Investigate The Effect Of Zinc On Depolymerized PET

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Abstract

Polyethylene terephthalate (PET) is a common synthetic polymer material, which has a wide range of applications. However, with the overuse of humans, more and more PET The product was found to be improperly recycled.

The alcoholysis method is a depolymerized PET method with simple reaction conditions, a mild reaction process, and less unnecessary by-products. Also, the ester exchange reaction in the esterification reaction is combined with the alcoholysis method for the reaction. The alcohol used in this study-ethylene glycol (EG) can be esterified with the free acid. Because zinc metal is an amphoteric substance, can catalyze the reaction and produce new esters and new alcohols. Use zinc in waste batteries as a catalyst to depolymerize PET into monomer polyethylene terephthalate (BHET) and discuss in-depth the factors affecting the reaction and its development and application. Using zinc from waste batteries as a catalyst is not only low cost, but also more in line with the core of this research-green chemistry. This research has searched through optimal conditions and found that 5 grams of PET can be depolymerized when the catalyst usage is 0.2 grams, the reaction time is 4 hours, and the reaction temperature is 180 degrees.

Keyword
alcoholysis method, PET, catalyze, waste batteries, polyethylene terephthalate

1. Introduction

In addition to reducing people's space for activities, improperly handled plastic products will also have a series of effects on marine life. For example, in southern Thailand, the death of a whale caused national mourning. I have accidentally eaten more than 85 plastic bags of garbage, and the endangered finless porpoise and short-nose dolphins have also been found eating plastic in Thailand many times. Back in Taiwan, the coastal garbage per kilometer is 2.4 times that of Japan and 1.7 times that of South Korea. There are as many as 13 large black garbage bags per 100 meters

of coastal garbage. The global amount of marine debris can even circle the earth more than 400 times.

Plastics generally take 500 to 1,000 years to decompose naturally. In other words, most plastic products exist in some form. At present, there are many methods for processing plastic products, such as separating the non-polyester bottle cap, bottle base, label, etc. on the polyester bottle by machine methods, and then washing, crushing, and granulating the polyester bottle. There is also an alcoholysis method that needs to be completed at a certain temperature and pressure. Therefore, this study explores the alcoholysis method based on zinc as a catalyst for the transesterification reaction.

1.1 Objectives

Search the literature for various methods of PET reuse

Understand the principle of zinc as a catalyst affecting the reaction

Use DSC to confirm that the product of PET depolymerization is BHET

Explore the influence of various variables (time, temperature, catalyst dosage, catalyst type) on the conversion rate of PET and the yield of the product BHET to find the optimal conditions for depolymerization of PET

Recovering the catalyst zinc and conducting many experiments to explore its influence on the depolymerization reaction

Use different zinc compounds to compare conversion and yield

2. Literature Review

2.1 Introduction of polyester recycling methods

We have a thorough understanding of the recycling methods of various types of polyester products, and selected more common recycling methods for comparison, as shown in Table 1.

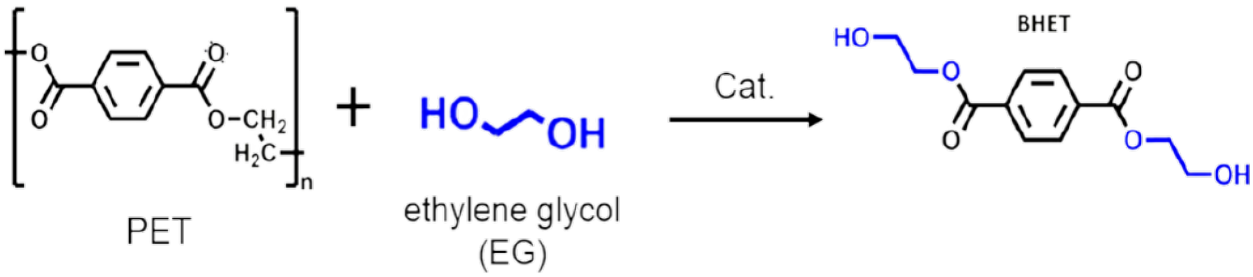
Table 1. Types of tertiary tertiary recycling method

Name	Production Method	Characteristic

Hydrolysis	EG and TPA monomer can be obtained by reacting in alkaline solution under certain temperature and pressure or hydrolyzing PET by microwave radiation.	The former requires a certain temperature and pressure, and the latter does not need to add the catalyst.
Alcoholysis	The polyester chips are added to the alcohol solution (methanol or glycol) and heated, and then decomposed into monomers or oligomers.	Use methanol to produce DMT and EG; use ethylene glycol to produce BHET and its oligomers.
Supercritical fluid method	The polyester product is decomposed in supercritical methanol to produce DMT, a small amount of BHET, and its oligomers.	It is easily affected by temperature and reaction time.

Compared with other methods, the use of alcoholysis to depolymerize PET has benefits in addition to the products that can be used to synthesize polyester fiber materials. When the product BHET is remade into PET, it can avoid pollution. And then made into food-related packaging products. Although the temperature and pressure requirements in this process are more stringent, compared with other recycling methods, this method is more in line with economic benefits and achieves the effect of regeneration.

2.2 Experimental principle



The esterification reaction is reversible, and the transesterification reaction can proceed because of the reversibility of the esterification reaction. The alcohol in the transesterification reaction can undergo an esterification reaction with the free acid to produce new esters and new alcohols. The catalysts for the transesterification reaction can be divided into basic catalysts, acidic catalysts, and biological catalysts. Among them, acid and alkaline catalysts can be divided into alcohol-soluble catalysts and solid catalysts. However, in various solid alkaline catalysts, the effect of using zinc

as a catalyst is compared to other alkaline catalysts. Is better.

In this research, based on the consideration of green chemistry, we hope to achieve the principle of exhaustion and regeneration and try to search for the zinc-containing and easily available waste materials commonly used in daily life. Therefore, we chose to use the zinc shell of the waste battery as a catalyst for the experiment. In the research, the zinc shells from the waste batteries were disassembled, and the zinc shells were added and cut into fragments of similar size to act as a catalyst for PET depolymerization.

3. Methods

3.1 Research steps

Using the amount of catalyst zinc, reaction time, and reaction temperature as operating variables, observe changes in the conversion rate of polyethylene terephthalate (PET) and the yield of ethylene terephthalate (BHET). The photo shown in Figure 1. The preparation process is as follows:

Weighing experimental drugs

Put the required materials and stir bar into the round bottom flask.

Put it on a heating stirrer and stir for a few minutes to mix evenly and put it in the silicone oil at the specified temperature (150°C, 160°C, 170°C, 180°C, 190°C) and heat it for several hours and then reduce to Room temperature.

Using a Buchner funnel and a Buchner flask, the mixture is filtered with air to separate the unreacted polyethylene terephthalate (PET) and the solution, and the unreacted polyethylene terephthalate (PET) is separated from the solution. PET) dry for 24 hours.

Add 300 ml of deionized water to the filtrate of step (4), heat and concentrate to 250 ml, cool at room temperature and put it in the refrigerator for more than 16 hours.

The solution after putting it in the refrigerator will produce white needle-like crystals (BHET) in the solution.

Separate needle-shaped crystals and solution by suction and filtration.

Dry the crystals in an oven for 24 hours, and pour the separated solution into the organic

waste liquid bucket.

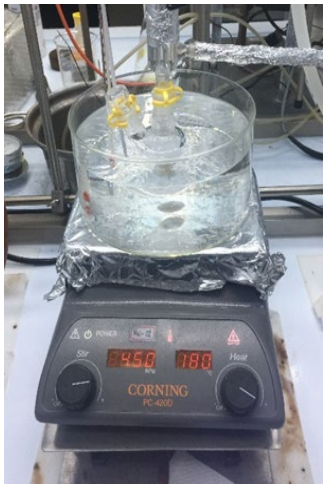
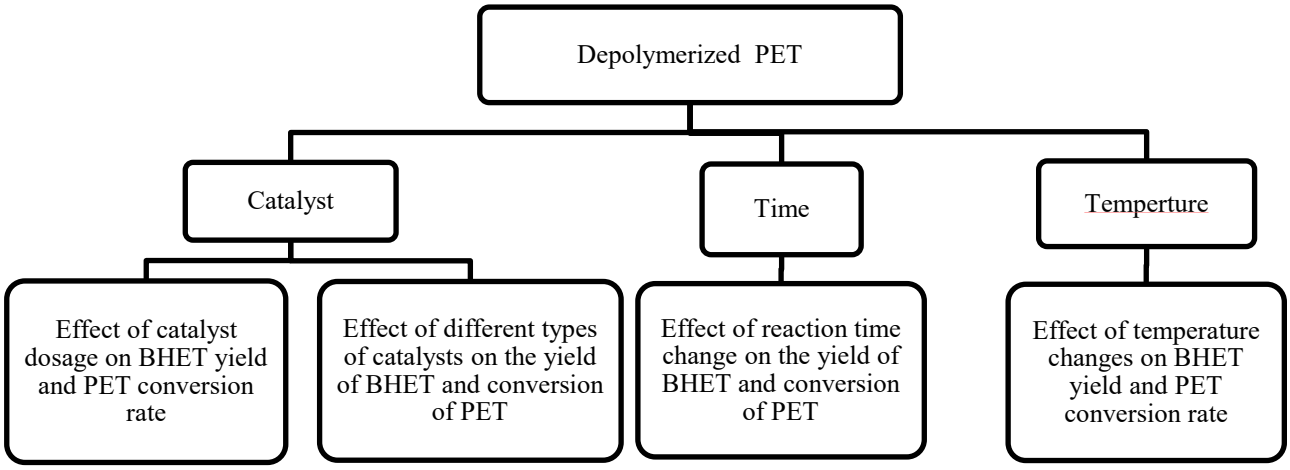
		
Heat and stir the solution	Filter solution	Dry BHET (product)

Figure 1. Experimental process diagram

3.2 Research structure



4. Results and Discussion

Experiment 1: Confirm that the product is BHET by DSC

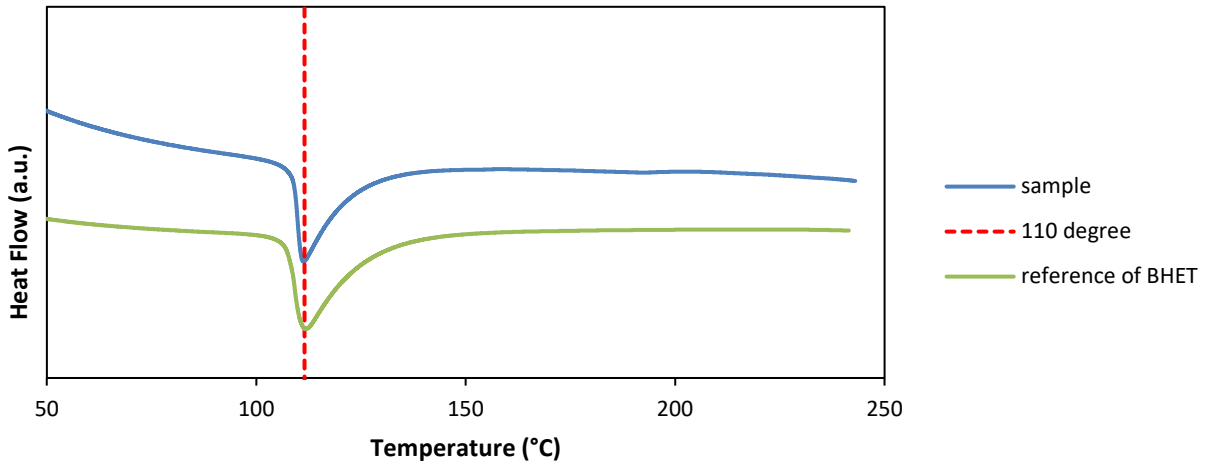


Figure 2. Comparative analysis chart of the melting point of needle crystal and BHET

Experiment 2: Find the optimal conditions for depolymerization of PET

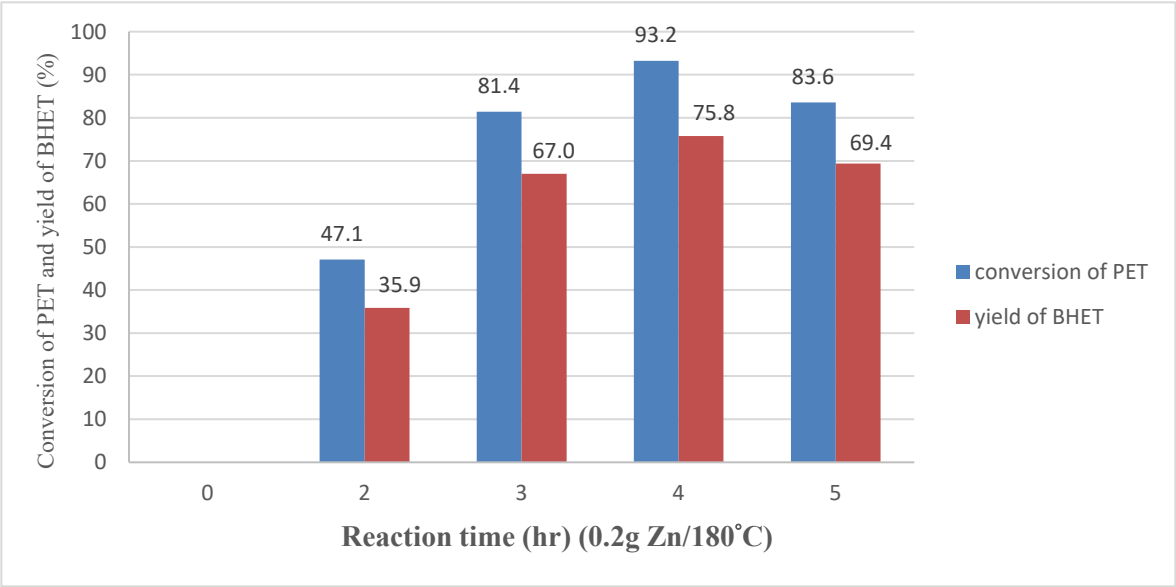


Figure 3. The relationship between the change of reaction time on the yield of BHET and the conversion of PET

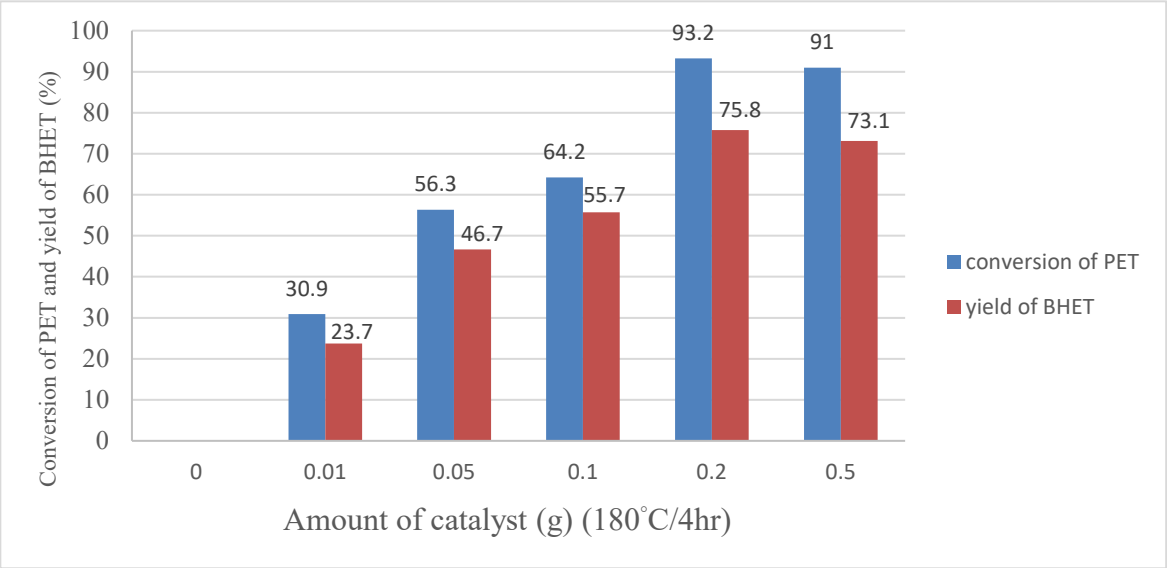


Figure 4. The relationship between the change of the catalyst zinc dosaget on the yield of BHET and the conversion of PET

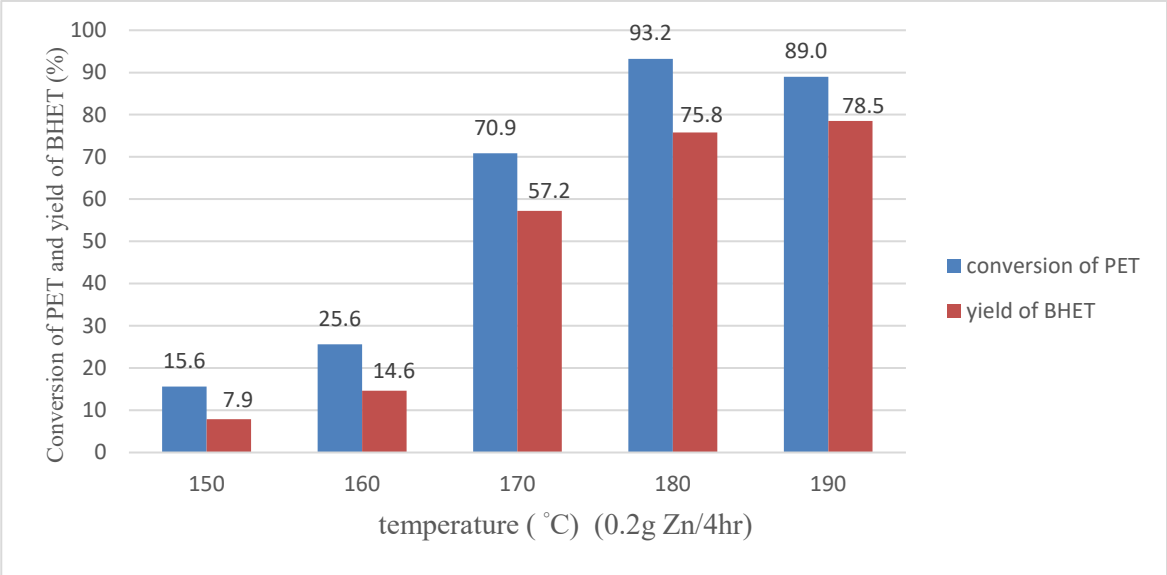


Figure 5. Diagram of the influence of temperature changes on BHET yield and PET conversion rate

Experiment 3: The effect of different types of zinc as catalysts on BHET yield and PET conversion rate

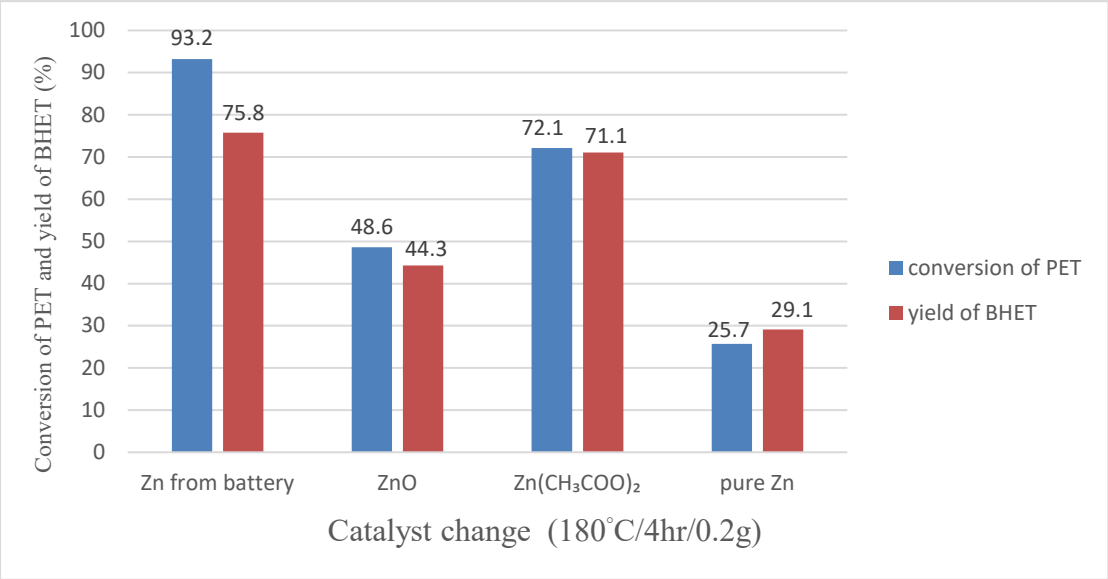


Figure 6. The relationship between changing the catalyst type on the BHET yield and PET conversion rate

5. Results and Discussion

5.1 Numerical Results

In the Experiment 2, this study uses the zinc shell disassembled from the waste battery as a catalyst to experiment PET depolymerization into BHET. It is pointed out that after the optimization experiment, the catalyst dosage, reaction time, reaction temperature, and other variables have an impact on BHET production. Rate and PET conversion rate. It is also pointed out that when the amount of catalyst used is 0.2 grams, the reaction time is 4 hours, and the reaction temperature is 180°C, the best BHET yield is 75.8% and the PET conversion rate is 93.2%, as shown in Figure 3, Figure 4 and Figure 5..

5.2 Graphical Results

In the Experiment 3, this experiment shows that when the catalyst is 0.2 g, the reaction temperature is 180 degrees, and the reaction time is 4 hours, zinc, zinc oxide, zinc acetate, and pure zinc in the waste battery are used as catalysts to compare the BHET yield and the PET conversion rate. Among them, the most efficient reaction is to use zinc in waste batteries as a catalyst, with a reaction yield of 75.8% and a conversion rate of 93.2%, as shown in Figure 6.

5.3 Proposed Improvement

Because before the production experiment, this study believes that the pure solution method is to simply use zinc as a catalyst for depolymerization. In experiment 3, it is pointed out that the yield and conversion rate of pure zinc is far lower than other compounds. The zinc in the waste battery is more efficient as a catalyst to depolymerize PET. Therefore, we currently speculate that when the zinc in the waste battery is used for alcoholysis, the zinc flakes will cause the yield and conversion rate of the alcoholysis due to the chemical reaction in the battery There is a huge improvement. However, because zinc acetate and zinc oxide use their powders for experiments, the contact area of zinc and pure zinc is larger than that of bulky waste battery zinc and pure zinc. Therefore, the contact area will also be included in the discussion in the future for continuous comparison.

5.4 Validation

In the Experiment 1, we put the sample to be tested into DSC and then the system starts to heat up to the temperature you want to set, and observe the weight loss and heat flow change of the sample during this period of time, and the heat flow of the sample Change to determine the melting point of the sample. The characteristic peak of the melting point of the product falls near 110°C, which is consistent with BHET. Therefore, it can be determined that the product of this study is indeed PET monomer BHET.

6. Conclusion

Through comparison with other polyester recycling methods, it is understood that the alcoholysis method is more environmentally friendly and efficient than other methods.

According to the literature discussion, it is known that zinc metal can be used as a catalyst to accelerate the reaction.

In this study, we used self-dismantling of the waste battery to collect the zinc shell of the battery and cut it to use as a catalyst to try to catalyze the depolymerization of PET. Experimental research can indeed use zinc metal as a catalyst to depolymerize PET.

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Reference

Stevens, Malcolm P. ,*Polymer Chemistry an Introduction*, 3rd Edition, New York,1999

Carraher Jr,Charles E., *Introduction of Polymer Chemistry* , 2nd Edition, New York,2010

L Monsigny., Depolymerization of Waste Plastics to Monomers and Chemicals Using a Hydrosilylation Strategy Facilitated by Brookhart's Iridium(III) Catalyst, Available: https://pubs.acs.org/doi/10.1021/acssuschemeng.8b01842 ,June 8, 2018

Sepa Nanayakkara, Antonio F. Pattia, Kei Saito., Chemical depolymerization of lignin involving the redistribution mechanism with phenols and repolymerization of depolymerized products, Available: https://pubs.rsc.org/en/content/articlelanding/2014/gc/c3gc41708e#!divAbstract ,November 11,2013

Biographies

Po-Kai, Fang, and he is currently in the 11th grade. He is very happy to have this opportunity to come to the stage of the International Science Fair. Using chemical engineering to improve the environment is our common interest, and we also learned a lot in this high school. This is also the first time that we have designed experiments and discussed research results ourselves. Thanks to the teachers who have helped us along the way and the partners in the research exhibition.

Yu-Chien, Wu, and he is in grade 11 this year. He likes to do research, especially in chemistry. Although it is tiring to think about the flow of research and the principles of inquiry, however, when he saw the products of hard experiments, he felt fortunate that he persisted. He is very happy to participate in the IEOM held this year, and hope that the results of our efforts can be seen by everyone!

Ying-Ci, Lin. Enrolled in grade 11 this year. Since she was young, she likes to participate in scientific activities and actively explore natural sciences. She is really honored to enter the laboratory for research and learning in high school. Thanks to the professors who provided us with resources and worked hard to guide us, as well as to help our

laboratory senior sister when we are in difficulties so that we can complete the experiment and leave good memories!