Hong Kong Student Science Project Competition 2023

Template of Extended Abstract (Investigation)
(Word Limit: 1,600 words, Pages: 3 pages only)

Team Number: SBPE052

Project Title: Usage of Piezoelectric Effect to Generate Electricity with Sound

Project Type: Investigation

***To our best knowledge, there <u>are no</u> similar works in the field*; (if there are,) related research links are as below:**

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

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

- Provide background information of project and/or state the problem to tackle
- Provide highlights of the **<u>literature review</u>** with the support of pertinent and reliable references
- Provide an overview of work and mention the **<u>research gap that the project is trying to fill</u>**

Fossil fuels are the main source of energy in the world, but they are not renewable and reliable, leading to climate change and global warming. There is an urgent need to develop renewable and clean energy sources to replace fossil fuels.

We aim to make use of the piezoelectric properties of certain materials to create piezoelectric devices that can efficiently convert mechanical energy from sound to electrical energy.

II. Objectives

- State the **<u>aim(s)</u>** of project

We aim to create a device that converts sound energy into electrical energy to be used on roads with heavy traffic. The piezoelectric crystal inside the device will vibrate when it receives sound waves and generates electricity, which can be used as a substitute energy source to relieve energy problems.

III. Hypothesis

- Propose an explanation for a phenomenon and stating how the **<u>hypothesis</u>** can be tested by experiments

The piezoelectric effect is the result of a property called piezoelectricity, which is the ability of certain materials to generate an electrical charge when subjected to mechanical stress or strain. This property is the result of a physical phenomenon known as polarization reversal, which occurs when the molecular structure of certain crystals changes in response to external forces. In response to this change in molecular structure, the piezoelectric material will accumulate a charge, which can then be harnessed for use in electronics.

We can test our hypothesis by seeing if sound energy can successfully be converted to electrical

energy.

IV. Methodology

- List out the materials used
- Describe the **experimental protocol** including the set-up of **control experiment** (if any), **repeated experiment** (if any), and its scientific theory
- Indicate with the support of reasons, the **analysis** used in the investigation

Materials:

- Wires
- 1 Voltmeter
- 1 Capacitor (470 microfarad 10V)
- 1 Rectifier BR106 (10A 600V)
- 2 Plastic Rectangular Container (7cm x 4cm x 1.3cm)
- 2 Copper plates
- 1 Data logger (Sound intensity)
- 1 Data logger (Voltage)
- 1 Ipad
- Sodium Carbonate
- Potassium Bitartrate
- 1 250mL beaker
- Refrigerator
- 1 Speaker

Experimental protocol:

1. Connect the capacitor to the data logger (voltage). Record the readings on the ipad.
2a. Put the piezoelectric device above the speaker's diaphragm
2b. Put the piezoelectric device below the speaker's diaphragm on the table, with the diaphragm pointing at the device.
3. Turn on the volume of the speaker to play traffic noise for 2 minutes. At the same time, hold the data logger (sound intensity) pointing towards the speaker and start recording the sound intensity on the ipad.
4. Disconnect the capacitor from the piezoelectric setup. Connect the capacitor to the data logger (voltage) and start recording the voltage on the ipad.
5. Repeat the above steps with different types of crystal and method of vibrating the crystal.

Scientific theory:
Piezoelectricity happens when a stress is applied to a certain material. This stress compresses the material which alters the structure of its ions/atoms, causing these ions/atoms to take up a new position. The temporary position of ions differs from the original position of the ions/atoms by a little bit which creates opposite charges on both sides of the material depending on how the

material is compressed. In the original arrangement, ions are connected in a way that the whole material has an even distribution of charges, but after compressing or expanding the material, charges are unevenly distributed, resulting in a potential difference on both sides.

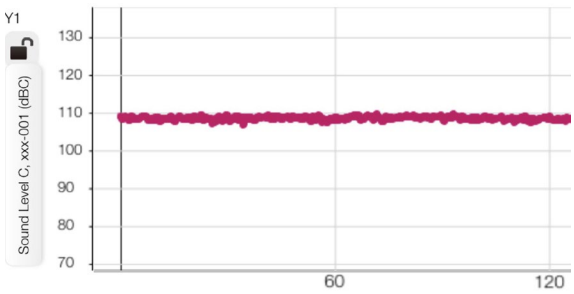
Analysis:
For step 2a, the diaphragm vibrates and hits the crystal, directly causing the piezoelectric crystal to vibrate. For step 2b, The sound waves produced by the speaker vibrate the crystal. The sound wave produced by the diaphragm will cause the piezoelectric crystal in the device to vibrate and generate an AC current. The current will be converted to DC after passing through the rectifier. Then the capacitor can store the electrical energy generated. The data logger (sound intensity) can record the decibel of the traffic noise played, simulating the intensity of sound on the road required to vibrate the crystal. The data logger (voltage) can show the new voltage produced by the capacitor. After comparing it to the initial voltage, we can calculate the power of the piezoelectric device.

V. Results

- Present the **data** with figures, tables or photos
- **Data analysis** (if any, with emphasis on data reliability and the reproducibility based on statistics)
- Interpret the results and its implication
- Discuss **limitation** and compare with existing related works (if any)
- Discuss the importance or impact of the research and how it is applicable to real problems

After performing the experiment, there is a potential difference across the two copper plates, which is measured by the voltmeter. The results are as follows:

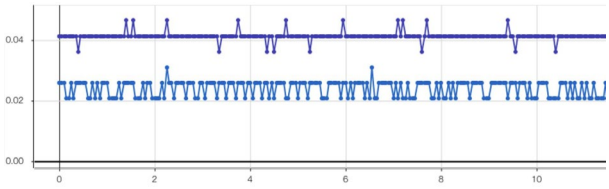
Sound intensity reading:



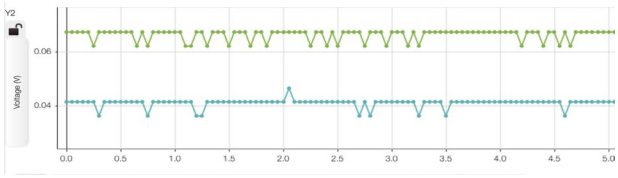
x-axis: time/s
y-axis: sound intensity level/dB

- Sound intensity level is around 110 decibels
- Since we play the same recording with the same volume for every trial of the experiment, the sound intensity of all trials are the same.

Voltage reading:
1. Using method 2b with small crystals in the piezoelectric device



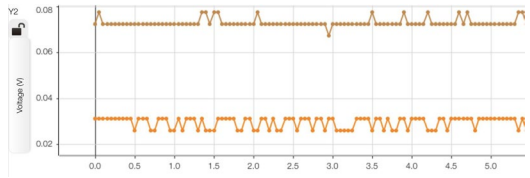
light blue: Initial reading
Deep blue: Final reading
x-axis: time/s
y-axis: voltage/V



Blue-green: Initial reading
Green-yellow: Final reading
x-axis: time/s
y-axis: voltage/V

- The increase in voltage of both trials is around 0.02V
- Energy generated = ½ x V^2 x 470 x 10^{-6} = 9.4 x 10^{-8} J
- Power = 9.4 x 10^{-8} / 120 = 7.83 x 10^{-10} W

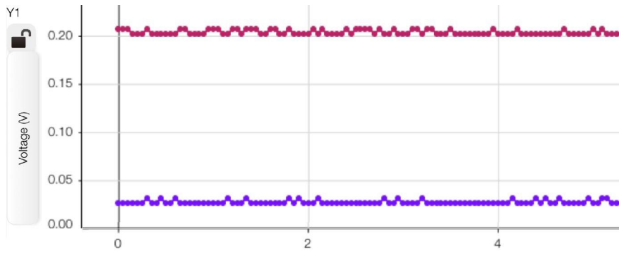
2. Using method 2b with big crystals in the piezoelectric device



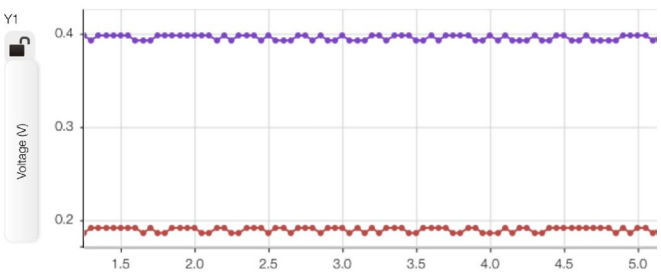
Orange: Initial reading
Brown: Final reading
x-axis: time/s
y-axis: voltage/V

- The increase in voltage is around 0.04V
- Energy generated = 3.76 x 10^{-7} J
- Power = 3.13 x 10^{-9} W

3. Using method 2a with small crystals in the piezoelectric device



Purple: Initial reading
Red: Final reading
x-axis: time/s
y-axis: voltage/V



Red: Initial reading
Purple: Final reading
x-axis: time/s
y-axis: voltage/V

- The increase in voltage is around 0.2V
- Energy generated = 9.4×10^{-6} J
- Power = 7.83×10^{-8} W

Limitations:

The crystal used is rochelle salt, which is not as efficient as other substances such as lead zirconate titanate, barium titanate, and polyvinylidene fluoride. To increase the efficiency of energy conversion in piezoelectric devices, we can explore new material compositions and structures

Impact:

Piezoelectric devices can act as a renewable substitute to reduce fossil fuel consumption and relieve energy problems. It also does not cause any pollution during the generation of electricity, so it can help solve the environmental problems caused by energy consumption.

VI. If your team will compete 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)***

We aim to ensure access to affordable, reliable, sustainable, and modern energy for all. Fossil fuels are currently the main source of energy in the world, supplying about 80% of the world's energy. As it takes millions of years for them to form, they are not a renewable energy source. If we continue to burn fossil fuels at our current rate, it is estimated that all our fossil fuels will be depleted by 2060. Another problem with burning fossil fuels is that it produces a lot of CO_2 and other harmful gasses, leading to many social and environmental problems such as climate change and global warming. Therefore, there is an urgent need to develop renewable and clean energy sources that can replace fossil fuels and meet the demand of people's energy consumption. Although there are quite a few renewable energy sources being developed, such as wind, solar and hydropower. However, these energy sources cannot fully replace fossil fuels due to their high cost and limitations. More renewable energy sources need to be tested and developed to help tackle the energy problems. We believe that piezoelectricity is one of the solutions to this problem. We can make use of the piezoelectric properties of certain materials to create piezoelectric devices that can efficiently convert mechanical energy from sound to electrical energy. Roads and highways with heavy traffic are one of the loudest places, where traffic noises are constantly produced during the day. Therefore, we hope to install piezoelectric devices on these roads to collect and utilize the wasted sound energy. Piezoelectric devices can act as a renewable substitute to reduce fossil fuel consumption and relieve energy problems. It also does not cause any pollution during the generation of electricity. So it can help solve the environmental problems caused by energy consumption.

VII. If your team will compete 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)

VIII. Conclusion

- Make a **data-driven** conclusion of the project and the way forward of the research
- Justify if the proposed project meets the objective(s)

Electricity can be generated from sound. Using a diaphragm to directly vibrate the crystal generates more energy than using sound waves. In addition, big crystals generate electricity more efficiently than small crystals.

✖ Our project is developed based on previous project and the enhancement is below: