ISSS（TJ-SSFタイ政府主催科学フェア）参加報告

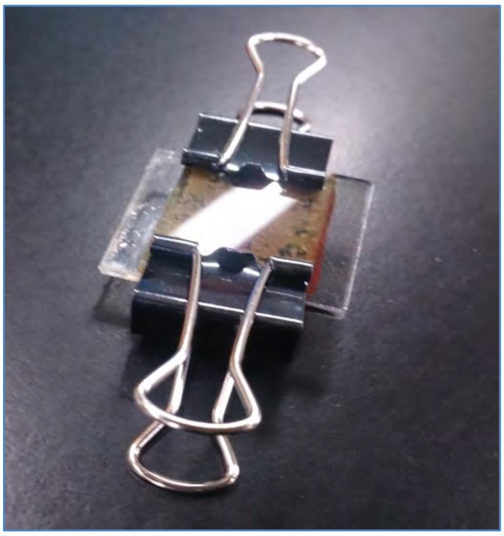
2015年度は国際交流事業ISSSとして、タイで開催されたサイエンスフェアであるTJ-SSF（Thailand-Japan Student　Science Fair 2015 “Seeding Innovations through Fostering Thailand-Japan Youth Friendship”）にサイエンス研究会4, 5年生5名が参加しました。化学班がサイエンス研究会を代表して、ポスター発表「Dye-sensitized solar battery experiment」を行いました。

期間　2015年12月20日(日)～24日(金)
会場　Princess Chulabhorn Science High School Phetchaburi（以下、PCSHS-P）
参加校　日本25校、タイ41校
参加者　５年Ａ組　稲石　大義、西本　有里、４年Ｂ組　山田　莉彩、
　　　　４年Ｃ組　出水　明日香、中谷　駿介

日程（タイでの活動）

月 日	訪問先等(発着)	時刻	実施内容	宿泊地
12/21 （月）	関西国際空港発 バンコク国際空港着 PCSHS-P	深夜 早朝 午後	TG673バンコク行き バンコク到着 PCSHS-P到着 文化交流	生徒 寄宿舎 教員 ホテル
12/22 （火）	PCSHS-P	午前 午後	オープニングセレモニー 講演会 ポスタープレゼンテーション	同上
12/23 （水）	PCSHS-P	全日 夜	口頭発表会（グループ別） ポスタープレゼンテーション 天体観測	同上
12/24 （木）	環境研究所 PCSHS-P	午前 午後	フィールドトリップ まとめ・発表	同上
12/25 （金）	PCSHS-P バンコク国際空港発 関西空港着	3:40発 11:00発 18:10着	先方手配送迎車にて移動 TG672関西空港行き直行便 帰国	

このサイエンスフェアで化学班がポスター発表を行った
「Dye-sensitized solar battery experiment」
の概要が次ページにあります。英語でのプレゼンテーションを堂々と行い、タイの生徒とも積極的に交流しました。



NISHIMOTO Yuri
INAISHI Tomoki
Instructor MUSO Tomoko
Instructor KOSHINO Shozo

Nara Women's University Secondary School,
Nara, 630-8305, Japan

Dye-sensitized solar battery experiment

Abstract

The organic dye-sensitized batteries were studied. These batteries make voltage by titanium oxide's ability to absorb ultraviolet rays which excites electrons to create charges. It is said that it becomes possible to generate power by not only ultraviolet rays but also by light whose wavelength is longer than ultraviolet by mixing organic dye with titanium oxide. By changing how to make the titanium oxide paste and using these properties, we expected to generate more voltage. When we made the sample, we added only Polyethylene glycol into the titanium oxide paste and then heated the mixture, which changed the thickness. To study the relationship between the thickness and electromotive force, we heated them. However, the surface of the paste of the sample which contained only Polyethylene glycol cracked and peeled off from the glass substrate when it absorbed the dye, so it did not work as expected. Then, we had doubts about the methodology of adding only Poly-ethylene glycol to the paste and continued our research by studying other methods of making the paste. So, we decided that instead of focusing on the old way of making the paste by using Polyethylene, we decided to use acetic acid.

Keywords: dye-sensitized solar battery, titanium oxide, acetic acid

Introduction

Since the Great East Japan earthquake occurred, nuclear power plants in Japan have been stopped due to safety concerns, causing shortages of power in many regions. These days we have to secure energy sources, and we realized that solar power may be a solution.

Solar batteries can generate semi-permanent power in any location if there are the facilities which are required. Solar power is different from thermal power or nuclear power generation, and it is good for the environment because it does not produce any toxic gases or liquids. On the other hand, current solar batteries are said to be dangerous if the building in which it is located does not meet the earthquake resistance standards, so many wooden buildings are not suitable sites. Furthermore, the color is dark, so places in which these can be located is limited. So we thought that if we could produce a small, light, clear battery we could position them in different places such as on windows or walls and produce more electricity.
One type of solar battery, that we studied, that can achieve this purpose are dye-sensitized solar batteries. Dye-sensitized solar batteries don't require expensive materials, can be made at low cost, and plastic can be used as a base, so we can make them lighter and smaller. With these advantages we can also place them where we can't place them now. In addition, we can make semi-transparent or change its color, through altering the pigments, some groups are investigating alternative designs. For example, with a clear solar battery, they can be placed on widows, without impacting the view.
Last year we studied about the relationship between a paste's thickness and the electricity which is generated. This year we changed the materials of the paste, and determined that the best condition is that of using fine crystals of TiO_2 which become a porous structure and the surface area becomes larger which can absorb the pigment better. This time we mixed Polyethylene glycol which is a type of polymeric material into the TiO_2 paste.

How to Produce Electricity

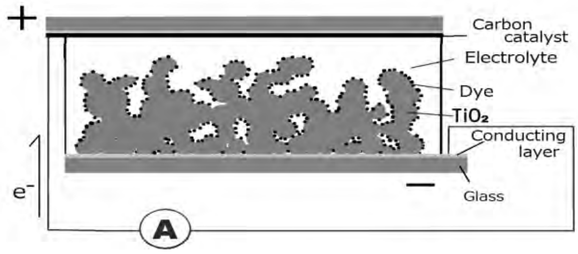


Figure 1

As shown in Figure 1, dye-sensitized solar batteries are constructed by using a transparent electrode organic pigment which absorbs visible rays. The TiO_2's porous structure which connects the organic pigment electrolyte solution contains I- and the opposite cathode which is covered by a black lead. This dye sensitive solar battery principle of power generating occurs like this:

1. The organic pigment absorbs visible rays causing the electronics which is in the pigment to excite and go into the TiO_2 coating.
2. The electrons on the transparent electrode move to the opposite cathode through the outside circuit.
3. I^{3-} which is the electrode solution gets additional electrons which have reached to the opposite cathode and change into I^-.
4. On the other hand, the organic pigment which lost electrons becomes oxidized and gets electrons from I^- which are in the electrolyte solution and regenerates.

When these reactions are constant, direct current is produced. Because of these processes, dye-sensitized solar batteries produce electricity from light.

Materials and Methods

The first step is to establish the best way to produce TiO_2 crystals. The other factors, such as the color of paste, should be considered after that.

The objective of the following three experiments is to find the best TiO_2 crystal construction.

Overview

Experiment I

In the experiment I, the focus is to be put on the the thickness of TiO_2 paste coating the transparent electrode.

We tested the pastes of three different thickness with the three different heating powers.

We also used two different temperatures approx.80 ℃ and 120℃ when baking the paste. However we couldn't collect reliable data. That's because we couldn't make exact measurement of the heating power .

Experiment II

In the experiment II, the focus is put on to establish how the differences in thickness of the paste and heating power used in making the paste affect the amount of generated power. We measured how much power is generated from the six different batteries A to E with six different pastes in thickness and heating power. Cracks on the surface of the paste is to be examined.

Experiment III

After Experiment II, we realized the need of an additional experiment, which is Experiment III. That is because the result of Experiment II is totally different from our expectations. In Experiment III, we tested three different substances to be put in the paste. We measured the three different batteries and measured how much power is generated.

Experiment I

Objective

To find the best thickness of the paste under some different conditions

Hypothesis

The thinner paste has the less number of cracks.

Materials

The powder of TiO_2 (8g), PEG(4g), Pure water(16g), Detergent (including 42% surface active agent), Ethanol

Preparation

(1) Produce TiO_2 paste

[1.] Melt PEG in water

[2.] Make20% PEG solution.

[3.] Churn TiO_2 and PEG for 30minutes.

[4.] Put the mixture in the bottle with a syringe.

(2) Cleanse conducting glass with three kinds of liquid: a) five fold dilution of detergent b)pure water c) ethanol

・Pick the conducting glass with a tweezer and wash it by shaking it in the liquid.

・In the same way, cleanse the tweezer and the glass stick.

Procedure

(1) Coat conducting glass

1. After washing the glass, stick tape as shown in Figure 2 on the conducting side.

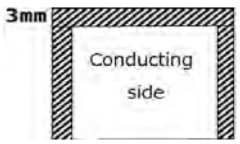


Figure 2

2. After shaking the bottle, put the paste on the glass.
3. Make the thickness even and remove the bubbles by sliding the glass stick.

(2) Bake TiO_2 paste

1. Put the glass with the paste on the stainless board not to be heated directly. In addition, put the windshield around the glass.
2. Bake it by Gus burner for 20 minutes.
3. Cool it to normal temperature for 15 minutes.

Below is the tale to indicated the combination of the different thicknesses and the different heating powers.

Temp. \ Thickness	1	2	3
80℃	A	C	E
120℃	B	D	F

Table 1

Observation

Several cracks were spotted on the surface of every paste.

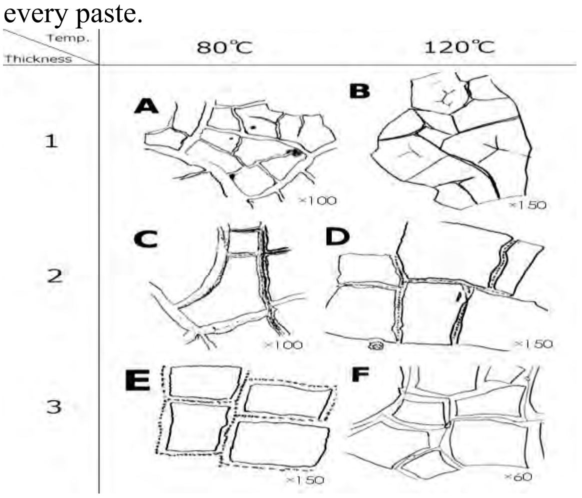
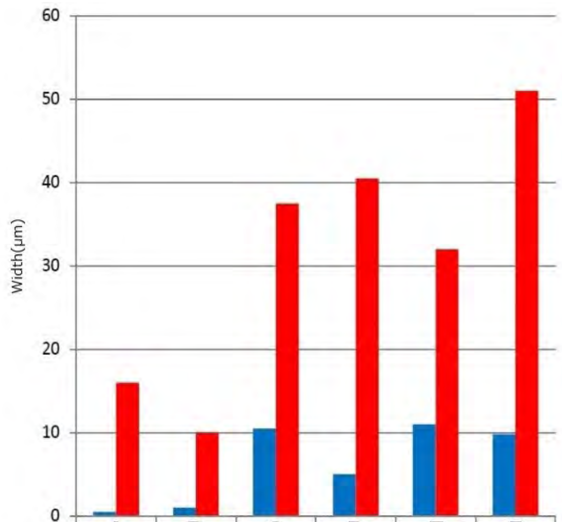


Figure 3

We observed the size and condition with an optical microscope. Below is the sketch of them on Figure 3, and the graph about crack's size on Figure 4.



	A	B	C	D	E	F
Max	0.5	1	10.5	5	11	9.8
Min	16	10	37.5	40.5	32	51
Color	White	Pale amber	White	Pale amber	White	Pale amber

Figure 4

Experiment II

Objective

To confirm that the paste with the fewer cracks produces the larger amount of electricity

Hypothesis

The paste with the fewer cracks produces the larger amount of electricity.

Materials

Pentax of mallow blue (0.5g), Pure water (20ml), Electrolyte solution which include Iodide ion, Pencil (6B)

Preparation

(1) Dye extraction

1. Added water 20ml to Pentax of mallow blue and left it for 10minutes.
2. Take out the Pentax with squeezing.

(2) Adsorption

Take the pigment by a tweezer , put it on the TiO_2 coat 3 or 4 drops and left it for 10 minutes.

(3) Making of electrodes

Coat the conduction surface by painting with a pencil, holding the glass with a tweezer.

(4) Building batteries

1. Put the glass with black lead on the glass covered with TiO_2 paste and absorbed pigment.
2. Hold an edge with a clip.
3. Add a couple of drops of electricity solutions from the other edge and hold the other end with a clip fasted.

Procedure

1. Measure the amount of the power generated by the batteries from A to B. We measured their reverse voltage and resistance in two situations, without light and with LED's light from the distance.
2. Measure the amount of electricity generated from the pairs of the batteries. Because of the lack of equipment, we couldn't measure the six different batteries simultaneously, so we measured the three different pairs (AB,CD,EF) at the same time on different days.
3. In addition we grouped the six batteries into two groups in terms of the sun light angles: ABEF and CD. They have the totally opposite angles.
4. We also made a difference between ABCD and EF in terms of the timing to measure after pouring electrolyte solution.
5. We measured batteries A, B, C and D in couple of hours after pouring it. On the other hand we measured batteries E and F three days after pouring it.

Observation

Measuring the batteries individuality

The table shows that the resistance value isn't stable. We recorded the maximum and the minimum. In the left side is the minimum, and in the right side is maximum.

Date：A～D 12/25 12:30 cloudy

E,F 12/22 15:30

A	Voltage (mV)
No light	0.9
LED	1.1
Sunlight	11.6

B	Voltage(mV)	Resistance(kΩ)	
No light	0.0	0.844	0.874
LED	0.0	0.816	0.821
Sunlight	0.3	0.771	0.784

C	Voltage (mV)	Resistance (kΩ)	
No light	0.0	14.51	15.54
LED	−0.80	13.83	14.40

D	Voltage (mV)	Resistance (kΩ)	
No light	0.0	105.7	107.6
LED	−3.7	104.9	105.5
Sunlight	18.2	100.2	101.2

E	Voltage (mV)
NO light	5.0
LED	6.8

F	Voltage (mV)
No light	33.9
LED	19.5

Without light, Most of their electromotive values are near 0mV, and only in the battery we measured 5.0. There is a stark contrast between F and the other batteries.

Under the LED light, most of them changed positive cathode from the side of black lead to the side of TiO_2 coats .

Under the sun light, the side of black lead became the active cathode. With LED light, the resistances inside the batteries became a little smaller, and with sunlight, it became very smaller.

Measuring in same date and time

Date:12/25 14:45～ cloudy

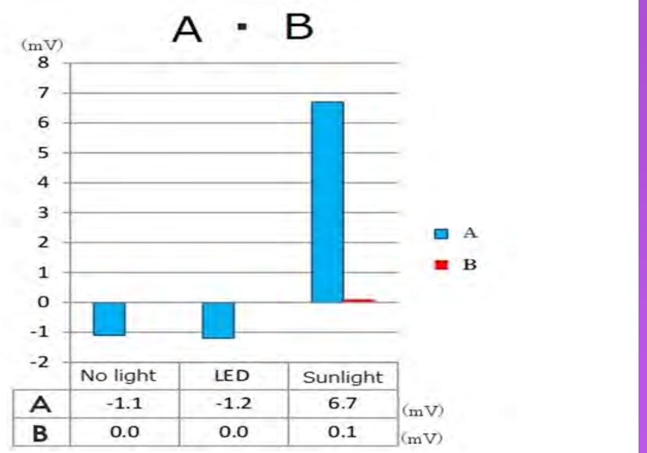


Figure 5

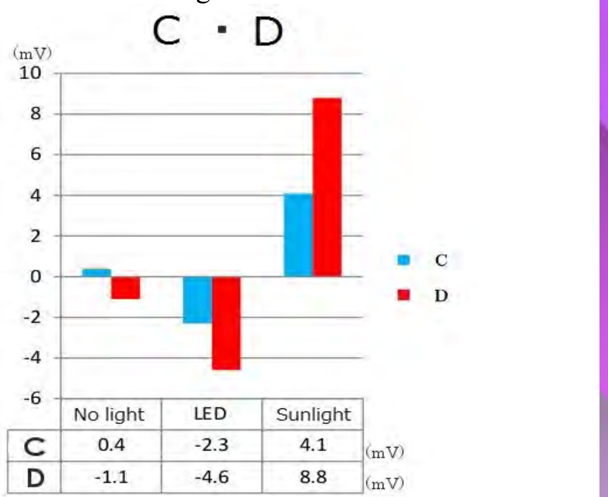


Figure 6

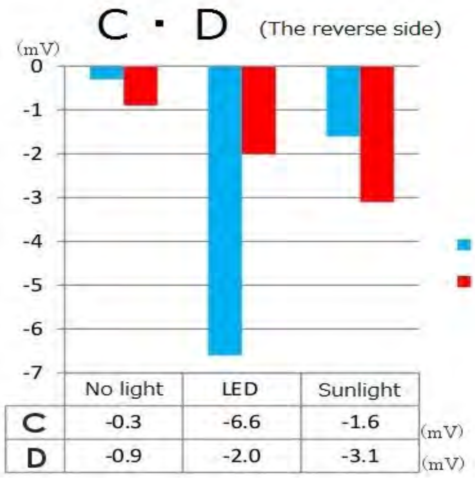


Figure 7

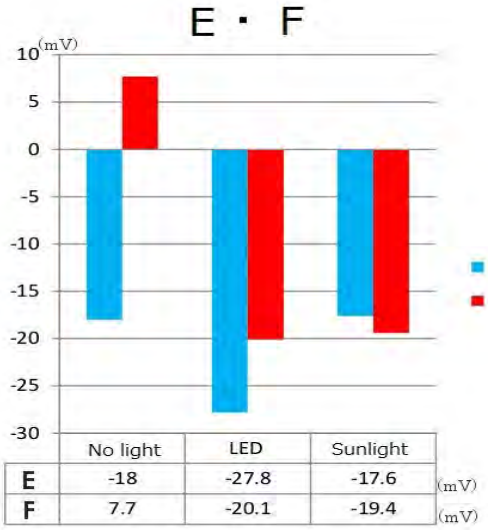


Figure 8

The graphs 5-8 show the amount of electricity generated under several conditions. The battery A produced electricity but the battery B produced little. (Figure 5)Both of the batteries C and D produced electromotive force and the battery D produced more. (Figure 6)

The batteries of larger number of crackers produced the less amount of electricity. In addition, when we shined from the side of black lead, the active cathode changed from the originally side and became the TiO_2 side.(Figure7) The electromotive force of the batteries E and F without the light was far from 0mV.(Figure 8)

Experiment III

Overview

As shown in Figure 5-8, we measured the opposite direction of electricity against our expectations. So we decided to make an additional experiment. We guessed that the temperature is closely related with the peeling off. So we raised the heating temperature to 450 ℃. As a result of the experiment it turned out that the temperature is not the culprit. That' s because we couldn't see a big difference between the two different temperatures. From this comes an inference that other factors are involved.

Objective

To find the best substance to be put in the paste in order to make the battery more effective

To confirm what is the best of the substances, such as, acetic acid and PEG or the combination.

To confirm that TiO_2 peeled off when we poured electrolyte solution, which adverse the electric current.

Materials

7.5g of powdered TiO_2, 15g of pure water, PEG

Preparation

Make three types of TiO_2 paste

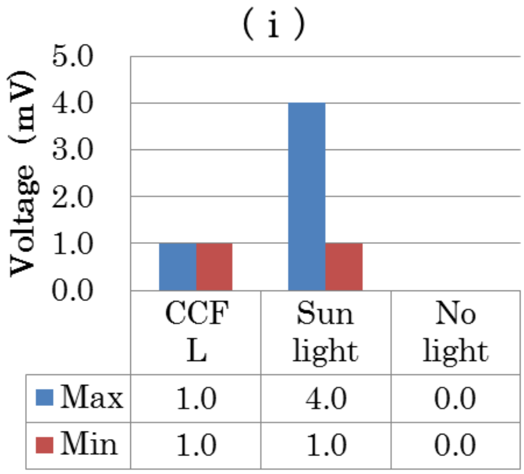
1. The paste which includes only pure water. Mix the 7.5g of powdered TiO_2 and pure water 15g for 30 minutes
2. The paste which includes only acetic acid
   a. Make acetic acid 3% aqueous solution
   b. Mix 15g of the Acetic acid solution and 7.5g of the powdered TiO_2 for 30 minutes
3. The paste which includes acetic acid and PEG. Mix 7.5g of powdered TiO_2, 15g of acetic acid 15g and 4g of PEG4g for 30 minutes.

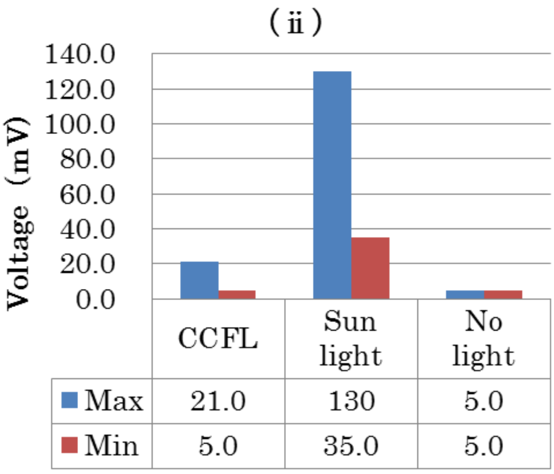
Procedures

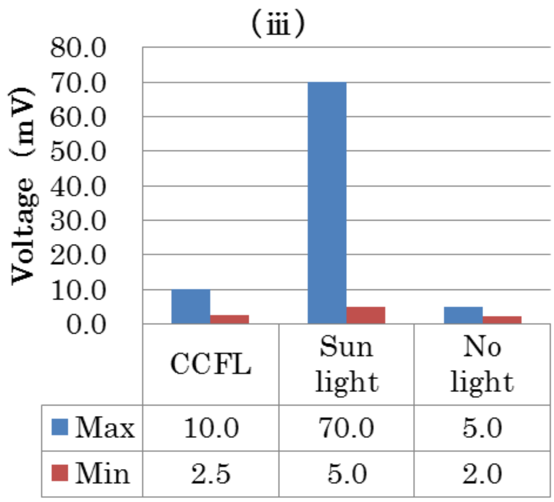
1. Put the paste on the glass
2. Put the paste in the same way as the experiment I.
3. Bake TiO_2 paste
4. We heated the glass covered with TiO_2 paste in electric furnace in 450c for 15 minutes.
5. Get together and absorb dye
6. We took them together like the experiment Ⅲ.
7. Power generation experiment
8. We measured electromotive force of three kinds under three situations; sunlight, fluorescent lamp and no light

Observation

All of three batteries measured the biggest number immediately after started measuring and kept the number around minimum number. The battery (1) took very different number from others, so there might be something wrong when we measured.







Conclusions

From these results, we confirmed that the thinner paste produces the larger amount of electricity. At the same time we find that the most important factor to make an effective battery is the number of cracks on the surface of the paste. The thinner paste produces the fewer number of the cracks on the surface. In order to make an effective battery, it is crucial to make the paste as thin as possible.

As for the substance to be used in making the paste, the use of both acetic acid and PEG is the most effective.
The types of light are also a very important factor to be considered. Under the fluorescent lamp, the battery produces less electricity than under the sun. That's because the fluorescent light includes less shorter-wavelength under ultraviolet rays.

Further challenge

A stable and effective battery requires electrolyte to exist as long as possible without evaporating. It might be possible to lower the melting point of electrolyte but it is also important to devise a good way of preventing electrolyte from evaporating.

We also need to establish what color of dye is the most effective and how the dye is put in the paste. In these experiments we coat the solid paste with the dye. Another alternative is to put the dye in the paste material before it is put into a mold.

Acknowledgment

We are grateful to Mr. Koshino and Ms. Muso for helpful advice and support.