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Highest Efficiency Dssc Fabrication With Natural Dye and Chemical Dye

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Abstract

DSSC fabrication can be carried out using various methods, such as hydrothermal, doctor blade technique, sol gel spin coating method. With electrolytes such as I2/I3-, KI, ZnO, TiO2 in DSSC fabrication. The greatest efficiency for natural dyes is around 2.68%, while for chemical dyes it is 10.4%. Efficiency is influenced by the concentration of the dye and the type of electrolyte used. From several DSSC manufacturing methods described previously, with natural and chemical dyes, it can be concluded that what influences the high efficiency of DSSC is as follows. Dyes, these dyes must have high light absorption values in the long range. broad waves, as well as the ability to produce stable electrons after absorbing light photons. The liquid electrolyte in DSSC plays a role in conducting electrons between the dye and the electrode. The type and quality of electrolyte can affect the electron transfer rate and energy conversion efficiency. Electrodes, electrodes are components in DSSC which function to collect electrons produced by the dye and channel them to the solar cell. Electrode material and good contact between the electrode and the sensitizer material also have an impact on DSSC efficiency. Solar cell design, DSSC solar cell design including layer structure and electrode configuration can affect energy conversion efficiency. Good design can maximize light absorption and reduce energy loss. Light Intensity: The efficiency of a DSSC depends on the intensity of sunlight it receives. High DSSC efficiency when direct or high sunlight. Temperature during DSSC operation, high temperatures can increase electron mobility and speed up chemical reactions in solar cells, but must be managed properly so as not to damage DSSC components. Damage to DSSC components can reduce DSSC efficiency. To make DSSc with natural dyes, the method used by Helga et al produces an efficiency of 2.68% compared to the method used by Utami et al which only produces 0.72%. To make DSSC with chemical dyes, the method used by Whon Chu et al, Suruthi Priya Nagalingam, Anurag Roy et al, and M. Chinnari produces the greatest efficiency of 10.4%. This efficiency is produced by research by Whun Chun Oh et al. So it can be concluded that to produce higher efficiency, method optimization needs to be carried out in the research of Helga et al and Whun Chun Oh.

Keywords: DSSC, Efficiency, Natural Dye

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INTRODUCTION

DSSC solar cells continue to be studied continuously with the aim of increasing the efficiency value of DSSC so that it can be widely implemented. The reason why research on DSSC is gaining more attention is because it is relatively cheap and does not produce dangerous waste, especially for DSSC with natural dyes. The electrolytes commonly used in DSSC fabrication are TiO2, ZnO, KI and I3/I-. In DSSC fabrication with natural dyes carried out by Helga Dwi Fahyuan et al

with the steps of cleaning the FTO substrate and making graphite/TiO2 colloids using the doctor blade technique [1], extracting anthocyanin dye from mangosteen and pomegranate peels [2], making a solution PEG and KI based electrolytes [3], assembly of DSSC solar cells using sandwich layer technique [5] and IV characteristic testing and layer morphology analysis using SEM [7]. DSSC fabrication with natural dyes carried out by Utami Oktavia et al using the sol gel spin method coating[6]. DSSC fabrication with chemical dyes was carried out by Won Chun et al using hydrothermal[8]. DSSC fabrication with chemical dyes was carried out by Suruthi Priya Nagalingam et al with electrode preparation steps [9], PEDOT deposition[9], Characterization [10], making DSSCs [11][12], fabricating DSSCs with chemical dyes carried out by Anurag Roy et al using a sono-chemical synthesis method using bovine serum albumin (BSA) as a biotemplate [13] and fabricating DSSCs with chemical dyes carried out by M. Chinnari et al was a combination of solvothermal and chemical reduction methods to produce Ag-TiO2 nanospheres (NS) with an even Ag distribution [14]. The electrolytes that are often used in making DSSC are KI, I2, PEG, I -/I3- and polysulfide.

METHOD

Natural Dye

The manufacturing method used by Helga Dwi Fahyuan et al is as follows

Cleaning the FTO substrate with an ultrasonic cleaner then drying it using a hair dryer. Then the graphite/TiO2 colloid was made by dissolving Polyvinyl Alcohol (PVA) in distilled water. Next, TiO2 powder is added and stirred until a paste/colloid is formed. Then graphite powder is added with variations (0%, 8%, 10%, 12%, 14%) as an impurity which has been dissolved in distilled water until a graphite/TiO2 colloid is formed. Then the graphite/TiO2 colloid is deposited on the FTO substrate using the doctorblade technique to form a thin, even layer. Then the layers were analyzed using UV-Vis, XRD and SEM.

Anthocyanin dye is extracted from the skin of mangosteen and pomegranate fruit, 20 grams each which has been cut into small pieces, ground with a mortar until smooth, then soaked in a solvent consisting of methanol, acetic acid and distilled water for 24 hours. The anthocyanin dye extract was filtered using filter paper. Then the dye is absorbed onto the graphite/TiO2 layer. The carbon electrode counter preparation stage uses a 2B pencil (Faber Castel) as a carbon source by shading the 2B pencil on the conductive part of the FTO until it is evenly distributed, then the glass is burned on top of the candle with the shading position facing the flame. Burning is carried out until the flame soot covers the conductive surface of the FTO. The electrolyte solution used is redox pair (I-/I3-) in the form of a solid electrolyte based on PEG (Polyethylene Glycol) 4000 which is dissolved in chloroform until it forms a gel, then in another place the potassium iodide (KI) is dissolved in acetonitrile, stirred using a magnetic stirrer, then 0.127 grams (0.05M) of I2 was added and stirred again until homogeneous. After that, the two solutions were mixed and stirred using a magnetic stirrer, then the solution was stored in a closed bottle.

The final stage is assembly and testing of the DSSC solar cells. DSSC assembly was carried out using the sandwich layer technique, which can be seen in Figure 1a

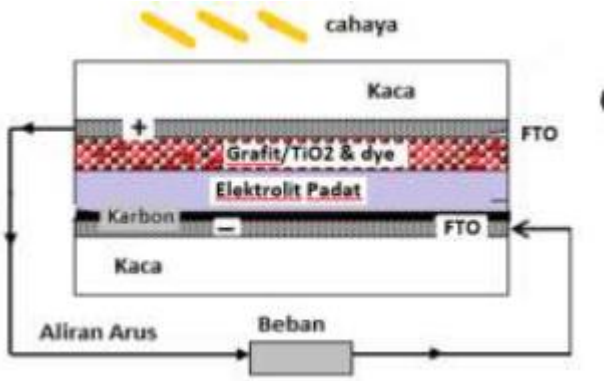
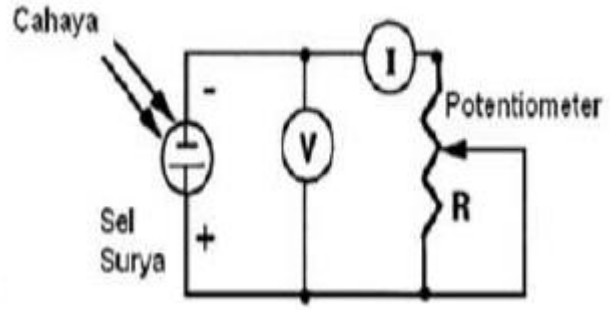


Figure 1a DSSC Component Layer Structure Components

That is, by placing the FTO substrate which has been coated with carbon on a flat surface with the surface coated with carbon facing upwards, then on top of it, place the solid electrolyte and the FTO substrate which has been coated with graphite/TiO2 and dye in such a way that the graphite/TiO2 and dye layers face the carbon layer with sandwich structure then the left and right sides of the cell are clamped with paper so that it does not move and the cell is ready to be tested.

The characteristics of the current voltage IV are measured by assembling solar cells in a test circuit as shown in the image below. The light source used is an incandescent lamp with a power of 100W whose intensity can be adjusted.



Illumination using lights aims to control the amount of photons that hit the DSSC. Current and voltage (IV) measurements will be carried out by varying the light intensity of the lamp, namely 250Lux, 500Lux, 750Lux, and 1000Lux.

The method for making DSSC by Utami Oktavia et al is as follows

Making giant magnoteresis (GMR) thin films

a. Preparation of precursor CoFe2O4, 0.25M

   1.4550 grams of Co(NO3)2.6H2O powder and 4.0395 grams of Fe(NO3)2.9H2O powder were dissolved in 20ml of ethanol, then sonicated with an ultrasonic cleaner for 30 minutes to form a homogeneous sol.

b. Preparation of 0.5M Zn precursor

   2,195 grams of (CH3COO)2Zn.2H2O powder was dissolved in 20ml of methanol, then the solution was homogenized with an ultrasonic cleaner for 30 minutes. The solution was called MEA 3 drops

c. Preparation of glass substrate

The glass plate will be coated with the above material and cleaned first using acetone so that the dirt on the surface of the glass plate can be removed so that it does not disturb the layer that will form. After rinsing with acetone the glass plate was heated at 1000 C for 15 minutes. Then cooled and ready to be coated.

d. The process of making CoFeO4 thin films

CoFeO4 nano particles are coated onto a glass plate using the spin coating method with a coating rotation of 2000rpm for 30s, then oven at 1000C for 1 hour, calcined at 3000C for 3 hours (pre-annealing) at 5000C for 1 hour (post-annealing).

e. Process for making CoFeO4/Zn/ CoFeO4 thin films

A thin layer of Giant Magnetoresistance (GMR) with a sandwich structure is made by coating a glass plate coated with CoFeO4 on top with Zn precursor and then baking it in an oven at a temperature of 1000C for 3 hours (pre-annealing) at a temperature of 5000C for 1 hour (post-annealing) then coated again with CoFeO4 on top and calcined with the same temperature variations. Characterization of CoFeO4/Zn/ CoFeO4 Thin Films

f. Analyze the morphology of the thin layer using SEM

The sample to be analyzed is a thin layer of CoFeO4. A thin layer of CoFeO4 is placed into the sample holder. The sample surface is bombarded with a high-energy electron beam. The results obtained are images of a thin layer of the surface at a certain magnification.

g. Analyzing thin layer crystallization using XRD

The sample in the form of a thin layer of CoFeO4 is inserted into the set holder. Scan the sample on and obtain a difactogram. The difactogram is analyzed by determining the degree of crystallinity of the resulting thin layer$2\theta(1-100^0)$

h. 4-point Probe System.

i. ZnO Electrode Preparation

ZnO was weighed as much as 6 grams, added with 10ml of ethanol then stirred using a magnetic stirrer for 30 minutes. After that, the ZnO paste is coated on the glass and then sintered at a temperature of 3000C using a furnace.

Purple Potato Dye Extract.

40 grams of purple sweet potato, cut into small pieces and finely crushed with a mortar, then soaked in ethanol: 1M HCl (50:10 ml volume ratio) for 24 hours. During soaking, the purple sweet potato extract solution must be stored in a dark place

Immersion of ZnO electrodes in dye solution

The ZnO electrodes that had been made were then soaked in purple sweet potato extract, respectively at concentrations of 10%, 20%, 30%, 40% and 50% for 1 hour. Then the glass is dried and the optimum efficiency is measured. Then the ZnO electrode is soaked with the optimum dye concentration for 1 hour, 2 hours, 3 hours, 4 hours and 5 hours.

Preparation of Electrolyte Solutions

The electrolyte was made from 0.5M KI, 0.05M I2 and PEG (polyethylene glycol), 0.498 grams of KI was dissolved in 6ml of acetonitrile in a beaker until dissolved. In another beaker, 0.076 grams of I2 is dissolved in 6 ml of acetonitrile

until dissolved. The two solutions were dissolved until homogeneous. Then 2.4 grams of PEG was added to the electrolyte solution that had been made and stirred until it formed a gel

Carbon Electrode Preparation

The carbon used is a 2B pencil. The 2B pencil is scraped finely and the powder is placed on the GMR glass using a small sieve. Then the glass is heated at 3000C for 1 hour.

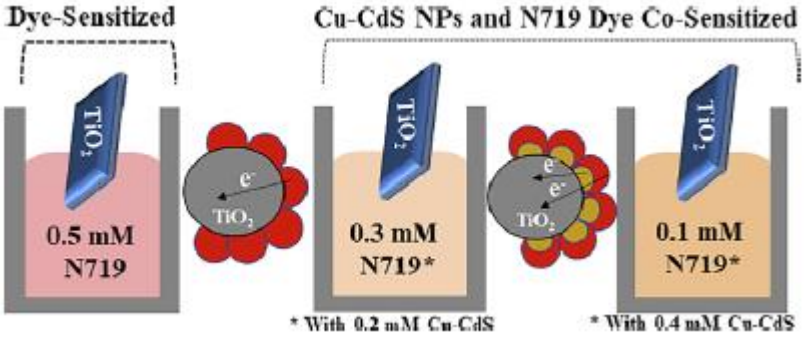
Chemical Dyes

The DSSC manufacturing method used by Anugrag Roy et al

a. Synthesis of Cds nanoparticles, CdS nanoparticles were synthesized using a BSA-mediated process under sonication. The aqueous solution of 0.1M Cd(NO3)2.4H2O and 1.25x10-6M (BSA) was sonicated (Rivotek ultrasonic probe 30k Hz, 250W) for 45 minutes followed by immediate addition of 0.1M Na2S drop by drop until the pH of the resultant solution reached ~4. Sonication was continued for 1.5 hours. The yellowish orange precipitate was centrifuged at a speed of 10,000 rpm followed by thorough washing with ethanol and water. The precipitate was then dried at 700C and calcined at 3000C for 2 hours. The resulting yellowish orange powder was used for further studies.
b. Colloidal Cu-doped CdS nanoparticles have been synthesized using a bovineserum albumin (BSA)-mediated process under sonication. An ethanol solution of 1.3 and 5 mol weight CuM (BSA) under sonication (NO3)2 was added with 0.1M Cd(NO3)2.4H2O and 1.25 x106 constant in an ultrasonic probe (rivotek-30KHz 250W) for 45 minutes and immediately afterward aqueous solution of 0.1 M Na2S was added drop by drop until the pH of the resulting solution reached 4.18
c. Synthesis of Mesoporous TiO2 nanoparticles. Mesoporous TiO2 samples were synthesized using the soft template method with titanium isopropoxide as a titanium source. Various catonic surfactant molecules such as CTAB, SDS and DTAB are used as templates. CTAB, SDS, DTAB, Titanium isopropoxide (TTIP) and ethanol have high purity content and are obtained from sigma -Aldrich. Commercial titania powder P25 with a grain size of 21nm was used for comparison purposes. Here we present a synthetic methodology for the representative case of mesoporous TiO2 with a CTAB template. A definite weight (3.64 grams) of CTAB was taken from the bottom of the flask and dissolved in a mixture of deionized water and ethanol with a volume ratio of 4:1. For this, 14.31 ml of TTIP solution was added drop by drop while stirring. The resulting gel is then stirred continuously for several hours. The precipitate is then filtered by a centrifugation process using water and ethanol. The powder is removed and calcined for 2 hours at 4500C to release the soft template and increase cross-linking of inorganic functional groups

Note: CTAB (Cetyl Trimethyl Ammonium Bromide)
SDS (Sodium Dodecyl Sulfate)
DTAB (Dodecyl Trimethylammonium Bromide)

d. The dye- and Cu-CdS-sensitive N719 device was fabricated using P25TiO2 nanoparticles and following the protocol reported in point c. Usually 0.5mM N719 dye is used for DSSC fabrication but to reduce the concentration of N719 dye molecules, as a result the amount is reduced to 0.1mM during the concentration process. This scheme can be seen in scheme 1



DSSC manufacturing method by Won-Chun oh et al

a. Synthesis of Graphene La2CrFeW6 (G-LCFW)

Synthesis of G-LCFW nanoparticles via a simple hydrothermal method. Graphene sheets were prepared following Hummers' method. The first step 0.9M lanthanium(III) chloride heptahydrate, 0.5M chromium(III) chloride, 0.5M iron(III) chloride and tungsten(VI) chloride were dissolved in DI and stirred for half an hour. Then add 0.5gram graphene powder and 2M ethylene glycol gradually. The solution was stirred for 2 hours before being poured into a 100ml lined stainless steel autoclave, sealed and stored under 1500C for 10 hours. After that, the autoclave was cooled to room temperature. The precipitate obtained was separated by centrifugation, rinsed with DI water and anhydrous ethanol several times and then dried in air at 800C for 8 hours.

b. Synthesis of Graphene La2CrFeW6 @organik (G-LCFW @organik)

Graphene La2CrFeW6@Urea is obtained via hydrothermal method. G-LCFW was dispersed in 60ml DI water under ultrasonication for half an hour then we added 0.41 grams of urea to the solution and stirred it at 250C for 1 hour until it dispersed homogeneously. After that we transferred the mixture into a Teflon-lined autoclave and kept it under 1800C for 10 hours. After cooling naturally, the final product was washed with ethanol and DI water and dried in an oven at 600C for 8 hours. Graphene La2CrFeW6 @CdSe, Graphene La2CrFeW6 @Galvanized (G-LCFW@G) and Graphene La2CrFeW6 @Sodium dodecyl Sulfate (G- LCFW@S) was synthesized under the same conditions.

c. Cell Assembly for DSSC

To make G-LCFW@CdSe paste, 2ml of the prepared G-LCFW@CdSe and EtOH solution was mixed with 0.5 grams of ethyl cellulose and 29-a terpineol. Then the mixed solution was crushed with a mortar and pestle. After that, the GLCFW@CdSe paste was coated on the cleaned FTO glass which was cleaned and placed on a hot plate at 4000C for 30 minutes to remove ethyl cellulose and terpineol G-LCFW@Gallic CE, G-

LCFW@sulfate CE, and G-LCFW@urea carried out using the same method. For the photoanode electrode TiO2 NPs were prepared by coating TiO2 paste onto FTO glass. The thickness of the annealed composite of TiO2 film is about 10mm. The TiO2 NPs electrode was prepared by coating TiO2 paste on FTO glass treated with 40mM TiCl4. Then the sample is sintered under 5000C for half an hour in a furnace. TiO2 was soaked in a 40mM TiCl4 solution at a temperature of 700C for half an hour and counterstained with water, then sintered at a temperature of 5000C for half an hour. Next, the TiO2 film was placed in a 0.3mM N719 dye solution and stored for 24 hours at room temperature. Then the cell is attached by 60mM Surlyn in a sandwich type cell filled with iodine electrolyte through holes located in the cell and then sealed.

The method for making DSSC by Suruthi Priya Nagalingam et al

a. Synthesis of Ti3C2Tx

Approximately 750mg Ti3AlC2 phase (MAX) was etched using 15ml (HF) 40% for a day. The resulting suspension was centrifuged many times and rinsed repeatedly with deionized water to obtain Ti3C2Tx powder. The solution obtained was then filtered through polytetrafluoroethylene (PTFE membrane opening 0.45mm, size 50mm). Finally, the product was filtered using deionized water and dried overnight at 600C.

b. Making FTO Glass Photoanodes

Cleaned with detergent, acetone, ethanol, and isopropanol by sonicating for 10 minutes at each step. Approximately 50mg of Ti3C2Tx powder was made into a slurry using N-methyl-2-pyrodidone as a solvent and coated onto FTO using the doctor blading technique.

Then the deposited FTO was dried at a temperature of 1200C using Ag/AgCl as a reference electrode, FTO coated with Ti3C2Tx as a working electrode and Pt wire as CE, PEDOT was deposited using an amperometric technique with a constant voltage of 1.1 volts for 15 seconds using 0.05M EDOT monomer in CAN electrolyte. taken along with 0.1M LiClO4 and dried at 600C in a three-electrode setup such that PEDOT was polymerized into blank FTO for comparison. To prepare Pt CE 0.01M of H2PtCl6 is dissolved in isopropanol and dropped onto FTO which has been cleaned and annealed at 4500C for half an hour.

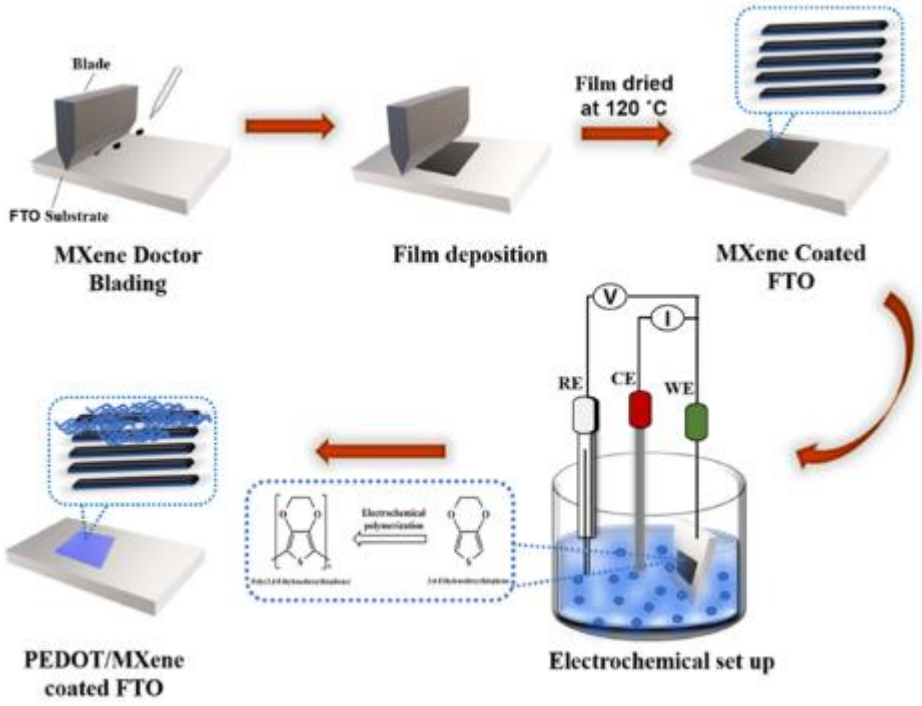
c. Making Photoanodes

The TiO2 solid layer was made using FTO that had been cleaned and soaked in a 10mM TiCl4 titanium chloride solution at a temperature of 700C for 30 minutes. Next, TiO2 paste was made using 300mg TiO2P25 powder, 300ml distilled water, 30ml HNO3 0.1M, and 10ml triton finely ground using a mortar and pestle, then formed into a paste then coated onto FTO which had been cleaned using the doctor blade technique and sintered at 450oC for half an hour. . The TiO2 layer that has been dyed is then treated with ethanol and dried in air. The redox electrolyte I/I3 was prepared using 0.1M 4-tert-butyl pyridine 0.5M Lil and 0.05M I2 and 15ml ACN solution.

d. Making DSSC using a prepared photocathode

Using Ti3C2Tx-CE, PEDOT-CE, PEDOT@Ti3C2Tx-CE DSSCs were individually fabricated by sandwiching the CE and photoanode with spacers

filled with prepared redox electrolyte and tested for solar cell performance with a test area of 0.16cm2. The process scheme is given in the image below



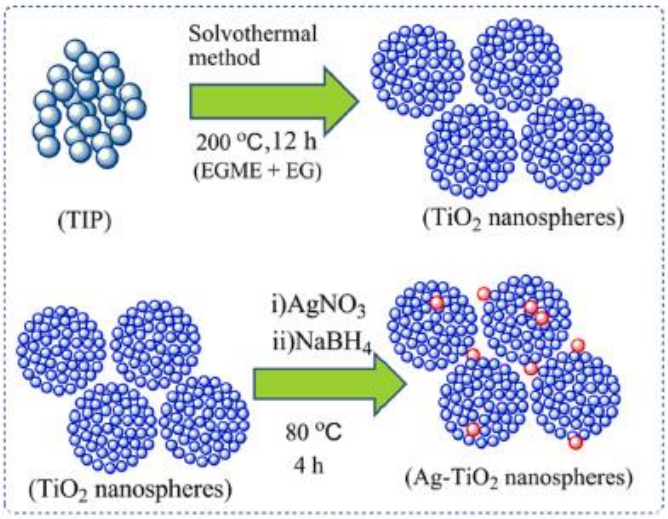
The method for making DSSC by M. Chinnarani et al

a. Synthesis of TiO2 Nanospheres

TiO2(TiO2Ns) nanospheres were formed via the one-pot solvothermal method of 40ml monomethyl mixed with 10ml ethylene glycol and stirred at room temperature for 20 minutes. Next, 2ml of titanium IV isopropoxide was added which was put into the autoclave. After being heated at 2000C for 12 hours the resulting precipitate was collected in centrifugation, washed several times with ethanol and dried at 60oC, the resulting product was calcined at 500oC for 2 hours.

b. Synthesis of TiO2 nanospheres containing Ag (Ag-TiO2 Ns)

TiO2 nanospheres loaded with Ag nanoparticles (2 wt%) were prepared using a simple chemical reduction route with the scheme below:



1 gram of prepared TiO2Ns powder and 2% Ag (silver nitrate) by weight were distributed in 200ml of double distilled water and heated using an oil bath at 800C for 2 hours. Then ice-cold NaBH4 was added drop by drop to reduce Ag+ to Ag indicating the formation of NPAg loaded TiO2NS. The AgTiO2NS obtained was washed with distilled water and ethanol many times, dried at 1000C for 3 hours and calcined at 4000C for 2 hours.

RESULT

Natural Dye

Table 1 Performance Parameters of DSSC Solar Cells dyed Mangosteen Peel Graphite/TiO2 Coating

Intensitas cahaya (Lux)	TC0M				TC8M				TC10M				TC12M				TC14M			
	250	500	750	1000	250	500	750	1000	250	500	750	1000	250	500	750	1000	250	500	750	1000
I_{sc} (mA)	0,06	0,05	0,08	0.1	0,09	0.1	0.12	0.15	0,22	0,23	0,27	0,28	0.2	0,24	0,28	0,35	0,3	0,45	0,7	1,1
V_{oc} (mV)	179,7	177	183,3	188,8	179	181,2	183,8	199,6	316.5	321.7	345	352	341	368,2	375,4	395	446,5	451,6	463,1	469
P_{max} (μW)	3,77	3,04	5,75	6,16	7,81	8,73	11,7	13,57	38,95	37,79	46,64	48,0	41,70	41,99	47,6	73,73	53,36	83,4	114	148,8
FF	0,35	0,34	0,39	0,32	0,49	0,48	0,53	0,43	0,56	0,51	0,50	0,49	0,61	0,48	0.45	0.55	0,40	0,41	0,35	0,28
η (%)	0,19	0,08	0,10	0,08	0,39	0,21	0,20	0,17	1,96	0,95	0,78	0,60	2.1	1,06	0,80	0,95	2,68	2,1	1,91	1,87

Table 2 Performance Parameters of DSSC Solar Cells dyed Pomegranate with Graphite/TiO2 Layer

Intensitas cahaya (Lux)	TC0D				TC8D				TC10D				TC12D				TC14D			
	250	500	750	1000	250	500	750	1000	250	500	750	1000	250	500	750	1000	250	500	750	1000
I_{sc} (mA)	0.03	0.04	0.05	0.07	0.05	0.08	0.09	0.11	0.08	0.11	0.13	0.16	0,23	0,29	0,38	0,44	0,26	0,33	0,42	0,6
V_{oc} (mV)	159	165	168.7	172.1	162	168.8	173	185.5	296	310	332,5	340	300	328	345	351	320	335	347	354
P_{max} (μW)	1,84	2.48	3.88	4.92	3,12	4,59	6,41	8,94	11,41	18,29	21,13	30,9	30,64	43,33	52,36	77,71	43,01	49,55	70,3	89,01
FF	0.39	0.38	0.46	0.41	0.38	0.34	0.41	0.44	0,48	0,54	0,49	0,57	0,44	0,46	0,40	0,50	0,52	0,49	0,48	0,42
η (%)	0.09	0.06	0.06	0.06	0.16	0.,12	0,11	0,11	0,57	0,46	0,35	0,39	1,54	1,09	0,88	0,98	2,16	1,25	1,18	1,12

Results of measurements carried out by Utami Oktavia et al

Table 3 Results of DSSC Voltage, Resistance and Efficiency Measurements on Absorption Time of Purple Sweet Potato Extract.

No	Time	V(mV)	R(kohm)	η%
1	1 hour	216.8	1.98	.19
2	2 hours	297.2	2.3	.31
3	3 hours	328.0	1.90	.47
4	4 hours	338.8	1.63	.58
5	5 hours	360	1.47	.72

Chemical Dyes

Results of measurements carried out by Wun-Chun Oh et al

Table 4 Photovoltaic Measurement Results from several CEs

CEs	J_{sc} (mA cm^{-2})	V_{oc} (V)	FF	η (%)	R_s (Ω cm^{-2})	R_{ct} (Ω cm^{-2})
G-LCFW-CdSe	21.8	0.68	62.1	9.20	13.8	5.2
G-LCFW@Gallic	26.1	0.68	58.6	10.40	14.3	4.5
G-LCFW@Urea	22.4	0.67	56.0	8.40	14.1	6.9
G-LCFW@Sulfate	22.0	0.65	53.1	7.59	14.2	5.3
Pt	18.1	0.67	61.8	7.49	14.1	6.1

Results of measurements carried out by Suruthi Priya Nagalingam et al

Table 5. Results of measuring the spectroscopic and PV characteristics of DSSC

Electrode	R_s (Ω)	R_{ct} (Ω)	V_{oc} (V)	J_{sc} (mA/cm^2)	Fill factor	η
Pt	13.1	2.8	0.69	18.9	67	8.7
$Ti_3C_2T_x$	33.2	41	0.67	14.7	45	4.4
PEDOT	15.7	20.7	0.61	15.1	60	5.6
PEDOT@ $Ti_3C_2T_x$	17.06	4.22	0.69	15.4	67	7.12

Results of measurements carried out by Anurag Roy et al

Table 6 Results of DSSC Characteristics

Device	$J_{SC} \pm 0.3$ (mA/cm^2)	V_{OC} (V)	FF	Efficiency $\pm$ 0.5
Only N719	11.96	0.71	0.63	6.21
Only Cu: CdS (3 %)	3.71	0.64	0.62	1.43
N719 + 1 % Cu:CdS	13.22	0.71	0.62	7.32
N719 + 3 % Cu:CdS	17.02	0.70	0.62	8.15

Results of measurements carried out by M. Chinnarani et al

Table 7 Photovoltaic Parameters for DSSC, which are produced

Photoanode	J_{sc} (mA cm^{-2})	V_{oc} (V)	J_{max} (mA cm^{-2})	V_{max} (V)	FF	η (%)
Pristine TiO_2 NSs	10.36	0.67	8.99	0.47	0.60	4.16
1-Ag- TiO_2 NC	11.76	0.74	10.61	0.52	0.66	5.74
2-Ag- TiO_2 NC	13.56	0.75	11.41	0.53	0.59	6.04
3-Ag- TiO_2 NC	12.67	0.74	9.17	0.53	0.54	5.06
4-Ag- TiO_2 NC	8.48	0.75	6.94	0.55	0.60	3.82
5-Ag- TiO_2 NC	7.74	0.76	6.29	0.55	0.59	3.47

Analysis

Natural Dye.

Data obtained by Helga Dwi Fahyuan et al., which had the greatest efficiency of 2.68% with mangosteen peel with a light intensity of 250 Lux, occurred at TC14M (14% graphite doping). TiO2 gap

The shortcomings in the method used so that its efficiency is not optimal are as follows

- Low photon absorption efficiency: The wide bandgap in TiO2 (3.2 eV to 3.8 eV) results in low photon absorption efficiency, so that only a small portion of photons can be absorbed [1]
- Limited availability and high cost of synthetic dyes: The use of synthetic dyes containing ruthenium complexes such as N719 and N3 in DSSC can increase efficiency. However, this dye is expensive and difficult to synthesize, so its availability is limited.[1]
- Short lifetime of liquid electrolytes: The use of liquid electrolytes in DSSCs can result in short lifetimes due to their evaporation properties[1]
- Uneven TiO2 surface: Uneven TiO2 surface can cause light reflection at various angles, resulting in reduced light absorption
- Limited efficiency of natural dyes: Although natural dyes extracted from plants have been used as an alternative to synthetic dyes, the efficiency achieved is still lower [1]
- Limited stability of liquid electrolytes: Liquid electrolytes are chemically and electrochemically unstable resulting in reduced DSSC stability. [1]
- Limited electron diffusion in TiO2: Electron diffusion in TiO2 can be slow affecting the overall electron transfer process and reducing DSSC efficiency [2]
- Small TiO2 crystal size: The small size of TiO2 crystals in the nanometer range can limit the amount of dye that can be absorbed, resulting in reduced photon absorption [2].
- Short lifespan of DSSCs: The use of liquid electrolytes and potential degradation of natural dyes can cause short lifespans of DSSCs.

In making DSSC carried out by Utami Oktavia et al

The method used has several advantages. First, the sol-gel spin coating method is used to create a thin layer of CoFe2O4/ZnO/CoFe2O4 with a low resistance value, so that it can be used as a substrate in DSSC [6]. Another advantage is that this method can produce thin layers with adjustable thickness, which affects the resistance value [15]. Apart from that, this method can also be

used to characterize thin layers using SEM, XRD, and 4-point probe system techniques [16, 17].

From the two DSSC manufacturing methods used by Helga et al and Utami et al, it can be seen that one of these methods can produce an efficiency of up to 2.68%. Efficiency refers to the ability of a solar cell to convert light energy into electrical energy. The greater the efficiency value, the higher the light converted into electricity. Efficiency is influenced by several factors, namely the rate of electron flow between cell components.

Chemical Dyes. Analysis of DSSC creation carried out by Whon -Chun Oh et al

The advantages of the method used by Whon Chun Oh et al are as follows

- The use of graphene nanocomposite La2CrFeW6 (G-LCFW) as a counter electrode in DSSC shows excellent electrocatalytic activity with low charge transfer resistance. This is caused by the synergistic catalytic effect between graphene sheets and La2CrFeW6 provskite with organic-inorganic materials [18].
- The special structure of this nanocomposite also increases the active sites for the reduction of triiodide ions on the counter electrode. The photoconversion efficiency of DSSC solar cells using gallic-based counter electrodes reaches a higher value of 10.40% compared to traditional Pt electrodes of 7.49%. [18]
- G-LCFW made with an organic-inorganic based counter electrode is also more efficient than that reported in previous research that used graphene as the counter electrode material [19].
- The G-LCFW nanocomposite synthesis method uses a simple hydrothermal technique, so it can be considered as an environmentally friendly, cheap, and highly efficient counter electrode material for DSSC [19].

Analysis of DSSC Making carried out by Suruthi Priya Nagalingam et al

The advantages of the method used by Suruthi Priya Nagalingam et al are as follows

- Low production costs: DSSCs have minimal production costs and easy fabrication procedures, making them more economical compared to other third generation solar cell technologies [9].
- High performance: DSSC using PEDOT@Ti3C2Tx composite electrodes has a power conversion efficiency (PCE) of 7.12% with an open circuit voltage (Voc) of 0.69V, a fill factor (FF) of 67%, and a high current density [12] .
- Good stability: DSSC with PEDOT@Ti3C2Tx electrode showed a PCE reduction of only 40% after 15 days of stability testing, indicating robust performance and resistance to iodide/triiodide electrolytes[11].
- Potential Pt replacement: The PEDOT@Ti3C2Tx composite electrode shows good electrocatalytic activity and significant charge transfer capability, making it a promising candidate to replace Pt as a counter electrode in DSSCs [20]
- Disadvantages in the method used by Suruthi Priya Nagalingam
- Lack of comparison with other methods: This journal does not provide a direct comparison with other DSSC manufacturing methods. This makes it difficult to directly evaluate the advantages and disadvantages of the methods used in this journal [9].

- Limitations of characterization: Although this journal provides a characterization of the PEDOT@Ti3C2Tx composite electrode, it does not provide a complete and in-depth characterization. Some characterization such as electrochemical impedance analysis or more detailed crystal structure analysis may provide a better understanding of the electrode performance [21].
- Long-term Stability Limitations: Although the PEDOT@Ti3C2Tx electrode showed good stability in a 15-day stability test, it is unknown to what extent this electrode is stable over a longer period of time. Longer stability testing can provide more accurate information about the performance and reliability of these electrodes over longer periods of time [11].

Analysis of DSSC manufacturing carried out by Anurag Roy et al

The superiority of the method used by Anurag Roy et al

- Bio-inspired synthesis: This method follows a bio-inspired strategy by using bovine serum albumin (BSA) as a biotemplating agent to synthesize functionalized colloidal CdS nanoparticles [22][223].
- Easy to use technique: In contrast to other synthesis methods that use organic covering agents, polymers, surfactants or enzymes, this method uses BSA which is considered easier to use [22][23].
- Stable dispersion: BSA-based synthesis produces a stable dispersion of CdS nanoparticles without any nanoparticle aggregation which is beneficial for further applications [22][23].
- Surface functionalization: Various disulfide bonds, thiol residues, and hydroxyl groups present on BSA can function as effective surface functionalization groups on the CdS surface, thereby enabling better adhesion with metal oxide-based photoanodes [22][23].
- Enhanced performance: CdS-sensitized solar cells fabricated using this method show enhanced performance compared to conventional electrolytes, even without expensive Pt-based electrodes [24][25].

The disadvantages of the method used by Anurag Roy et al are as follows

- Low efficiency: Although this method produces improved performance compared to ordinary electrolytes, the conversion efficiency of the resulting solar cells is still low, not exceeding 1% [13].
- Disadvantages of surface passivation: This method produces many unpassivated or only partially passivated surface states that can affect the performance of the solar cell [13].
- Colloid sensitivity approach: This method uses an ex situ colloid sensitivity approach which can influence the control of the properties of the CdS sensitizer [13]
- Uncontrolled aggregation of nanoparticles: Synthesis using BSA as a biotemplating agent can cause uncontrolled aggregation of nanoparticles, which can affect electron conduction and increase the recombination rate [13].
- Limitations of characterization: this journal does not provide sufficient information about the characterization of the materials and structures used, making it difficult to understand in depth the shortcomings of the methods used [26][27].

Analysis of DSSC creation by M. Chinnari et al

The advantages of the method used by M. Chinnari et al

- This method combines solvothermal and chemical reduction methods to produce Ag-TiO2 nanospheres (NS) with even Ag distribution [28]. These advantages enable increased interfacial charge transfer and reduced photo-induced charge recommendations [14].
- The use of Ag as an alternative photoanode material for DSSC applications [14]. In this research, the addition of Ag to TiO2 NS produces a better light absorption effect and faster electron transfer, which increases the energy conversion efficiency of solar cells [29].
- This method is relatively simple and efficient. The one-step chemical reduction method used in this study allows the synthesis of Ag-TiO2 NS[28].
- This method produces Ag-TiO2 NS with high energy conversion efficiency. In this study, DSSC with Ag-TiO2 NS photoanode achieved an energy conversion efficiency of 6.04% which was higher than that of pure TiO2 NS photoanode (4.16%) [29].

Disadvantages of the method used by M. Chinnari et al

- This method does not provide sufficient information about the stability and lifetime of Ag-TiO2 NS in DSSC applications. It is then necessary to understand how Ag-TiO2 NS will behave over a longer period of time and under different environmental conditions [14].
- This method does not provide sufficient information about the effect of varying Ag concentrations on DSSC performance. In this study, only one Ag concentration was used, 2wt%, so it is not known whether a higher or lower concentration will provide better results [14].
- This method does not compare the performance of Ag-TiO2 NS with other photoanodes used in DSSC. Next, it is necessary to compare the energy conversion efficiency of Ag-TiO2 NS with other photoanode such as pure TiO2 or photoanode with other additional materials [14].
- This method does not provide sufficient information about the mechanisms of charge transfer and electron transfer in Ag-TiO2 NS affecting charge transfer and electron transfer in DSSC [14].

From several DSSC manufacturing methods described previously, with natural and chemical dyes, it can be concluded that the factors that influence the high efficiency of DSSC are as follows.

- Dyes, these dyes must have high light absorption values in a wide wavelength range, as well as the ability to produce stable electrons after absorbing light photons.
- The liquid electrolyte in DSSC plays a role in conducting electrons between the dye and the electrode. The type and quality of electrolyte can affect the electron transfer rate and energy conversion efficiency.
- Electrode, the electrode is a component in DSSC which functions to collect electrons produced by the dye and channel them to the solar cell. Electrode material and good contact between the electrode and the sensitizer material also have an impact on DSSC efficiency.

- Solar cell design, DSSC solar cell design including layer structure and electrode configuration can affect energy conversion efficiency. Good design can maximize light absorption and reduce energy loss.
- Light Intensity: The efficiency of a DSSC depends on the intensity of sunlight it receives. High DSSC efficiency when direct or high sunlight.
- Temperature during DSSC operation, high temperatures can increase electron mobility and speed up chemical reactions in solar cells, but must be managed properly so as not to damage DSSC components
- Damage to DSSC components can reduce DSSC efficiency.

To make DSSc with natural dyes, the method used by Helga et al produces an efficiency of 2.68% compared to the method used by Utami et al which only produces 0.72%. To make DSSC with chemical dyes, the method used by Whon Chu et al, Suruthi Priya Nagalingam, Anurag Roy et al, and M. Chinnari produces the greatest efficiency of 10.4%. This efficiency is produced by research by Whun Chun Oh et al.

So it can be concluded that to produce higher efficiency, method optimization needs to be carried out in the research of Helga et al and Whun Chun Oh et al.

CONCLUSION

Suggestions for research conducted by Helga Dwi Fahyuan:

- Optimization of dye extraction: The efficiency of natural dyes can be increased by optimizing the extraction process. This may include exploring different extraction methods such as ultrasound-assisted extraction or microwave-assisted extraction, to improve the yield and quality of the extracted dye [1]
- TiO2 layer modification: TiO2 layer can be modified to improve light absorption properties. This can be achieved by using different forms of TiO2 such as nanorods or nanoparticles by combining other materials such as carbon nanotubes or graphene for electron transport and reducing recombination losses.[2]
- Exploration of alternative electrolytes: Liquid electrolytes have limitations in terms of stability and lifetime. Exploring alternative electrolytes, such as solid electrolytes or gel electrolytes, can increase the stability and service life of DSSCs[1]
- Optimization of fabrication techniques: Fabrication techniques, such as the doctor blade technique used to place graphite/TiO2 layers, can be optimized to achieve a more uniform and controlled layer thickness. This can be done by adjusting parameters such as speed and pressure during deployment to improve the overall performance of the DSSC [30].

Research on co-sensitization: co-sensitization involves the use of multiple dyes to increase the light absorption range and improve the overall efficiency of DSSCs. Exploring co-sensitization of natural dyes with different absorption spectra can result in higher efficiency and better utilization of the solar spectrum [1].

Suggestions for DSSC makers made by Utami Oktavia et al

- Expanding the variation of parameters studied: This research can involve varying other parameters such as temperature, drying time, or chemical concentration to see their effect on the results obtained [6]

- Using a more comprehensive characterization method: apart from SEM,
- Carrying out further tests on DSSC efficiency: Apart from measuring voltage and resistance, this research can involve measuring other parameters such as current, maximum power, and energy conversion efficiency of DSSCs that use CoFe2O4/ZnO/CoFe2O4 thin layers[31,32]
- Carrying out static analysis: To obtain more valid and reliable results, this research can involve statistical analysis to test the significance of differences between different treatment groups [6]
- Carrying out experimental replication: to ensure consistent repeatability of results, research can carry out experimental replication using different samples [6].

Suggestions for making DSSC made by Whon Chun Oh et al

- Carry out a more in-depth characterization of the graphene nanocomposite La2CrFeW6 (G-LCFW) to understand its structure, physical properties and chemical properties better [8].
- Conducted a more detailed analysis of the reaction mechanism and interaction between G-LCFW and organic-inorganic materials in the counter electrode [18].
- Optimizing G-LCFW nanocomposite synthesis parameters such as temperature, time and reagent concentration to achieve optimal structure and properties [8].
- Conducted a more in-depth study on the performance of DSSC using G-LCFW as a counter electrode including further analysis of the photoconversion efficiency of the open armature short current density and fill factor [33].
- Comparing the performance of DSSC using G-LCFW with other counter electrodes, such as Pt to evaluate the advantages and disadvantages of the method carried out in this journal [33].

Suggestions for DSSC manufacturing methods made by Suruthi Priya Nagalingam

- Electrode concentration optimization: Optimizing the PEDOT@Ti3C2Tx electrode concentration to achieve higher power conversion efficiency (PCE). In this journal, PEDOT concentration optimization has been carried out and it was found that using a concentration of 0.05M produces a higher PCE [12].
- Improved Characterization: Carry out a more detailed and comprehensive characterization of the PEDOT@Ti3C2Tx composite electrode, such as electrochemical impedance analysis, crystal structure analysis, and morphology analysis using techniques such as HR-SEM, XRD, and XPS. This will provide a better understanding of electrode properties and performance [21][34].
- Longer Long term stability testing: Carrying out stability testing of the PEDOT@Ti3C2Tx electrode, over a longer period of time to determine the extent of its stability under continuous conditions. Longer stability testing will provide more accurate information about and reliability of the electrode over a longer period of time. older [11][35].
- Comparison with other methods: conducting direct comparisons with other DSSC manufacturing methods to evaluate the advantages and disadvantages of the method used by Suhuhi Priya Nagalingam et al.

Suggestions for making DSSC made by Anurag Roy et al

- Optimize synthesis conditions: Varying parameters such as temperature, time and reagent concentration can be optimized to achieve the desired nanoparticle size and dispersion [13].
- Surface passivation control: Efforts should be made to ensure effective surface passivation of CdS nanoparticles, which can reduce unpassivated surface states and increase energy conversion efficiency[13].
- More detailed characterization: A more in-depth characterization of the structure, size, and optical properties of the synthesized CdS nanoparticles should be carried out to better understand the relationship between structure and performance of solar cells [26][27].
- Increasing conversion efficiency: Efforts should be made to increase the energy conversion efficiency of CdS sensitized solar cells by improving electrode design, optimizing electrolyte composition, or using more effective alternative sensitizing materials [24].
- Reaction mechanism studies: More research is needed to understand the reaction mechanisms involved in the synthesis of CdS nanoparticles using BSA as a biotemplating agent, so as to identify ways to improve control and stability of synthesis [22].

Suggestions for making DSSC made by M. Chinnari et al.

- Optimize Ag concentration: Further research can be carried out to test different variations of Ag concentration in TiO2 NS. This can help determine the Ag concentration that provides the best results in terms of DSSC energy conversion efficiency[14].
- More in-depth characterization: further research can be carried out to understand the mechanisms of charge transfer and electron transfer in Ag-TiO2 NS. More sophisticated characterization methods, such as surface plasmon resonance spectroscopy, can be used to study the interaction between Ag and TiO2 NS in more detail [14].
- Stability and lifetime tests: It is important to carry out stability and lifetime tests of Ag-TiO2 NS in DSSC applications. Further research can be carried out to understand how Ag-TiO2 NS will behave over longer periods of time and in different environmental conditions[14].

Comparison with other photoanodes : It is important to compare the performance of Ag-TiO2 NS with other photoanodes used in DSSC. Further research can be carried out to compare the energy conversion efficiency of Ag-TiO2NS with other photoanode, such as pure TiO2 or photoanode with other additional materials [14].

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