Specific electrical conductivity of K2SO4 electrolyte solution for nitrate production by air plasma electrolysis

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Specific Electrical Conductivity of K_2SO_4 Electrolyte Solution for Nitrate Production by Air Plasma Electrolysis

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Abstract. This research was conducted to determine the effect of conductivity of electrolyte solution K_2SO_4 on the energy consumed for plasma formation in air plasma electrolysis applied to the production of liquid nitrate fertilizer. The experimental parameters consist of various conductivity solutions. Difference the conductivity of the electrolyte solution K_2SO_4 is expressed by different concentrations (0.01, 0.02, 0.03, 0.04 and 0.05 M). Batch reactor (10 cm diameter, 20 cm high) with stainless steel electrode as cathode (diameter 6 mm) and tungsten as anode (diameter 0.5 mm) were used by applying a continuous cooling system. At the moment observed at various voltages (40 – 400 V) for 20 seconds at each voltage. Energy consumption for vapor formation and release plasma was found to be higher at deeper positions anode. At the higher conductivity of the electrolyte solution, despite the energy consumption for the vapor formation was observed to be lower, the energy consumption for the depleted plasma was found to be higher.

INTRODUCTION

Research on the synthesis of nitrate using plasma electrolysis has not been done much at this time. So that this research is a technological breakthrough in the world of agriculture for the availability of nitrate fertilizers[1]. Currently available fertilizers are nitrogen fertilizers derived from the Haber Bosch Process where hydrogen is needed as raw material from nature[2]. The resulting emissions also cause air pollution. The synthesis of nitrate fertilizers using plasma electrolysis is safer for the environment[3]. Based on research that has been done using direct current, plasma electrolysis can be generated continuously around the anode in K_2SO_4 electrolyte solution[4]. At sufficiently high voltages, conventional electrolysis changes spontaneously to plasma electrolysis. [5]. Plasma formation is important to analyze because the phenomenon of plasma formation is influenced by the voltage used based on Ohm's Law[6]. The plasma identification process in nitrate synthesis is divided into three zones, namely (1) Ohmic Zone, in this zone there is an increase in current linearly with an increase in voltage. This causes the rate of heat formation to be greater until the current increases at the maximum point where the voltage at that point is called the breakdown voltage (Vb)[7]. The value of Vb will decrease as the concentration of the electrolyte solution increases, so that in this study it is important to know the effect of conductivity because different electrolyte concentrations cause different conductivity[8]. (2) Transition Zone, after reaching the breakdown voltage (Vb), the current will start to decrease but the voltage will increase. The current reaches a minimum value and the voltage at this condition is called the discharge voltage (Vd), at which glow discharge plasma begins to form. Changes in concentration cause changes in conductivity which affect the value of Vd. (3) Plasma Glow Discharge Zone, there is an increase in current and an increase in voltage until the heat generated forms plasma at the anode[7][8]. The

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energy required to start the formation of plasma (breakdown energy) is the product of the breakdown voltage (Vb) and the breakdown current (Ib)[9]. The minimum electrical energy required for a stable plasma to form (discharge energy) is the product of the discharge voltage (Vd) and the critical current (Id). [10]. The purpose of this study in addition to analyzing the energy of plasma formation is also to analyze the effect of the conductivity of the electrolyte solution K_2SO_4 on the production of nitrate. K_2SO_4 electrolyte plays a role in increasing the conductivity of the flow of electric current in the in solution so that the resulting plasma is more stable and supports chemical reactions occurs optimally. The concentration of electrolyte compounds affects the conductivity of water, where the higher the concentration of an electrolyte compound, the greater the conductivity of water. The amount of conductivity will affect the speed at which a plasma is formed and trigger the production of more hydroxyl radicals. The higher the hydroxyl radicals produced, the nitrate production will also increase.

METHODS

Materials

The material used in this research is an electrolyte solution consisting of distilled water and 0.01 M; 0.02 M; 0.03M; 0.04 M; 0.05M K_2SO_4 concentration, air injection (N_2 and O_2), for nitrate analysis used nitrate reagent.

Equipments

The equipment used includes a plasma electrolysis reactor with a volume of 1.2 liters. The electrodes used are stainless steel for the cathode and tungsten. For nitrate analysis used Spectrofotometer UV VIS Shimadzu 1800. Other equipment can be seen in Figure 1 below.

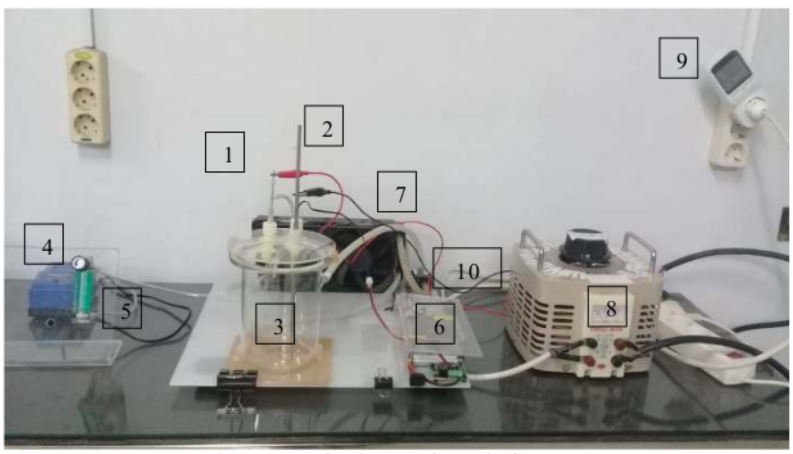

FIGURE 1. Air Plasma Electrolysis Reactor

Description:

1. Anode
2. Cathode
3. Conductometer
4. Air Injector
5. Flowmeter
6. Temperature Sensor
7. Condensor
8. Slide Regulator
9. Multimeter and Power Analyzer
10. Transformator and Dioda Bridge

Procedure

Current and voltage characteristics are carried out on each process variable electrolyte conductivity at air flow rate, and constant processing time, to determine the value of the range the optimal voltage and current in the Glow Discharge zone, namely the voltage when plasma already formed larger and more stable with marked current and voltage values straight back. Current is measured and data is taken at each increment voltage is 20 V. If the measured current fluctuates, the current value is recorded for 1 minute and then the average value was taken. Past current measurement data made a curve in the range of 300-800 V in increments of 20 V. To determine the level of nitrate (NO_3) in a solution using a UV-Visible Spectrophotometer with a measurement range of 0.01 mg to 1.0 mg NO_3 with a cuvette thickness (path length) of 1 cm or more, at length 543 nm wave.

RESULTS AND DISCUSSION

In Figure 2 it is shown that the increase in the electrolyte concentration of K_2SO_4 in distilled water represents an increase in conductivity. At a temperature of 60oC in a concentration range of 0.01-0.05 molar, the conductivity increased from 3.72 to 7.68 S.cm-1. The greater the concentration of electrolytes, the higher the conductivity of the solution and will makes it easier for electrons and reactive species formed from the plasma electrolysis process to flow in solution and will react with the injected air. The higher the conductivity of the K_2SO_4 electrolyte, the voltage to reach the glow discharge zone or known as the critical voltage (Vd) will be at a lower voltage. The greater the conductivity will also position Vd at a larger current value. In connection with the research of Sengupta et al (1996), plasma will occur when the solution undergoes evaporation due to joule heating from the electrical energy generated by the power supply. This heating occurs during the electrolysis process. According to the law of thermal conductivity, a material with a higher conductivity will transfer heat faster so that plasma can form at a lower voltage. The higher the conductivity of the solution, the easier the current will flow in the solution so that it will accelerate the formation of a stable plasma.

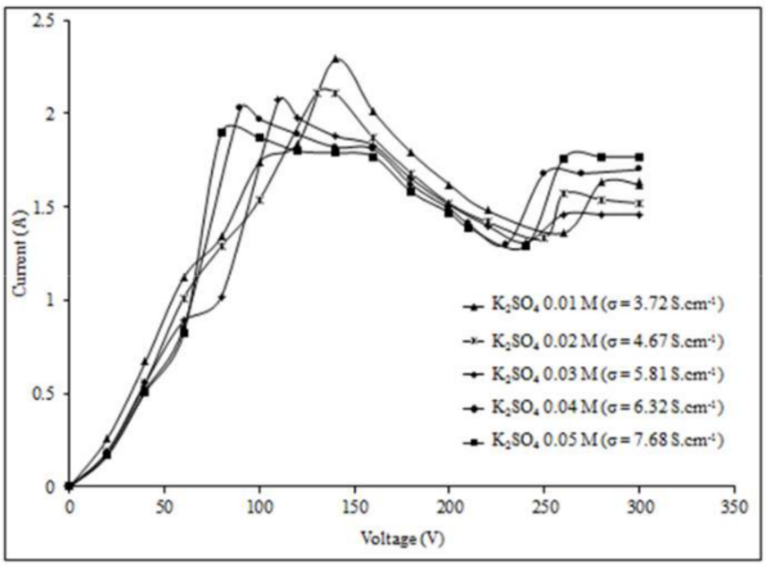

FIGURE 2. The Voltage-Current Characteristic in K_2SO_4 electrolyte Solution

The mechanism of plasma formation in nitrate synthesis is described using current and voltage characteristic curves. At very low voltages (0-40V) there is no visible current line which indicates no current flowing because the electrolysis process has not occurred. In this research, K_2SO_4 electrolyte solution was used, the cathode in the form of stainless steel and the anode in the form of tungsten which is inert, so that the reaction at the cathode and anode follows equations (1) and (2).

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

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

At the cathode there is a reduction process in water (H_2O) where H_2O has greater reduction potential than cations in the alkaline group (K^+). Similarly, the process that occurs at the anode where the water will be oxidized because the oxidation potential of water is greater than the ions that contains oxygen (SO_4^{2-}). Voltage rise during the electrolysis process Transition Zone: $Vb < V < Vd$; current starts to decrease with increasing voltage due to the formation of a gas envelope around the anode. In this phase it happens the process of forming and breaking the vapor envelope to give rise to current instability. The formation of a vapor layer at the anode causes the anode and the solution are no longer in contact so the current cannot increase anymore and begins to decrease with increasing voltage. It can be seen that the lowest current is obtained at the critical voltage (Vd) of 280 V. Plasma glow discharge zone: V > Vd; current in plasma glow discharge zone (GDP) starts to increase with increasing voltage. Voltage rise (VGDP) is directly proportional to the increase in energy (EGDP) so that the plasma becomes larger and the light emitted becomes brighter.

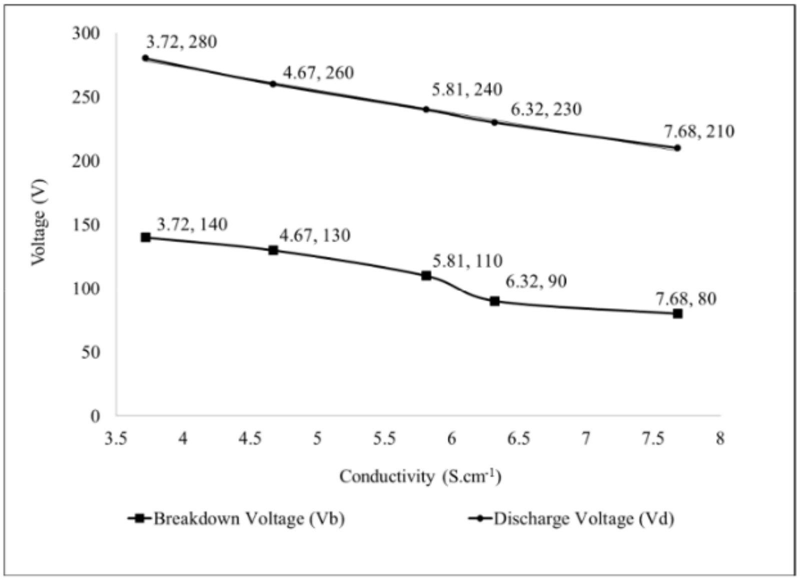

FIGURE 3. Breakdown and Discharge Voltage at Conductivity Solution Electrolyte

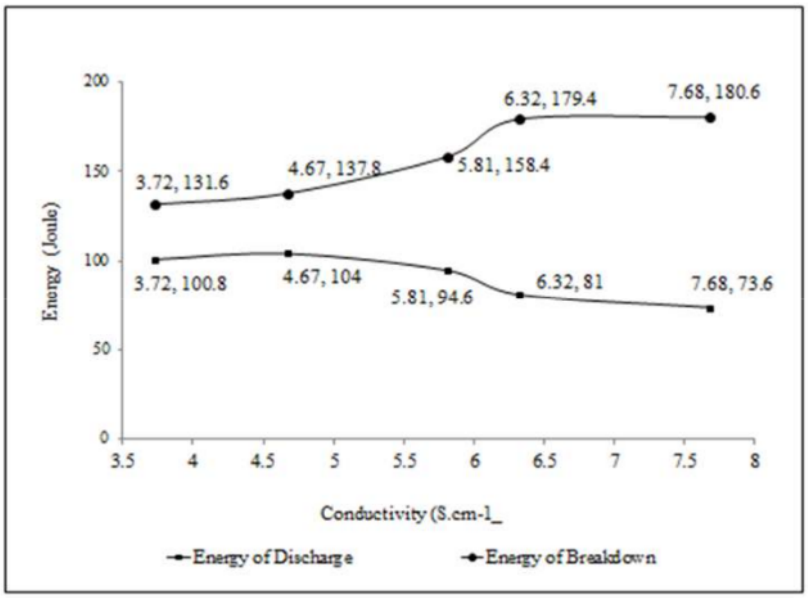

FIGURE 4. Energy of Breakdown and Discharge at Conductivity Solution Electrolyte

Based the figure 3 it reaches a breakdown voltage (Vb) which is occurs at the anode at a voltage of 140 V. Changes in conductivity also affect the critical voltage (Vd) where the higher the conductivity, the discharge occurs at a higher voltage low. However, even though the critical voltage decreases, the critical energy (Ed) at Plasma formation will increase with increasing solute concentration (Figure 4). This is due to the resistance (resistivity) between the anode and anolyte. In addition, the presence of high dielectric strength in the solution causes The power of discharge that occurs is lower in solutions with higher conductivity lower [9]. The higher the conductivity, the power (energy) discharge is getting bigger, which can be seen from the formation of plasma which is getting brighter. In addition to the conductivity of the solution, the energy consumption of plasma formation is also influenced by the position of the anode depth in the solution. The higher the voltage breakdown (Vb), breakdown current (Ib) and energy (Eb) required to start formation of a gas envelope. Similarly, the effect on the value of the voltage and the current at the critical point and in the region of full plasma formation, so that the energy required to start the formation of discharge (Eb) and energy in the region glow discharge plasma (EGDP) is increasing[11].

In this study, an analysis of the effect of electrolyte conductivity in producing nitrate fertilizer was carried out. The conductivity is adjusted according to the different K_2SO_4 electrolyte concentration, which is 0.01 M, 0.02 M, 0.03 M, 0.04 M with 0.05 M. With an increase in the concentration of the electrolyte as the process medium electrolysis, the nitrate formed will be more and more, as shown in Figure 5.

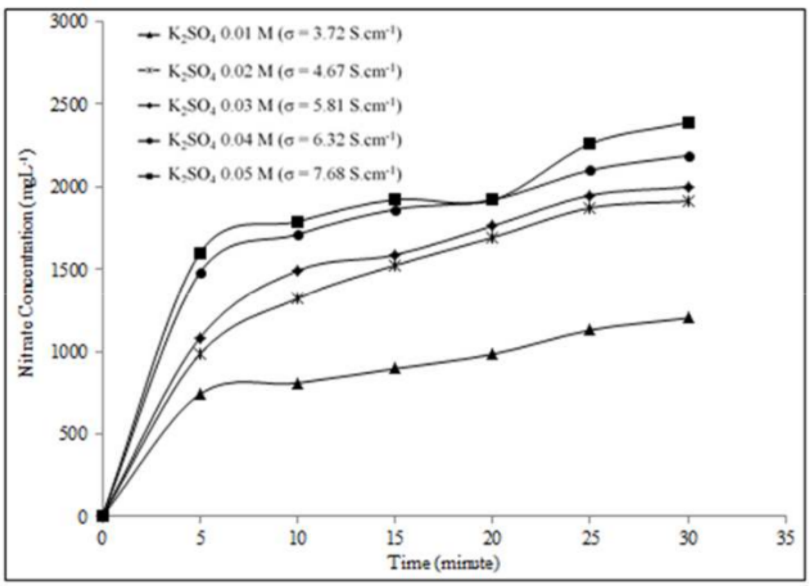

FIGURE 5. Nitrate Production at variation of Conductivity

Based from figure 5 the increase in electrolyte concentration will increase conductivity of the solution so that electrons and other reactive species formed from the Plasma Electrolysis process, it will be easier to conduct in solution [10] and reacts with the injected air. . The smaller the electrolyte concentration, the process voltage the greater it is. Then the greater the voltage, the number of reactive species produced also increases for all types of reactive species. However, the large voltage used can affect the type (composition) of the reactive species formed in the plasma.

CONCLUSION

In this study, the effect of the conductivity of the K_2SO_4 electrolyte solution on the energy consumed for Air plasma electrolysis can be applied in the production of liquid nitrate fertilizers. At the higher conductivity position, the energy required for plasma formation (Eb) and release (Ed) were observed to be higher. Conductivity change solution also affects the breakdown and release of energy in the formation of plasma in solution. On large conductivity, the breakdown energy (EB) is lower, while the discharge energy (Ed) becomes higher.

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GENERAL COMMENTS

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7