for MCG variation on the PG system; the resulting values are 1124 mV, 586 μA, 631 μA, 576 mV, 391 μA, and 225.26 μW, respectively. All observed results are provided in Tables 1, 2, 3, 4, 5 and 6 and Figures 2, 3 and 4.

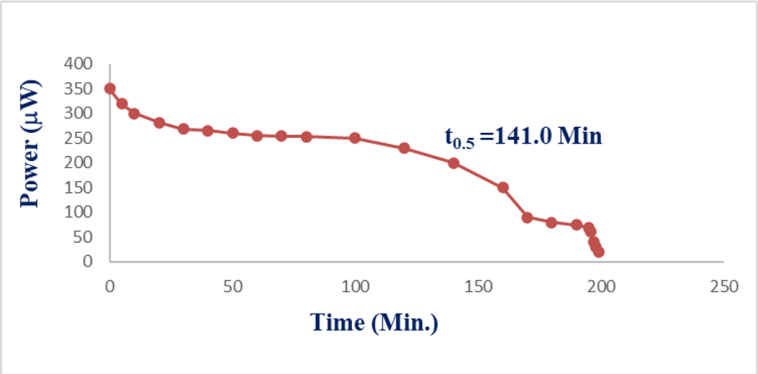

Fig 4. Performance of the PG cell

3.4. Variation of pH range

The concentration of hydrogen ions was measured for the current study. The MCG+NaLS+AA system dropped as the basic nature (pH) grew, and the current parameters were progressively increased as well, reaching an optimal value of a specific pH scale (pH=13.30). On a pH range of 12.64 and above (pH > 13.30), poor results are seen. Better results, however, are seen at the intermediate range (pH = 13.30). This is due to the better nature of dye molecules (MCG) for photochemical activities. The Open circuit voltage (Voc), Isc, Imax, Vpp, ipp, and Ppp are measured for MCG variation on the PG system; the resulting values are 1124 mV, 586 μA, 631 μA, 576 mV, 391 μA, and 225.26 μW, respectively. All observed results are provided in Tables 1, 2, 3, 4, 5 and 6 and Figures 2, 3 and 4.

Table 3. Variation of Reductant Concentration (Ascorbic acid)

Parameters	Ascorbic acid X 10^{-3} Mconcentration				
	0.2	0.4	0.6	0.8	1.0
V_{dark} (mV)	103	121	198	113	103
V_{max} (mV)	1101	1138	1167	1098	1024
V_{oc} (mV)	1044	1109	1124	1030	1011
i_{max} (μA)	276.0	431.0	631.0	435.0	375.0
i_{sc} or i_{eq} (μA)	462.0	511.0	586.0	433.0	320.0
V_{pp} (mV)	323.0	419.0	576.0	418.6	320.0
i_{pp} (μA)	205.0	207.0	391.0	206.0	210.0
P_{pp} (μW)	120.00	232.00	225.26	212.06	214.0

3.5. Variation of DL on the PG system

Experiments with diffusion lengths (DL) ranging from specific PG cell route were conducted using the cell. The electrical output of the PG cell was observed in the MCG+SLS+AA system. Increasing the diffusion length accelerates the rate of first photocurrent generation. Very good findings are obtained at 45.00 mm, where photocurrent and equilibrium photocurrent are measured, respectively. The photocurrent is collected in a comparable way because dye molecules cannot absorb the light source at lower and greater diffusion lengths, respectively.

The Open circuit voltage (Voc), Isc, Imax, Vpp, ipp, and Ppp are measured for MCG variation on the PG system; the resulting values are 1124 mV, 586 μA, 631 μA, 576 mV, 391 μA, and 225.26 μW, respectively. All observed results are provided in Tables 1, 2, 3, 4, 5 and 6 and Figures 2, 3 and 4, respectively.

3.6. Variation of EA of the cell

Electrode areas (EA) of 0.060 cm^2 to 1.00 cm^2 were used to compute the current properties of the PG cell. For better outcomes, the photocurrent and photocurrent were the subjects of the investigation. The Open circuit voltage (Voc), Isc, Imax, Vpp, ipp,

Table 4. Variation of NaOH Concentration (pH)

Parameters	pH of Solution				
	13.24	**13.27**	**13.30**	**13.33**	**13.26**
V_{dark} (mV)	105	125	198	119	109
V_{max} (mV)	1102	1134	1167	1097	1028
V_{oc} (mV)	1057	1109	1124	1031	1012
i_{max} (μA)	278.0	431.0	631.0	434.0	376.0
i_{sc} or i_{eq} (μA)	460.0	512.0	586.0	443.0	321.0
V_{pp} (mV)	321.0	419.0	576.0	408.6	321.0
i_{pp} (μA)	201.0	208.0	391.0	229.0	217.0
P_{pp} (μW)	120.10	232.20	225.26	213.00	210.0

and Ppp are measured for MCG variation on the PG system; the resulting values are 1124 mV, 586 μA, 631 μA, 576 mV, 391 μA, and 225.26 μW, respectively. All observed results are provided in Tables 1, 2, 3, 4, 5 and 6 and Figures 2, 3 and 4, and recorded at 1.00 cm^2 of electrode area.

Table 5. Pt electrode size (Length X Width) in cm and Area

Parameters	Variation of EA of the cell				
	0.3 x 0.2 (0.06 cm^2)	**0.4 x 0.2 (0.08 cm^2)**	**0.4 x 0.3 (0.12 cm^2)**	**0.5 x 0.3 (0.15 cm^2)**	**1.0 x 1.0 (1.00 cm^2)**
V_{dark} (mV)	102	123	198	115	103
V_{max} (mV)	1002	1139	1167	1083	1025
V_{oc} (mV)	1044	1100	1124	1031	1018
i_{max} (μA)	272.0	431.0	631.0	432.0	373.0
i_{sc} or i_{eq} (μA)	462.0	512.0	586.0	446.0	320.0
V_{pp} (mV)	323.0	410.0	576.0	403.6	320.0
i_{pp} (μA)	204.0	203.0	391.0	223.0	214.0
P_{pp} (μW)	120.00	232.30	225.26	211.00	219.0

3.7 (i-V) characteristics of the PG cell

Using Equation (1), the fill-factor (FF) and power point (PP) were determined.

$$Fill\ factor\,(n) = \frac{V_{pp} \times i_{pp}}{V_{oc} \times i_{sc}} \tag{1}$$

$$Power\ Point\ \ (pp) = V_{pp} \times i_{pp} \tag{2}$$

Where: V_{pp} is value of potential, i_{pp} is current at power point, V_{oc} is open circuit voltage, i_{sc} is short circuit current.

After calculating the circuit's FF, the Ppp for the PG cell was found to be 225.26 μW. The observed results for the (i-V) PG cell properties for the MCG+NaLS+AA system is shown in Table 6. Every PG cell (Figure 4) observation for the MCG+SLS+AA system is documented.

3.8. Cell performance and conversion efficiency (CE) of the PG system

The computed performance, expressed in terms of $t_{1/2}$, is displayed in (Figure 4), and the experimental result was 141.00 minutes in the dark. It was discovered that the CE of PG cells was 2.2521 percent (Equation (3)).

$$Conversion\ efficiency = \frac{V_{pp} \times i_{pp}}{A\ 10.4 mW cm^{-2}} \times 100\% \tag{3}$$

Where A is the cell's electrode area, Vpp is the photopotential at the cell's power point, and ipp is the photocurrent at the same point.

3.9. Effect of variation of light intensity

It was determined how much light there was surrounding the PG cell for electrode regions between 3.1 and 26.0 mWcm^{-2}. The maximum photocurrent (imax in mA) and equilibrium photocurrent (ieq in μA) were the subjects of the investigation. Very encouraging results are attained at 10.4 mWcm^{-2}, which shows the observed findings for the change in electrode area on the MCG+SLS+AA system.

Table 6. Photocurrent power (i-v) of modified PG cell

S. no.	Photocurrent (uA)	Photopotential (mV)	Power (uW)
1.	0.00	1124	000.0
2.	32.0	1062	33.984
3.	168.0	935	157.08
4.	285.0	720	205.20
5.	391.0	576	225.21
6.	420.0	515	216.30
7.	445.0	140	78.40
8.	020.0	580	11.60
9.	000.0	586	000.0

3.10. Mechanism

The movement of electrons within the PG cell's circuit is demonstrated by the following chemical reaction, which takes place in a laboratory setting.

3.10.1. Illuminate Chamber

Quantum photons are captured by the MCG molecules (Dye) and activated in the following ways in the process of photophysical and photochemical processes (Equation (4)). In the second step (Equation (5)), excited MCG absorbs electrons from reductants and transfers its energy to a range of other molecules.

$$MCG \xrightarrow{hv} MCG* \tag{4}$$

$$MCG* + AA \rightarrow MCG^{-} + AA^{+} \tag{5}$$

3.10.2. PG cell reaction at Pt electrode

However, semi- or leuco-form (Equation (6)) returns to its original form in the secondary reaction by transferring the electron to an electrode.

$$MCG^{-} \rightarrow MCG + e^{-} \tag{6}$$

3.10.3. PG cell reaction at dark Chamber

Equation (7) explains how, upon absorbing electrons from the counter electrode, the dye (MCG molecules) at the electrode changes into a semi- or leuco-form of MCG. Equation (8) illustrates that the MCG (leuco/semi-form) and the reducing agent combine to produce the original MCG and AA molecules, which marks the completion of the photochemical cycle.

$$MCG + e^{-} \rightarrow MCG^{-} \tag{7}$$

$$MCG^{-} + AA^{+} \rightarrow MCG + AA \tag{8}$$

Where: AA is ascorbic acid; AA+ is the oxidized form of reductant (ascorbic acid); MCG is Malachite Green dye; MCG* is excited form of MCG; and MCG^{-} is semi or leuco form of Malachite Green.

3.11. Importance of work

Based on the results of the conducted studies, we have found that the MCG+SLS+AA surfactants have improved the electrical output and energy conversion capability of the PG cell. In terms of current criteria for power and solar energy conversion, the PG cells would be the best option. The open circuit voltage of the BY+NaLS+AA cell is 1124.00 mV, as opposed to the 690.00 mV previously reported (published work by Lal and Gangotri, 2022). The EDTA+ACG+C DEA PG cell fill factor is 0.3082, which is different from previously reported fill values of 0.211, 0.200, 0.240, and 0.207 (published study by Koli et al., 2021). Even though the EDTA+TB+NaLS PGS recorded a good photocurrent of 150.00 uA, the study that was published in the "Indian Journal of Science and Technology" journal in 2022 already had specific numbers. To sum up, the results of the PG cell that was seen surpass those of the PG system that was released in 2022 by Lal and Gangotri. Koli et al., 2021; Rathore et al., 2022. The Open circuit voltage (Voc), Isc, Imax, Vpp, ipp, and Ppp are measured for MCG variation on the PG system; the resulting values are 1124 mV, 586 μA, 631 μA, 576 mV, 391 μA, and 225.26 μW, respectively. These are much higher electrical outputs than those of the MCG+SLS+AA system. By utilizing the effects, a PG cell with a higher electrical output than previously reported results will be produced (refer to references 15, 16, and 17). If efficient systems become sufficiently sophisticated, they might replace the solar cells that are now on the market and provide the electricity required for growth that is environmentally beneficial.

4 Conclusions

Novelty, Prospectus and Recommendation

The study is centered on improving the electrical performance and lower the cost of PG cells. By considering the good amount of storage capacity of the MCG+SLS+AA system, the goal has been achieved. If the price and overall efficiency of these systems be lowered to the required degree, the current PG cells on the market may be replaced and these effective systems may be able to meet all of humanity's electrical needs.

Abbreviations

MCG = Malachite Green, NaLS = Sodium lauryl sulphate, AA = Ascorbic Acid, PG cell = Photogalvanic cell, PGS = Photogalvanic system, i_{eq} = Photocurrent at equilibrium, i_{sc} = Short circuit current, i_{pp} = Photocurrent at power point, mV = Millivolt in cell circuit, ml = Milliliter for PG cell, V_{oc} = Open circuit voltage, $t_{1/2}$ = Storage capacity of cell, pp = Power point of cell, M = Molarity of solution used, V_{pp} = Photopotential at power point, μA = Microampere in cell circuit, h = Fill factor for PG cell, i_{max} = Maximum photocurrent, μW = Microwatt in cell circuit

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