IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Enhanced performance of a dye sensitized solar cell using metallic and bi-metallic nanoparticles

To cite this article: K Ranabhat *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **498** 012021

Enhanced performance of a dye sensitized solar cell using metallic and bi-metallic nanoparticles

K Ranabhat[1], **K S Skripkin**[1], **K F Chernyshova**[2], **E A Sofronova**[1], **A A Revina**[2], **A I Pylinina**[1], **L N Patrikeev**[1, 3] **and V A Lapshinsky**[1, 3]

[1]Peoples' Friendship University of Russia, Miklukho-Maklaya str. 6, Moscow, 117198, RussianFederation
[2]A.N. Frumkin Institute of Physical Chemistry and Electrochemistry of the Russian Academy of Sciences, Leninsky prospect 31, bld. 4, Moscow, 119071, Russian Federation
[3]National Research Nuclear University MEPhI, Kashirskoe shosse 31, Moscow, 115409, Russian Federation

Corresponding author e-mail address: Ranabhat.kiran@gmail.com

Abstract. Dye-sensitized solar cells (DSSCs) have emerged as a promising source to meet the energy demand as an environmentally friendly alternative. The work presented in this paper focuses on improving the efficiency of DSSCs using natural dyes and metallic and bi-metallic nanoparticles. The solar cell's performance in terms of efficiency (voltage vs. current) was tested under an indoor room light and fluorescent lamp. The experimental results demonstrate that cell with the dye from blue honeysuckle berries and Au nanoparticles as cathode produced greatest efficiency (η~9 %) under fluorescent lamp.

1. Introduction

Solar energy sources are considered one of the most promising renewable sources [1-6], since solar energy sources are clean, inexhaustible, environment friendly, plentiful and easy to utilize. Solar is considered to be profitable and safer investment for our family and business. There are various kinds of solar cells. Amongst solar photovoltaic, DSSCs are an efficient and affordable type of solar cells.

The DSSC was first reported in 1972 as a chlorophyll-sensitized zinc oxide (ZnO) electrode. Dye-sensitized solar cell (DSSC), invented by Professor M. Grätzel in 1991[7], is a most promising inexpensive route toward sunlight harvesting, owing to their simple structure, transparency, flexibility, low production cost, and wide range of application. Despite these advantages, the low efficiency of DSSCs compared to that of silicon-based cells has limited their commercial implementation [3-4].

DSSC are composed of only five components: a transparent conductive oxide (TCO) substrate, a nanostructured n-type semiconductor, a visible-light absorber dye, an electrolyte and a counter electrode (cathode) [5].

This research study focused on improving the methodology of producing dye-sensitized solar cells by the process of amalgamation with natural dyes and metallic and bimetallic nanoparticles. This research is done for maximizing cell efficiency and sustainable power production for mass manufacturing processes at the most economical cost.

2. Hypothesis

2.1. Application of metallic and bi-metallic nanoparticles in DSSC.
Observing the optical and electrochemical properties of metallic and bi-metallic nanoparticles [2], we decided to use metallic and bi-metallic nanoparticles in DSSCs manufacturing as an additive to different natural dyes and as cathode. It is assumed that use of the metallic and bi-metallic nanoparticles increase the efficiency of DSSCs.

3. Experimental Section

3.1. Dye Extraction Process
Preparation of the natural dye solution requires some skill of filtration. First around 50gm of samples (black grapes, pomegranate or blue honeysuckle berries) were grinded in a mortar until a crude mixture was observed, usually about 4-5 min. The crude mixture was then transferred slowly to a pre-assembled filtration apparatus. If the resulting mixture is very thick, i.e., no filtrate, several drops of water or acetone was used to wash the mixture and add the total liquid amount. A spatula or a glass rod can be used to swirl the mixture to give off more solution.

3.2. Preparation of nanoparticles
Metallic nanoparticles (NPs) Au, Ag and bimetallic NPs Au/Ag are synthesized by the method of "molecular assembly" using chemical (Chem) reduction reactions of Ag^+ ions and subsequently formation of metallic nanoparticles in reverse micelles in the presence of a natural pigment from the class of flavonoids - quercetin (QR) and molecular oxygen.

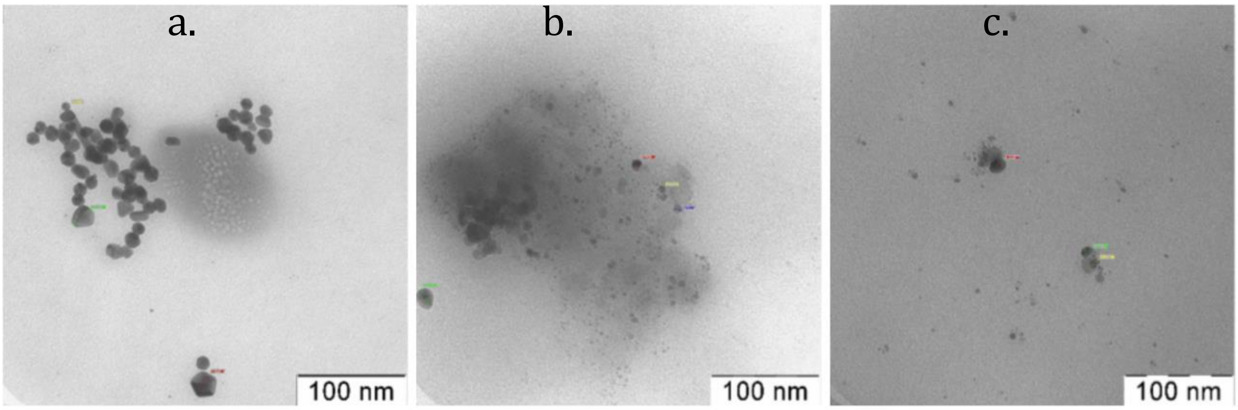


Figure 1. TEM microphotographs of metallic NPs: Au a); NPs Ag b) and bimetallic NPs Au-Ag c)

The dimensions of the nanoparticles were determined using transmission electron microscopy LEO 912AB OMEGA. The size of metallic nanoparticles (NPs) Au, Ag and bimetallic NPs Au/Ag used in this work is 1.5-20 nm, 6-12 nm and 10-15nm respectively (Figure 1).

3.3. Assembling the Dye-Sensitized Solar Cell
1. Determine the conductive side of glass by touching both of protruding leads of the multi-meter with one side of the glass as shown in Fig. 2.a. The conductive side could be identified with average resistance from 20-38 ohms.
2. Fix two sides of the plate using tape with the conductive sides facing up shown by Fig. 2.a.
3. Prepare the TiO_2 paste by adding a few drops of dilute acetic acid (0.035M) to 1 gram (about 2 table spoons) TiO_2. The resulting mixture was grinded in a mortar and pestle until a colloidal suspension with a smooth consistency (like cake icing) was observed [8].
4. Add 2-3 drops of the TiO_2 suspension onto the conductive side and spread out the TiO_2 evenly on the surface of the plate with glass rod. Leave it for 4-5 minutes in room temperature and carefully remove

IOP Conf. Series: Materials Science and Engineering **498** (2019) 012021 doi:10.1088/1757-899X/498/1/012021

the tape without perturbing the TiO_2 layer.
5. Dry the glass with TiO_2 under room temperature over 20 minutes and then heat it at 420° C for another 30 min, until the dried TiO_2 turns brown and then white again Fig.2. b-c.
6. While heating, coat the conductive side of the other piece of glass with graphite as cathode or 2-3 drops of nanoparticles and spread out evenly on the surface of plate with glass rod as cathode Fig. 2. d.
7. Cool both plates to room temperature.
8. Submerge the plate with TiO_2 face down in the dye solution and keep it for 24 hours Fig. 2.e.
9. Wash the dye layer with ethanol carefully.
10. Clamp both the plates together and apply 2 drops of standard iodine ($I^-/I3^-$) electrolyte solution onto the interface between the two plates. Allow the electrolyte to cover the surface of TiO_2 by capillary action.
11. Measure the photo-voltage and photocurrent under the indoor room light and fluorescent light using a laboratory multimeter Fig. 2. h-i.

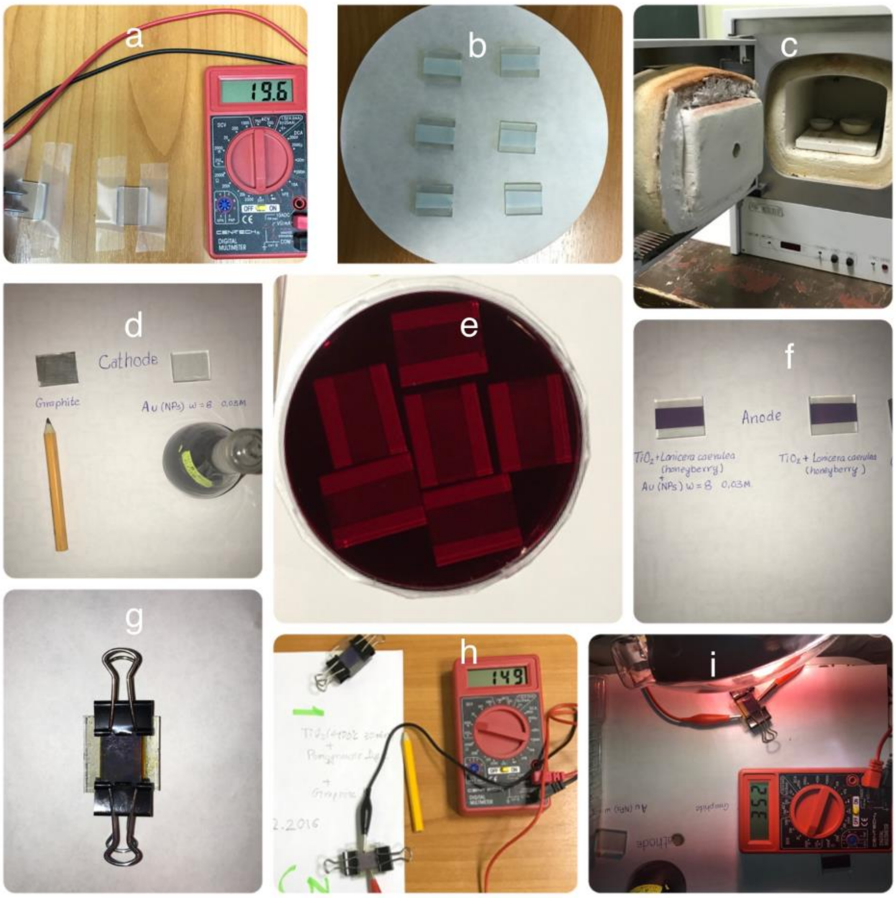


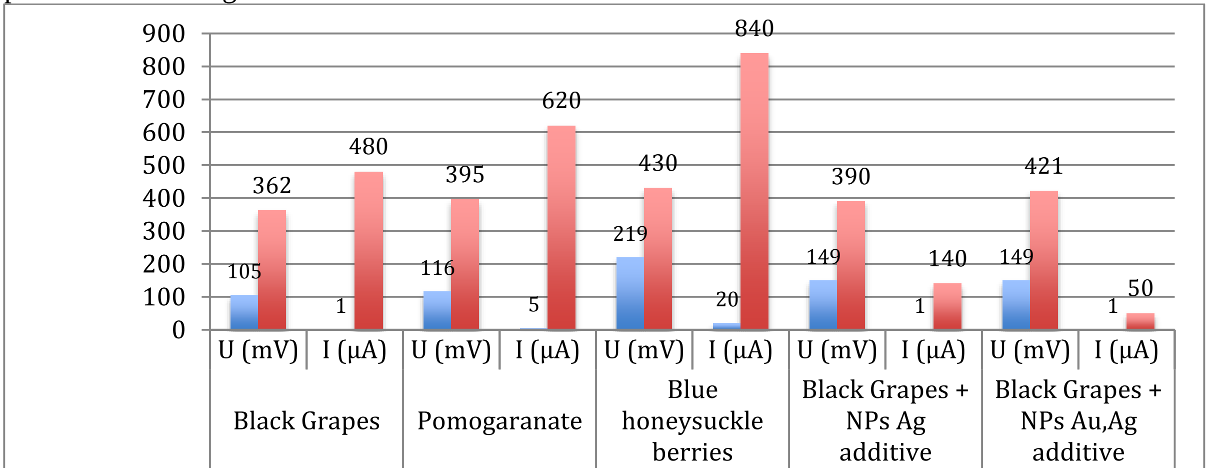
Figure 2. Assembling of Dye-Sensitized Solar Cell

4. Results and Discussion

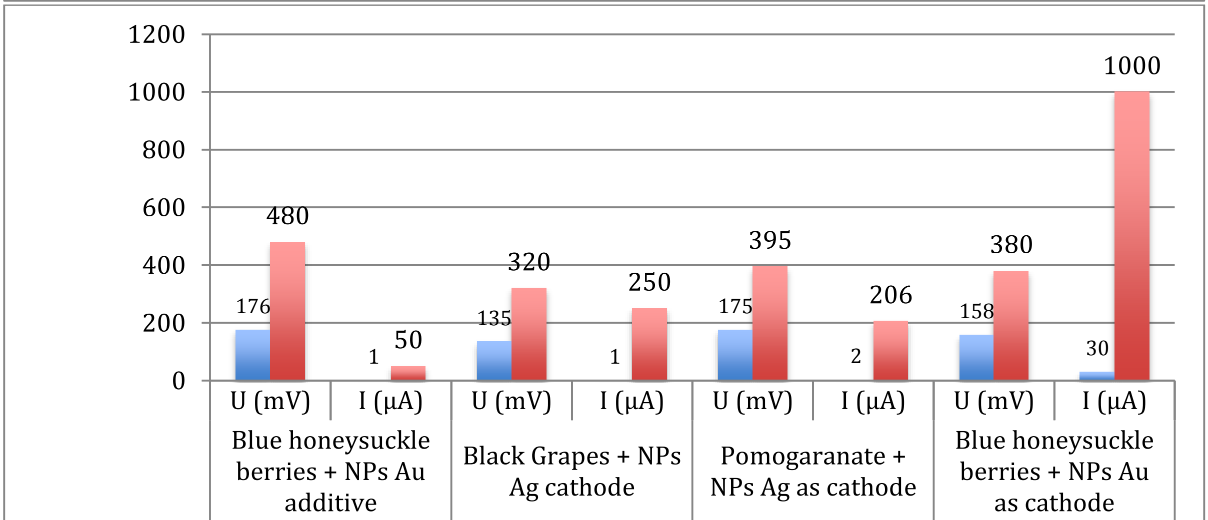
In this section, results from each experiment mentioned in the experimental section are presented and analyzed. All of the results were measured under standard condition (T = 298K and P= 1 atm) with the illumination of indoor light and fluorescent light.

4.1. Regular Voltage & Current Data

So the measurement of the power (voltage and current) generated by the dye-sensitized solar cells was carried out under two different conditions: Indoor light and fluorescent lamp. The main aim was to investigate the highest combination of voltage and current produced by solar cells. These solar cells were made with dye extract from different fruits samples and metallic & bimetallic nanoparticles were used as additive to dye and as a cathode. Each sample's voltage and current were averaged when tested under each light source for 3 minutes. The result obtained for solar cells with various dyes used, the various dyes with NPs additive and those obtained for the various dyes with NPs as cathode are presented in the Figure 3.



	Black Grapes U (mV)	Black Grapes I (µA)	Pomogaranate U (mV)	Pomogaranate I (µA)	Blue honeysuckle berries U (mV)	Blue honeysuckle berries I (µA)	Black Grapes + NPs Ag additive U (mV)	Black Grapes + NPs Ag additive I (µA)	Black Grapes + NPs Au,Ag additive U (mV)	Black Grapes + NPs Au,Ag additive I (µA)
Room light	105	1	116	5	219	20	149	1	149	1
Lamp	362	480	395	620	430	840	390	140	421	50



	Blue honeysuckle berries + NPs Au additive U (mV)	Blue honeysuckle berries + NPs Au additive I (µA)	Black Grapes + NPs Ag cathode U (mV)	Black Grapes + NPs Ag cathode I (µA)	Pomogaranate + NPs Ag as cathode U (mV)	Pomogaranate + NPs Ag as cathode I (µA)	Blue honeysuckle berries + NPs Au as cathode U (mV)	Blue honeysuckle berries + NPs Au as cathode I (µA)
Room light	176	1	135	1	175	2	158	30
Lamp	480	50	320	250	395	206	380	1000

Figure 3. Results of regular photo current-voltage production for DSSC

The current and voltage data of each solar cell was tested 5 times and measurements were carried out under indoor light and fluorescent lamp.

The voltage produced from the cell with blue honeysuckle berries + NPs Au additive 480 mV and the current from the cell with blue honeysuckle berries + NPs as cathode 1000 µA are maximum.

4.2. DSSC Power and Efficiency Formula and Calculations

The maximum efficiency of a solar photovoltaic cell is given by the following equation:

$$\eta_{max}(maximum\ efficiency) = \frac{P_{max}(maximum\ power\ output)}{E\ (Incident\ radiation\ flux) * A_c(Area\ of\ collector)}$$

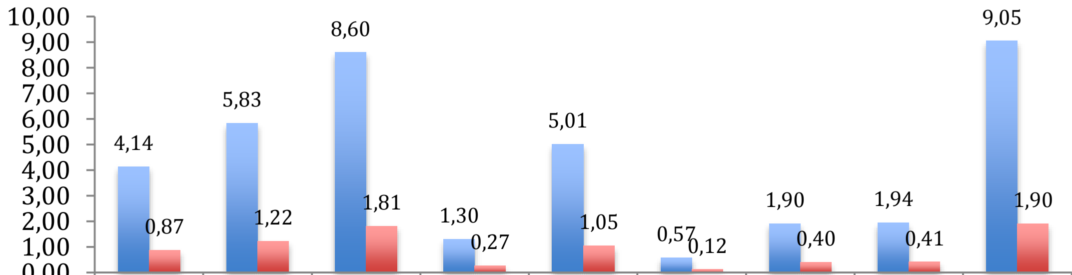
The intensity (power) of the incoming light from the fluorescent lamp has been calculated from the outset to be 21 W/m^2. The area of the conductive glass slide coated with TiO_2 is approximately 1cm x 2cm = 2cm^2, i.e. equals to 0.0002 m^2.

The efficiency of all the solar cells were measured using the formula above and the result is tabulated in Table 1. The comparison of highest power per surface area and efficiency is shown in the Figure 4. The maximum power output and maximum efficiency was from cells with blue honeysuckle berries + NPs additive about 1.9 W and 9.05% respectively.

Table 1. Results obtained for the power output and conversion efficiency for the solar cell exposed to a fluorescent lamp.

	I (A)	U (V)	SA (m^2)	P cell (I*V)/SA	Efficiency (η)
Black Grapes	0.0005	0.3620	0.0002	0.8688	4.1371
Pomegranate	0.0006	0.3950	0.0002	1.2245	5.8310
Blue honeysuckle berries	0.0008	0.4300	0.0002	1.8060	8.6000
Black Grapes + NPs Ag additive	0.0001	0.3900	0.0002	0.2730	1.3000
Black Grapes + NPs Au, Ag additive	0.0005	0.4210	0.0002	1.0525	5.0119
Blue honeysuckle berries + NPs additive	0.0001	0.4800	0.0002	0.1200	0.5714
Black Grapes + NPs Ag (cathode)	0.0003	0.3200	0.0002	0.4000	1.9048
Pomegranate + NPs Ag (cathode)	0.0002	0.3950	0.0002	0.4069	1.9374
Blue honeysuckle berries +NPs Ag (cathode)	0.0010	0.3800	0.0002	1.9000	9.0476

Our hypothesis and experiments was that to use metallic and bi-metallic nanoparticles in DSSCs manufacturing and to know how the metallic and bi-metallic nanoparticles affect the efficiency of a dye-sensitized solar cell. The result we obtained shows that using metallic and bi-metallic nanoparticles increases the efficiency of a dye-sensitized solar cell. More studies will be carried out to investigate the best method to improve the cell efficiency and performance.



	Black Grapes	Pomogranate	Blue honeysuckle berries	Black Grapes + NPs Ag additive	Black Grapes + NPs Au,Ag additive	Blue honeysuckle berries + NPs Au additive	Black Grapes + NPs Ag (w=5) as cathode	Pomogranate + NPs Ag (w=5) as cathode	Blue honeysuckle berries + NPs Ag (w=8) as cathode
Efficiency (η)	4,14	5,83	8,60	1,30	5,01	0,57	1,90	1,94	9,05
P (W)	0,87	1,22	1,81	0,27	1,05	0,12	0,40	0,41	1,90

Figure 4. Results obtained for the power output and conversion efficiency for DSSC exposed to a fluorescent light.

5. Conclusion

DSSCs are broadly regarded as the more promising third generation photovoltaic (solar) technology. These cells are the closest mankind has come to replicating nature's photosynthesis. The work presented in this paper aimed at increasing the efficiency of DSSCs using different natural dyes along with metallic and bimetallic nanoparticles. The data obtained from this research concludes that using metallic and bimetallic nanoparticles as an additive to dye and as cathode increases the efficiency of dye-sensitized solar cells.

Acknowledgements
This paper was done in the project No. 011615-0-000.

References

[1] Parkhomenko Y N and Polisan A A *2014 Physics and technology of Photonics devices: Solar power engineering and nanotechnology* (Moscow: National University of Science and Technology "MISIS")
[2] Ranabhat K, Pylinina A I, Skripkin K S, Sofronova E A, Revina A A, Kasatkin V E, Patrikeev L N and Lapshinsky V A 2016 *IOP Conference Series: Materials Science and Engineering* **151**
[3] O’Regan B and Grätzel M 1991 *Nature* **353** pp 737–740
[4] Lee B and Kim J 2009 *Curr. Appl. Phys.* **9** pp 404–408
[5] Bella F, Gerbaldi C, Barolo C and Gratzel M 2015 *Chemical Society Reviews* **44**
[6] Winans J D, Hungerford C, Shome K, Rothberg L J and Fauchet P M 2015 *Opt. Express* **23**
[7] O'Regan B and Graetzel M 1991 *Nature* **353** pp 737-740
[8] Gratzel M 2005 *Inorg. Chem*. **44** pp 6841-6851
[9] Chernyshova K F and Revina A A 2017 *High-tech nanotechnology* **18** pp 45-50 (Russian)