Hong Kong Student Science Project Competition 2023
Template of Extended Abstract (Invention)
(Word Limit: 1,600 words, Pages: 3 pages only)

Team Number: JAPE268

Project Title: Triboelectric Nanogenerator for Water Disinfection 水來電淨

Project Type: Invention

To our best knowledge, there are no similar works in the market.

I. Background

Background information

In regions of poverty, most sources of water are polluted by various human activities, such as agriculture. The majority of the population cannot receive safe water due to poor water infrastructures. Water therefore becomes a source of disease transmission, such as Cholera and diarrhoeal diseases. Epidemics of these diseases therefore break out, causing a serious threat to their health. According to the World Bank, 88 percent of all diseases are caused by unsafe water, inadequate sanitation and poor hygiene.

Scientific theory utilised

Electroporation:

When the strength of the electric field is strong enough (>5kV/m) , the process of turning over the cell membrane will be irreversible. Bacteria will lose their proliferation ability and thus disinfection can be done. As the electric field only requires a high voltage, TENG with high voltage and low current is ideal.

Triboelectric nanogenerator (TENG):

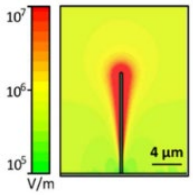
By sliding different materials one over another one, adhesion is formed between some parts of the two contact surfaces. Charges move from one material to another to equalise their electric potential. When the surfaces are separated, some of the bonded atoms may tend to keep extra electrons while some may give them away. As a result of building up the potential difference, a triboelectric effect is created and this produces triboelectric charges.

Triboelectric series

Triboelectric series is a list of materials created according to the tendency of materials to gain or lose electrons. A substance at the bottom in series would obtain negative charge when it touched the substance at the top. The farther the two substances are from each other on the list, the greater the charge transmitted.

Copper(II) oxide nanowires (CuO-NW):

Copper(II) oxide nanowire (CuO-NW) is chosen as the material for generating electric fields due to its special structure. Nanoparticles formed on the surface of CuO would gather electrons. By arranging two pieces of CuO nanowires, a greater potential difference is formed between the bottom and the top of the two pieces of nanowire.



Needs and Insights

Although multiple researches have been done on the triboelectric effect and electroporation, we still lack research on the combination of these two effects and the application of automatic machines. Therefore, our device will try to fill this blank.

II. Objectives

In view of the situation of unclean water in poverty regions, we aim to design a simple water sanitising apparatus to provide access to relatively clean water. It can be used in non-drinking purposes, such as household cleaning and maintaining personal hygiene. Basic sanitation conditions can therefore be maintained so as to suppress the spread of diseases due to the unsanitary water. We aim to automate the process and remove the need for man-power as an optimization.

III. Methodology

Materials

Copper mesh is prepared and heated under 500°C for 4 hours using a hotplate. Copper reacts to oxygen in air under high temperature. CuO is formed.

Material selection for triboelectric effect:

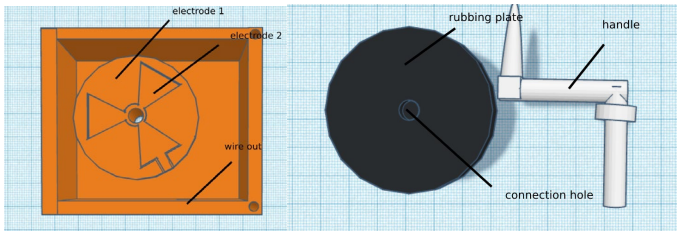
The surface potential of different materials are measured by using an Electrostatic Fieldmeter. Acrylic, FEP and PP are rubbed continuously for 1 minute before the respective surface potential is measured. Materials with a larger difference in surface potential will be chosen.

Experiments

The effectiveness of water disinfection is tested by the bacteria colonial count test. The oral bacteria are collected and mixed evenly with distilled water. Water sample is drawn and added to filter papers. Nitrile nylon and FEP film are used as the cathodic and anodic materials respectively. Same size of copper mesh and copper(II) oxide nanowire are cut and used as the electroporator. The soaked filter paper is placed between the copper mesh and CuO-NW without touching each other. By rubbing the nitrile nylon against the FEP film, voltage is generated and the water sample is expected to be disinfected. The samples are put into petri dishes. Bacteria are allowed to grow and the number of the bacterial colonies are recorded.

IV. Design of Invention

Hand driven TENG :

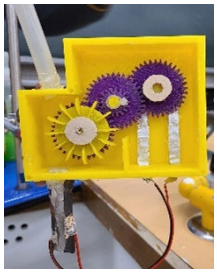


TENG box *Handle and rubbing plate*

Two pieces of aluminium foil will be sticked on the TENG base separately as the two electrodes. A piece of FEP in circular shape will be stuck on the TENG base and cover both electrodes as a friction material. The handle will insert the TENG box and be fixed with the connection hole of the rubbing plate. Nylon will be stuck on the rubbing plate. Users can rotate the rubbing plate with a handle to generate a voltage with TENG.

Self-powered TENG :

Water turbine connected to gear A will be turned by the water. It will drive gear B and gear C. The nylon stick backside Gear C will rub against the FEP stuck on aluminium foil to produce a triboelectric effect. The voltage produced is transferred to CuO-NW to generate an electric field.



Self-powered water disinfection machine prototype

V. Application / Market Need

Applications

The device can be installed in places including but not limited to water tanks of apartment buildings, taps of households, swimming pools. Our device can disinfect water for non-drinking purposes like household cleaning. In these scenarios, using boiled water may require too much energy and effort. Our device can be used to disinfect water with simple manpower or making use of the water flow. Especially for the automation case, we make use of the kinetic energy of water flowing through the pipes, meaning no extra energy is required.

Market needs

Common water disinfection techniques including boiling and the use of chlorine dioxide may require too much energy or are too expensive for poor regions if the water is not used for drinking purposes. As for the occasions where disinfected water is preferred, like house cleaning and showering, our device can be used.

There are also concerns on the inclusion of chemicals in water. By using our device as an alternative such that the usage of chemicals is reduced, the general public will be more likely to feel safer using the water.

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)***

Sustainable development refers to a development model that can meet the needs of the present without compromising the needs of future generations to meet their needs. From the United Nations website, clean water and sanitation is goal 6 of the 17 goals. At current rates, more than 733 million people are living in countries with high and critical levels of water stress. To our best knowledge, our product can help solve the problem of water scarcity, ensure availability and sustainable management of non-drink water from water. Triboelectric nanogenerator devices can serve as a cheap and effective means for sanitising water in poverty regions. Furthermore, it doesn't require high energy input and is not complicated. It is believed that our product is feasible and sustainable.

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)***

Our target group of our project is the people in regions of poverty who cannot access clean water. The mainstream method of water disinfection nowadays is chemical sanitation. However, it involves toxic chemicals, requires a large water sanitation system, and is very expensive. For example, Chlorine dioxide costs up $90000 per year. As a result, they can't afford it and unsafe water continues to threaten people's health.

Our device does not need any external energy or resources input. The set-up is also simple because it requires few materials to work. This ensures that it could be used in regions that lack resources. Moreover, It applies automation that makes use of the water flow to drive the whole device. It is easy to make such that everyone knows how to use it, reducing the work flow of water disinfection.

The device is convenient as it can be made in small scale, and it can also be specialised for different usages, such as water disinfection and household cleaning. Unlike chemical sanitation, it has a high flexibility. At last, CuO is replaceable as it only requires simple heating of copper.

VIII. Conclusion

In this device we made use of a water turbine to generate a motion that causes the triboelectric effect, and the produced voltage can be used in the copper(II) oxide electroporator. With this combination we hope the disinfection can be done automatically, instead of requiring extra energy sources. Compared with conventional methods, no chemicals are needed in this device, hence our device, after further refinements, is a better option for those in poverty.

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