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Research paper

Properties of Electrolytic Sterilization System of CNT Composit Cathode

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Abstract

Background/Objectives: Hydrogen, which can be produced in abundant water, is attracting attention as a new energy source. This paper describes the application of electrolyzed hydrogen water as disinfected water and suggests application fields.

Methods/Statistical analysis: CNT based composites were used instead of expensive platinum or iridium alloys to develop the cathodes of electrolysis devices. The anode was made of a Ti-Ru alloy having excellent durability and conductivity.

Findings: Electrolysis device was constructed and tap water electrolysis was performed, and it was fit to drinking water standard. In addition, harmful substances and bacteria were completely removed. As a result of applying it to the economic boats of ginseng, the growth rate was three times higher than that of soil cultivation and prevented root rot. It also showed excellent sterilization and cleaning ability when used for slaughtered pork.

Improvements/Applications: This device is excellent in disinfection and decomposition ability and is considered to be suitable for wastewater treatment that occurs in fruit washing and Haitai processing.

***Keywords*:** electrolysis, cathode, sterilization water, CNT, composit

1. Introduction

The water electrolysis process is a practical technique for producing hydrogen from non-fossil fuels. Water electrolysis is the simplest and most reliable. In addition, it is easy to mass-produce, and hydrogen of high purity can be obtained. Water electrolysis is a reaction in which water is decomposed to generate hydrogen and oxygen when electricity is applied. There are three main types of water electrolysis technology used for hydrogen generation. First, there is Alkaline Electrolysis, which uses an alkaline solution (NaOH, KOH) as an electrolyte to conduct electricity to water and separates the gas generated through the diaphragm between the anode and the cathode. Each electrode reaction in alkaline electrolysis is as follows.

Cathode: $2H_2O + 2e^- \rightarrow 2OH^- + H_2$ (1)

Anode: $2OH^- \rightarrow H_2O + 2e^- \frac{1}{2}O_2$ (2)

Devices for alkaline electrolysis include unipolar and positive electrodes. The unipolar equation is a form of equilibrium electrodes in a tank. This design is simple to install and maintain, but has the disadvantage of operating at low temperatures and low current densities. On the other hand, in the case of the anode type, the electrode is crossed like a filtration device and connected to the separation membrane. Cells are connected in parallel and therefore have a high cell voltage. This design can produce high pressure gas with high current density, but it has a disadvantage that it is difficult to repair. This method is in the commercialization stage, it exhibits high energy efficiency, and installation cost is lower than PEM electrolysis. However, due to the corrosiveness of the alkaline solution, an electrode having a high corrosion resistance is required, and electrolyte replenishment is required to maintain the concentration.

Second, a solid polymer electrolyte membrane is used as an electrolyte (Polymer Electrolyte Membrane Electrolysis, PEM Electrolysis). The membrane used in this method also separates the generated gas, such as the diaphragm of alkaline water electrolysis, and also acts as an ion exchanger to transport hydrogen ions from the anode to the cathode. The reaction at each electrode is as follows.

Cathode: $4H^+ + 4e^- \rightarrow 2H_2$ (3)

Anode: $2H_2O \rightarrow 4H^+ + 4e^- + O_2$ (4)

This method does not have a corrosive electrolyte because the electrolyte is stable, the cell structure is ttttsimple, and pure water is used. Compared to alkaline water electrolysis, it is possible to operate at high current density and the efficiency of the device is high. Polymer electrolysis is both portable and stationary. However, it is expensive to install and has low capacity. In addition, there is a disadvantage in that the efficiency is low and the life span is short. Therefore, the solid electrolytic water electrolysis method is not developed as the alkaline water electrolysis method [1,2].

Finally, high temperature electrolysis (HTE) using high temperature steam is a method utilizing the phenomenon that the theoretical decomposition voltage corresponding to electric energy among the energy required for water decomposition is lowered at high temperature. Since electrolysis takes place at high temperature (over 700 ℃), it is possible to decompose water with

high efficiency by using less electric energy. In addition, unlike alkaline water electrolysis, since the electrolyte is solid, it is unnecessary to replenish the electrolytic solution and it is easy to maintain because there is no problem of corrosion. It is the reverse reaction of solid oxide fuel cell (SOFC) and can be used as the basic technology of SOFC. However, it is necessary to develop a solid electrolyte which can be used at high temperature, and it is still in the basic research stage.

Electrode catalysts are the most representative of the performance in water electrolysis. The required voltage and performance are determined by the electrode material and surface conditions. Generally, the reaction step shown in Figure 1 occurs at the electrode surface for hydrogen generation. The hydrogen ions are reduced and adsorbed to the electrodes in the form of hydrogen atoms (Volmer reaction). Next, one adsorbed atom reacts with the hydrogen ion of the solution (Heyrowsky reaction), or hydrogen is generated by the bonding of two adsorbed atoms (Tafel reaction). The above reaction differs depending on the electrode material, and the activity thereof determines the efficiency of hydrogen generation. Precious metal catalysts including platinum are the best catalysts for hydrogen generation, and catalysts such as nickel, cobalt, and copper also have excellent hydrogen generation capability[3-5].

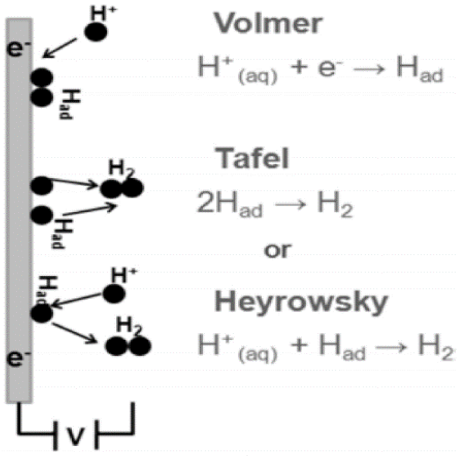

Figure 1:. On the origin of hydogen evolution reaction

2. CNT Cathod

2.1. *CNT Based Composite Material*

Carbon nanotube (CNT) is a carbon isotope having a cylindrical nanostructure. Nanotubes with length-to-diameter ratios of up to 132,000,000: 1 have also been made [6], the highest of all known materials. Carbon nanotubes have many unusual properties and can be used in various fields such as nanotechnology, electrical engineering, optical and material engineering. Especially, the thermal conductivity and the mechanical and electrical properties are very specific and have been applied as additives for various structural materials. For example, a small amount of carbon nanotubes may be added to baseball bats, golf clubs, automobile parts, and Damascus steel (mainly made of carbon fiber) [7,8]. Figure 2 shows the shape of the chaos or the notch.

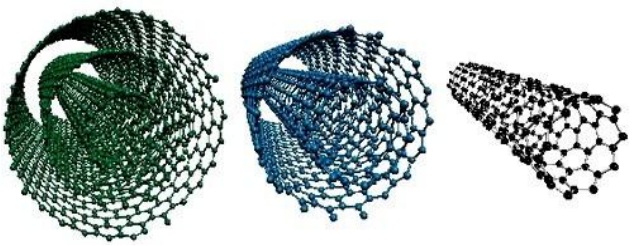

Figure 2:. Carbon nano tube(triple, double, single-walled carbon nanotube)

The developed composite material is a non - metal electroconductive CNT composite material with surface electric resistance of 0.5 Ω / □ or less. It has excellent chemical properties such as acidity, alkalinity, hydrochloric acid and sulfuric acid. Based on environmentally friendly polypropylene, dimensional stability has similar physical properties to that of ordinary PC, ABS, PPS, and PET. It is also an excellent electromagnetic shielding injection molding material. The manufacturing process is as follows.

(1) Prepare an acrylic anion resin dispersion.

(2) Mix CNT and water-dispersible acrylic anion resin.

(3) Control the moisture of the mixture.

(4) The mixture is extruded and pelletized.

(5) Pellet the prepared pellets by compounding them with a polypropylene resin and a thermoplastic elastomer.

CNT composite material having a high level of electrical conductivity having surface electric resistance of 0.5 Ω / □ or less is provided because CNT is contained in a high content and excellent in dispersibility of CNT. This CNT composite material is suitable for injection molding because of its excellent dimensional stability.

Since this CNT composite material is excellent in electrical conductivity without using a metal, it can be used without replacing a conventional metal product with no fear of corrosion. Therefore, it can be used as an electrolytic electrode material in place of a metal material. In addition, since CNT composites have excellent electromagnetic shielding ability due to their high electrical conductivity, they are particularly useful for the manufacture of products requiring electromagnetic shielding function, and they are excellent in chemical resistance and mechanical properties [9].

2.2. *Properties of CNT Based Composites*

Based on CNT, olefin polymer was used, and copper and aluminum wire can be substituted for electric wire and heating element. It is not oxidized in a damp place or in water. The radiant heat is excellent, so that local heat generation of the metal heating element can be compensated. Figure 3 shows the surface of a CNT based composite material by SEM. Figure 4 shows the pellet of a CNT composite material. Table 1 shows the properties of CNT composites.

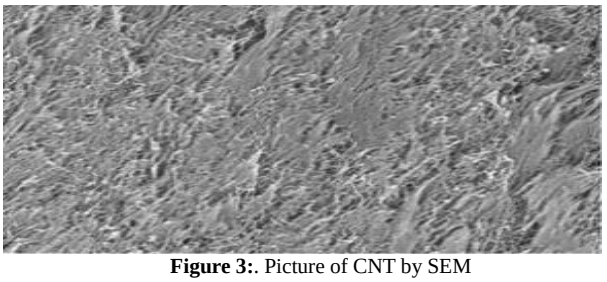

Figure 3:. Picture of CNT by SEM

Figure 4:. CNT composit pellet

Table 1:. The properties of CNT composites

division	CNT composites
contraction ratio	5/1000%
tensile strength	52.2kg/cm
elongation	94.7kg/cm2
density	1.05
surface resistance	0.25Ω/□
line resistance	0.004Ω

3. Electrolytic Sterilization Cleaning System

3.1. *Bactericidal Effect of Electrolyzed Water*

The disinfection device by electrolysis produces salt of hypochlorous acid by using salt water and sterilizes and disinfects it, so it does not deal with the toxic chlorine gas directly, so it is safer than the sterilization method by injecting chlorine gas directly from the water purification plant. Chlorine and hypochlorous acid ions produced by the reaction between chlorine and hydroxide ions, which are the main products in the electrolysis of salt water, react in the electrolyte between the electrodes, and have a sterilizing effect. The electrolysis process of chlorine is as follows.

In the electrolysis reactor, the electrolysis efficiency is influenced by the concentration of the electrolyte between the electrodes. In order to reduce electrical resistance and maintain high conductivity, electrolytic treatment is performed by using ionic substance in water in water treatment, and since electrolytic disinfection water uses salt, there is no need to add extra electrolyte ions [10].

3.2. *Electrolytic Device*

The cathode was made of CNT composite material and the anode was made of Ti-Ru alloy. A 5 - layer composite was used and the voltage was 12V. Figure 5 shows the shape of the cathode and anode combination and the hydrogen generator. Table 2 shows the specifications of the electrolytic apparatus used in the experiment.

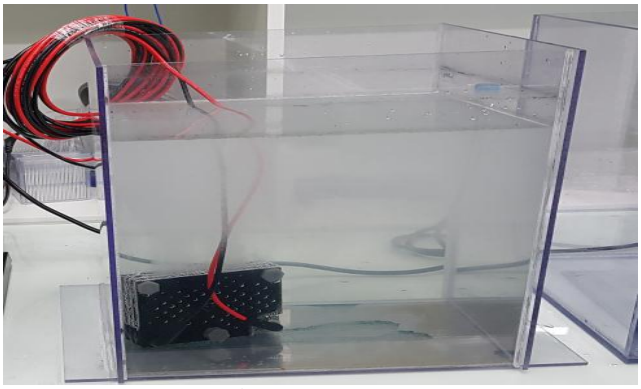

Figure 5:. Combination of cathodes and anodes(above) and hydrogen generation equipment(below)

Table 2:. Specification of electrolysis apparatus

Input voltage and electric current	DC 12V 9A
CNT electrode catalyst weight	480g
CNT electrode catalyst size	100mm×130mm×47mm
Water temperature	25℃
Water electrolysis rate per minute	0.62g/min

3.3. *Electrolysis Sterilization Cleaning Device Performance*

The tap water was put into the test equipment and operated. The test was conducted according to the drinking water test process standards, and the harmful substances were completely removed. The test environment was conducted at a temperature of 24-25 ° C and a humidity of 45-55%. Table 3 shows the test results of bacterial and hazardous material residues.

Table 3.: Bacterial and harmful substance residue

test items	unit	test water	result(10min)
Diazinon	ppm	0.0596	ND
Penitrothion	ppm	0.1142	ND
Legionella pnaumophilla	CFU/mL	6.0*105	10
Escherichia coli	CFU/mL	13000	0
Yellow grape normal	CFU/mL	10000	0
Salmonella	CFU/mL	12000	0
P. aeruginosa	CFU/mL	15000	0

The far infrared ray emissivity of CNT composites was measured at 40 ℃ and 0.9 was obtained in the range of 5-20 μm. Components of treated water via reference ingredient contents were presented in table 4.

Table 4: Drinking water content of treated water

Test Items	unit	Water quality standard	Results (10 minutes)
Detergent	mg/L	<0.5	ND
Cyan	mg/L	<0.01	ND
pH	-	5.6-8.5	7.6
Turbidity	NTU	<1	0.25
Chromaticity	eh	<5	ND
Flavor	-	ND	ND
Smell	-	ND	ND
Water hardness	mg/L	<300	49
Potassium permanganate consumption	mg/L	<10	0.9
Evaporation residue	mg/L	<500	125

4. Field Application Experiment

4.1. *Pork Washing*

Washing of pork with hydrogen water is sterilization and antibacterial ability, and it reduces inflammation and suppresses the generation of bacteria in future. It can also maintain freshness for a long time. After washing the pork with hydrogen water, the bacteria were not detected. Figure 6 shows the state of pork after washing with hydrogen water. This can be applied to livestock slaughterhouses. Spraying not only livestock products but also surrounding facilities can eliminate the smell and inhibit the generation of bacteria.

Figure 6:. After spray washing of pork

4.2. Ginseng Hydroponics

Spraying small amounts of water on ginseng hydroponics can also remove fungi on the front and back sides of the leaves. It also increases immunity and increases growth rate by 20-30%. Plants use light energy to change the carbon dioxide contained in the air and the water absorbed in the roots to produce oxygen and carbohydrates to feed the nutrients. Hydrogen is sprayed on the surface of the plant to eliminate the bacteria on the surface of the plant, the hydrogen penetrates into the plant smaller than the cell wall of the plant to expand the pores to help absorption of carbon dioxide helps to absorb nutrients and improve the growth rate. When hydroponic cultivation, water is added to the roots for 30 minutes or the root is completely submerged, and then the nutrient solution or water is replaced. Note that the electrolytic device should not be installed directly in the bottle. After supplying the drinking water, the nutrient solution may be added, or the nutrient solution may be mixed with the nutrient solution at a certain ratio.

Figure 7:. Examples of Ginseng Hydroponics

5. Conclusion

An electrolytic sterilization cleaning device using electrolysis using CNT composite material as cathode was developed. Platinum-based cathodes are expensive and unstable, and require electrode reversal around 15 minutes by mineral adsorption and petrification. However, the electrode catalyst of CNT composite material has excellent electric conductivity and has a far-infrared radiation effect. Also, it has characteristics of chemical resistance, moisture resistance and cold resistance. CNT composites have a lower ionization tendency than gold (Au) and are difficult to oxidize. As a result of measuring the sterilizing water component, harmful substances and bacteria were effectively removed and the far infrared ray emissivity of the negative electrode was 90% at 40 ° C. This device has shown good results in inhibiting bacterial growth in slaughterhouse cleaning, meat washing and ginseng hydroponics.

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