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Hong Kong Student Science Project Competition 2023
Extended Abstract (Investigation)

Team Number: SBBC060

Project Title: Sustainable Hydrogen Production by Electrolysis of Sea Water for Car Fuel
電解海水很「氫」易　綠色燃料替代廢電池

Project Type: Investigation

To our best knowledge, there ~~are /~~ are no * similar works in the field.

The enhancement our project made / the difference with related research are:

Title of the related research: A new, sustainable way to make hydrogen for fuel cells and fertilisers

Link to the related research: https://www.riken.jp/en/news_pubs/research_news/pr/2022/20220215_1/index.html

A new sustainable and practical method for producing hydrogen from water has been discovered by a team of researchers at the RIKEN Center for Sustainable Resource Science (CSRS) in Japan led by Ryuhei Nakamura. Our research differs from their research as we focus on investigating electrode combinations used in electrolysis in maximising hydrogen production while the researchers focus on finding out the catalysts in making hydrogen through electrolysis.

Please delete if not applicable. The competition values the originality of works. Students must do enough literature research to ensure that their works are unique and list relevant reference materials before starting research or invention.

I. Background

Problem to tackle

The government has planned to fully use electric cars by 2050, meaning that there will be a voracious amount of car battery waste being created, and the highly toxic chemicals contained are detrimental to the environment. Although hydrogen can be used to power electric cars, and the use of it can avoid creating battery waste, hydrogen propulsion is not yet widespread and the production of hydrogen from burning fossil fuels is detrimental to the environment due to the myriad amount of carbon emission.

Highlight of the literature review

Around the globe, the recycling rate of EV batteries is far behind its disposition rate, with experts stating that only 5% of EV batteries entered the recycling process. [1], with about 200,000 metric tons of waste lithium batteries to be produced yearly in Hong Kong in 2050 onwards. [2]

Overview

Riding on a Japanese research findings that certain electrodes can produce a certain amount of hydrogen in electrolysis of seawater, in hopes of cleaning and lowering the cost of hydrogen production, and further investigate the factors for maximising hydrogen production to propose the idea of a hydrogen filling station set on the coast. We propose the idea of a hydrogen plant and filling station set on the coast of Hong Kong powered by solar panels, hence sustaining the use of electric vehicles.

II. Objectives

To investigate the factors for maximising hydrogen production by electrolysis of seawater with solar panels.

III. Hypothesis

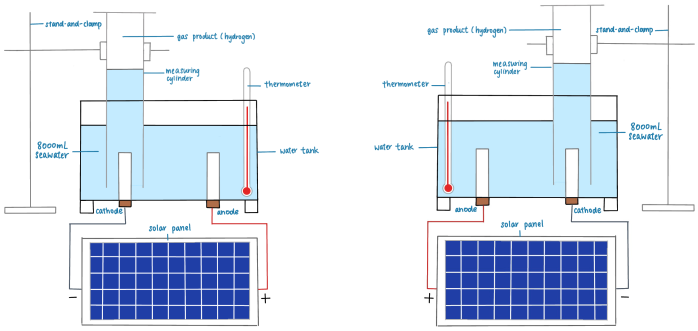
Nil.

IV. Methodology

Material used

1. Electrodes: Titanium, Iridium-Tantalum-Titanium metal oxide coated titanium, Copper, Brass,
2. Set-ups and apparatus: plastic reaction tank (2), large measuring cup (1), measuring cylinder (4), thermometer (2), stand-and-clamp (4), 6V 185mm x 285mm x 25mm Solar Panel (2), connecting wires (2 pairs), splint (1 pack), matches (1 box), gas syringe with a tube (1), disposable protective gloves (1 box)

Experimental Set-ups



Scientific theory and principles

Electrolysis: during electrolysis, positively charged ions move to the negative electrode to gain electrons and negative charged ions move to the positive electrode to lose electrons. When there are different ions in the solution, the ions would preferentially discharge or gain electrons based on their respective reactivity and concentration.

Variables that affect hydrogen production rate by electrolysis of seawater

1. Type of electrode
    a. Electrical conductivity: other factor holding constant, the higher the electrical conductivity of the electrode, the higher the rate of electrolysis
    b. Nature of electrode: chemically inert electrodes will not react with solution during electrolysis, while when reactive metal is connected at anode may dissolve.
2. Electrode combination
    a. The greater the distance between two electrode materials in E.C.S. Position, the higher the current and rate of electrolysis.

Analysis of investigation

Comparative analysis is used in our investigation. In each experiment, due to limited plastic tanks and as to minimise effect of temperature and light intensity in open area to two different sets of electrolysis of seawater with solar panels, two sets of electrolysis are conducted at the same time. By repeating the experiments twice and again with other electrode combinations, we can compare the volume of hydrogen produced in each round and sort out the more ideal electrode for the next round of comparison.

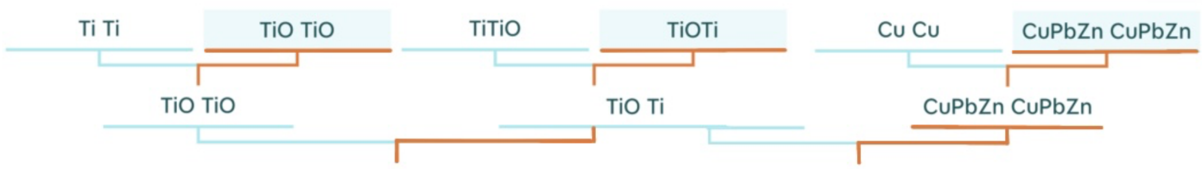
V. Results

Data

	Electrode combination (anode-cathode)	Averaged light intensity during experiment (W/m²)	Rate of hydrogen production (mL/h)
Experiment 1.1 (Day 1)	Ti-Ti	345.0	~0
	TiO-TiO	345.0	171
Experiment 1.2 (Day 2)	Ti-TiO	560.3	7.9
	TiO-Ti	560.3	155.5
Experiment 1.3 (Day 3)	Cu-Cu	269.2	56.7
	CuPbZn-CuPbZn	269.2	58.6
Experiment 2.1 (Day 4)	TiO-TiO	136.7	17.0
	TiO-Ti	136.7	17.6
Experiment 2.2 (Day 5)	TiO-Ti	279.2	84.6
	CuPbZn-CuPbZn	279.2	88.0

Data Analysis

According to the data collected, the results were summarised as follows:



Upper Row (from left to right): Experiment 1.1, Experiment 1.2, Experiment 1.3
Bottom Row (from left to right): Experiment 2.1, Experiment 2.2

CuPbZn-CuPbZn and TiO-Ti were the most effective electrode combinations in maximising hydrogen production.

Limitation

Due to limitations in apparatus (specifically plastic reaction tanks for electrolysis of seawater), we could only set up two setups per stage of experiment. In other words, the results can be and only be compared between the two set-ups in an experiment conducted on the same day. Results cannot be compared across different experiments. For example, one cannot compare the rate of hydrogen production in experiment 1.1 and experiment 1.2 because the two experiments are conducted on different days with varying light intensity during the experiment. To avoid errors in data analysis, we adopted the method of elimination to find out the most effective electrode combinations. Preferably, in ideal situations, we would prefer to have 6-8 plastic reaction tanks to try out all electrode combinations on the same day at the same time to reduce error due to varying sunlight.

Importance of Our Research Results

As a coastal city, Hong Kong has an abundant and a seemingly unlimited supply of sea water. We visionise that, by using our experimental set-up as a blueprint in micro-scale and implementing the concept in a large-scale societal context, electrolytic tanks could be built along the coastline to generate and store hydrogen, which could be transported, stored and used as fuels in electric automobiles powered by hydrogen fuel cells. Electrolysis inside the electrolytic tank is primarily powered by clean and non-toxic solar energy collected from solar panels, which is set up next to the coastline and on the sea. Hydrogen gas collected from the cathode in the electrolytic tanks is compressed, stored and eventually delivered in pressurised gas form into the combustion chambers of hydrogen engines at hydrogen-filling stations scattered in the 18 districts of Hong Kong, preferably with a close proximity to the seaside. The delivery of hydrogen is through underground pipes.

VI. If your team will compete for the Sustainable Development Award, please indicate the specific sustainable development goal the project is related to, and provide justification for competing for this award. ***(Word limit: 300 words)***

SDG 12 Ensure sustainable consumption and production patterns

Electric powered cars are a rising trend in this day and age. Some may even go as far as saying that electric cars are the future of automobiles. More and more manufacturing companies are putting more effort into moving from traditional vehicles to electric cars. Whilst we appreciate the environmental benefits of using electricity to power automobiles instead of burning fossil fuels, which releases large amounts of exhaust gases, we cannot deny the fact that there are some environmental consequences brought about by the battery of electric cars. The batteries of electric cars are often huge and chemically toxic. The disposal of batteries will bring devastating environmental harm, especially when maltreated. Not to mention that the extremely heavy car batteries accelerate the power consumption in electric cars, reducing the efficiency of electric cars. In light of this, our team explores ways to make powering electric cars more sustainable and environmentally friendly.

Hydrogen is a clean and renewable energy source, which can be used to power electric cars. Building on the findings by a group of Japanese scientists who researches on a new, sustainable way to make hydrogen by electrolysis of seawater, our team investigates various factors to maximise hydrogen production in electrolysis of seawater, in hopes of aiding the science community in conventionalising the use of hydrogen-fuel cells in electric cars and thereby reducing chemical waste in car batteries and improve the efficiency of electric cars.

VII. If your team will compete for the Social Innovation Award, please list the target group or social issue the project focuses on, and provide justification for competing for this award.
(Word limit: 300 words)

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Hong Kong, as a coastal city, has an abundant supply of sea water. We visionise that, in a large-scale context, plants electrolysing seawater could be built along the coastline to generate and store hydrogen, which could be transported and used as fuels in electric cars.

VIII. Conclusion

Experiment 1.1: TiO-TiO > Ti-Ti
Experiment 1.2: Ti-TiO > TiO-Ti
Experiment 1.3: CuPbZn-CuPbZn > Cu-Cu

Experiment 2.1: TiO-Ti > TiO-TiO
Experiment 2.2: CuPbZn-CuPbZn > TiO-Ti

By comparing the above experiments, conclusion can be drawn that set-up CuPbZn-CuPbZn is the most effective electrode combination in maximising hydrogen production, followed by setup TiO-Ti. It is believed that the project meets the objective because we can distinctly differentiate the better electrode combinations in maximising hydrogen production from the experimental results.