International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

Scalable Synthesis of Aluminium Oxide Nanoparticle for Cost Minimization in Battery Electrode

Shahruzaman Sulaiman, Azmi Hassan, Muhamad Husaini Abu Bakar, Ahamad Zaki Mohamed Noor

Abstract: Nanoparticle is hard to produce because the process is difficult, and the material amount is always insufficient. In conjunction, a high amount of cost will be used to produce nanoparticle. In addition, the current material to produce nanoparticle are expensive, hard to obtain and depleting. Hence, Aluminium oxide (Al_2O_3) was introduced to solve the problem exist with the current nanoparticle. In this paper, research was conducted for the manufacturer to provide a large amount of fine Al_2O_3 nanoparticle hence cost saving. Electric Discharge Machine (EDM) was used to produce the nanoparticle. Several stages will be drafted put in this paper in order to achieve the objectives. The stages involved was developed a new chamber for Al_2O_3. The next stage is to use this device and synthesis of the nanoparticle. This research is followed by extraction of the nanoparticle. Then, the samples were measured and characterize the Al_2O_3 nanoparticle. Currently, the size of Al_2O_3 nanoparticle obtained is 800nm. Hence, the experiment will be proceeded in order to achieve Al_2O_3 nanoparticle size from 1nm to 100nm. The aluminium nanoparticle should be improved in all aspects compare to the current material nanoparticle.

***Index Terms*: Aluminium oxide, electric discharge machine, nanoparticle, extraction nanoparticle, electrode battery**

I. INTRODUCTION

Nanotechnology is a well-known area of research which were carried out by a lot of research around the globe. This method is a new way to revolutionizing material into nano sized called as nanoparticle. The uniqueness can be seen from the size of nanoparticle because of the ratio of volume compared to large surface area. Usually the size is in the range of 1nm to 100nm [1]. Recently, the properties of thermal, electrical, catalytic and physical appearance made the researcher keen to carry out more research in nanoparticle technology [2].

Revised Manuscript Received on 30 July 2019.
* Correspondence Author
Shahruzaman Sulaiman*, Manufacturing Section, Universiti Kuala Lumpur Malaysian Spanish Institute, Kulim, Malaysia
Azmi Hassan, Electrical Electronic and Automation Section, Universiti Kuala Lumpur Malaysian Spanish Institute, Kulim, Malaysia
Muhamad Husaini Abu Bakar, Manufacturing Section, Universiti Kuala Lumpur Malaysian Spanish Institute, Kulim, Malaysia
Ahamad Zaki Mohamed Noor, Manufacturing Section, Universiti Kuala Lumpur Malaysian Spanish Institute, Kulim, Malaysia

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Problem faced in order to produce production nanoparticles are the size of nanoparticle is hard to be controlled. Furthermore, the nanoparticle synthesizing uses up a lot of cost in purchasing material, processing, extraction and distribute. Hence, it is important to find and easy, compact, flexible and cost saving method to produce aluminium nanoparticles at high yield rate. The objective of this paper is for other researcher to have a cheaper option in order to produce nanoparticle. This methodology paper shares a simple, compact, versatile and cost-effective method to produce aluminium nanoparticle. Aluminium material is used here as electrode battery are due to this material is cheap, easy to obtain and unique properties to replace lithium, nickel and other current used material in battery [3]. The scope established here is this paper will not discuss the specification of machine used and comparison of every material fabricated as nanoparticle.

Aluminium Oxide (Al_2O_3) nanoparticles made lot of manufacturer interested and made them as their primary option to process this material due to reasonable cost, unique characteristics and used widely in various applications such as automobiles, catalysis, explosives, lubrication, and other suitable application [4]. There were several varieties of liquid and vapor solution reaction for the purpose of synthesizing aluminium nanoparticles. They found that the aluminium nanoparticles were generated as collections comprises of primary particles whose diameter lies in the range of 10-140 nm [5]. Other researchers generate aluminium nanoparticles through laser ablation immersed in water and ethanol mixed with hydrogen. They discover that the particles shapes were near spherical shape with the shape size between 30-50 nm [6]. The disadvantage of this method is that the researcher for the manufacture must bear high cost to produce aluminium nanoparticle. Similarly, to wire explosion technique using different inert ambience makes the manufacturer spent extra cost compare to EDM [7]. EDM have the advantage compared to the two mentioned method whereby the nanoparticle can be produced even more in volume.

This paper presents the preparation of aluminium nanoparticle immersed in kerosene solution through the usage of Electrical Discharge Machining (EDM). EDM holds two rods which known as electrodes. With high amount of energy and suffice electrical field, plasmas were formed in between two electrodes [8]. Plasma is a mixture of positive ions, electrons and uncharged atoms. The two electrodes vaporize and melt during arc discharge process. This process is also called ionization [9].

The huge amount discharges in kerosene solution will aggregate, creating nanoparticles which stabilize as a suspension in the aqueous solution [10].

II. METHODOLOGY

This section discussed overall methodology to obtain nanoparticle through several phases. These phases are elaborated further in detailed flowchart. The phase available is developing new chamber suitable to process aluminium nanoparticle in EDM. The second phase of this method is nanoparticle synthesis. Whereby the aluminium is placed in the new chamber design and the electrode is melt due to high temperature by EDM machine until debris is formed. The third phase of this methodology is to extract nanoparticle using kerosene solution. The kerosene is mixed with detergent and the separation between aluminium debris or aluminium nanoparticle is separated using centrifuge motion at high rotational speed. The final phase of this overall methodology is to measure and categorized the samples of different size and shape of aluminium nanoparticle. Once complete, all the size of several parameter and material composition are analysed.

A. Explanation by Phase

This section elaborates of four phases as discussed in Figure 1 overall methodology. This section is to be presented for much clearer view in terms of parameter and condition to synthesize aluminium nanoparticle.

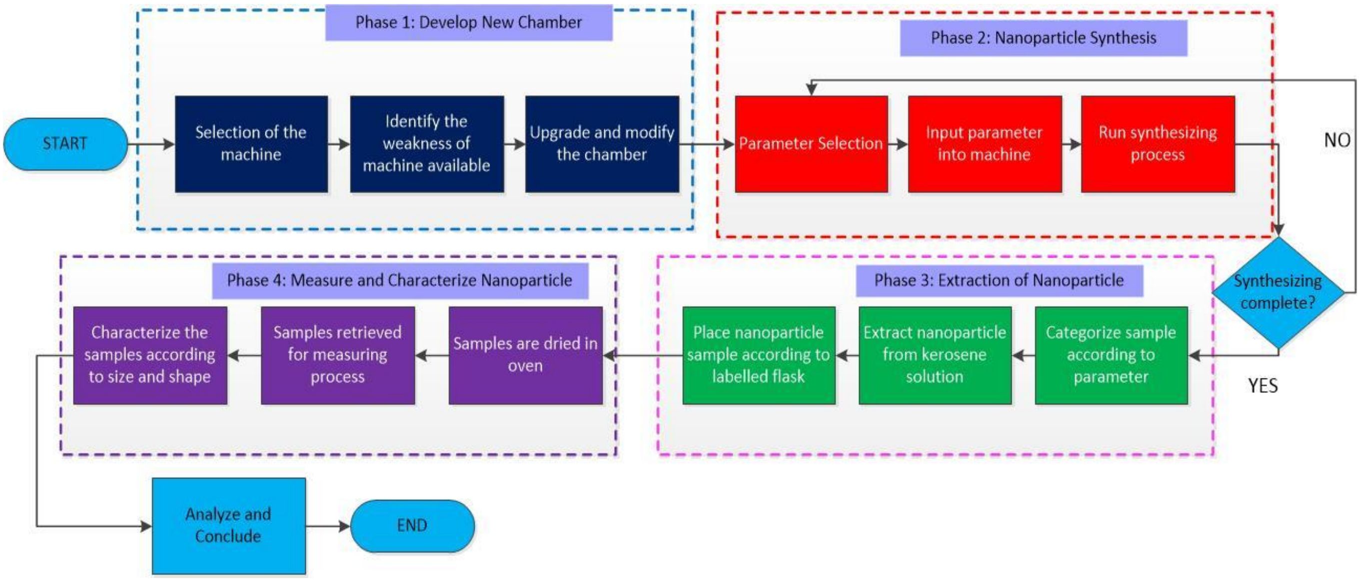

Figure 1: Overall methodology for aluminium nanoparticle

B. Phase 1: Develop New Chamber

Figure 2 is the detailed flowchart of phase 1. Initially, comparison of machine was made. However, the machine selected was the cheapest and less tedious. The machine selected was EDM compared to wire explosion, laser ablation and other suitable machines for nanoparticle synthesis. The weaknesses of current EDM machine for aluminium nanoparticle synthesis are plenty. The weakness is such as the tank to place rod is too big, no close circuit for current flow and the flushing system is not suitable. Hence this phase is crucial in order to upgrade and develop a new chamber that is compatible for this application.

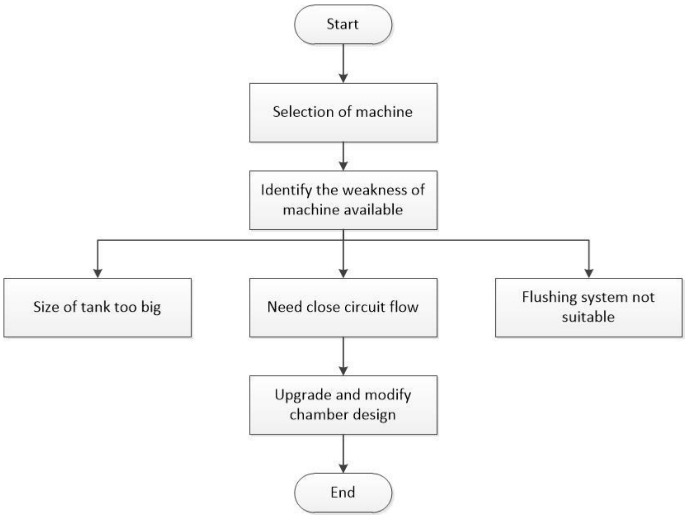

Figure 2: Procedure to develop new chamber for aluminium nanoparticle synthesizing

C. Phase 2: Nanoparticle Synthesis

Figure 3 shows detail flowchart of phase 2 namely nanoparticle synthesis. In this section, few parameters were taken into consideration. The parameters are pulse duration, voltage and current. These parameters are some manipulated and remained constant. The manipulated variable in this case is current.

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DOI: 10.35940/ijrte.B2366.078219
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However, the voltage and pulse duration are remained constant. After select few parameters, these parameters are input into EDM machine for synthesizing process. If the material is not synthesized enough, another parameter will be selected to obtain more granule nanoparticle.

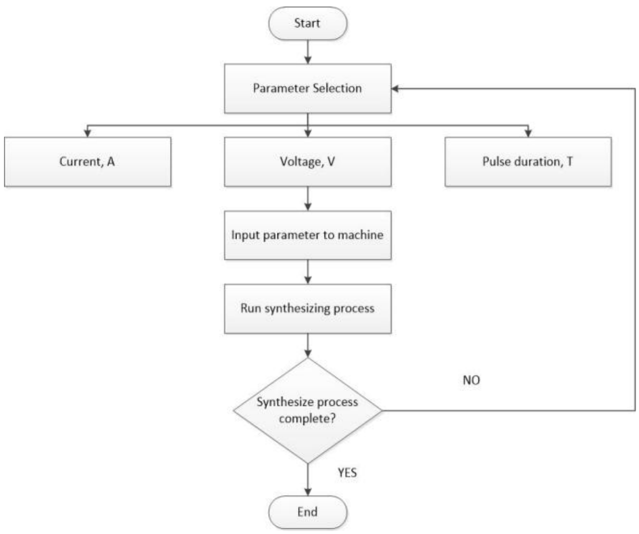

Figure 3: Procedure to synthesize aluminium nanoparticle

D. Experimental set up

Figure 4 shows aluminium electrodes diameter of 5mm were used and immersed in kerosene solution also known as dielectric fluid. Initially, the tool is moved approaching the work piece with the guide of vertical slide till the gap reaches suitable distance to generate spark at the supplied frequency across the plasma channel. The spark is generated in the dielectric fluid. The solution was mixed and stirred during the process commence by using both stirring bar and magnetic stirrer. Debris formed and removed from both electrodes end. Through melting and evaporation by the initiation of repetitive spark discharges. The debris of aluminium is suspended in the mixed solvent and the obtained colloidal suspension was collected and stored in glass vials.

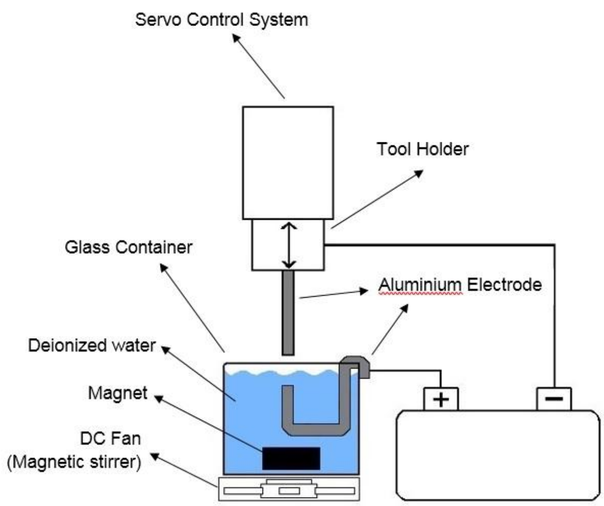

Figure 4: Schematic diagram of EDM setup for Aluminium (Al_2O_3) nanoparticles synthesis

E. Phase 3: Extraction of Nanoparticles

Extraction of nanoparticle is important in this research. As discussed in introduction, in is a necessity to have a solution so that the nanoparticle can be kept still. During the sparking process in EDM machine, heat is dissipated. Hence, the nanoparticle is hot initially, and the purpose of this solution is to quench the temperature so that the nanoparticle can be retrieved and separate for other activities [11]. In this phase, samples need to be categorized according to parameter combinations. The samples are labelled according to parameters to differentiate the aluminium nanoparticle. The combination parameters are 1A 50V, 3A 50V and 5A 50V were tested. These samples were selected by previous research conducted whereby the parameter used became a benchmark of this experiment [12]. Once all the nanoparticle obtained, the nanoparticle spin in centrifuge motion with high rotational speed. The purpose of this experiment is to isolate nanoparticle and kerosene solution. The nanoparticle was extracted from the solution and placed in labelled glass vials. Figure 5 shows the flow chart in order to achieve the extraction of Al_2O_3 nanoparticles.

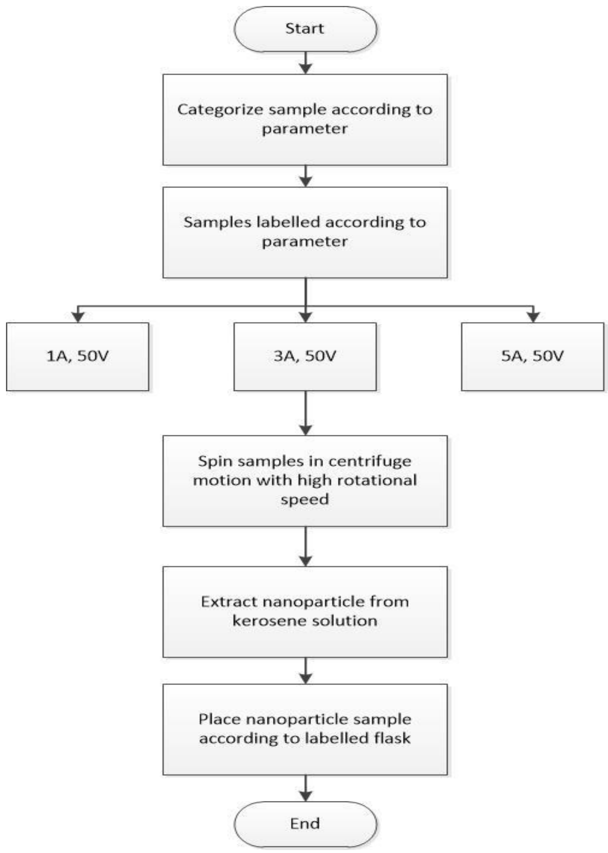

Figure 5: Procedure to extract aluminium nanoparticle from kerosene solution

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F. Phase 4: Measuring and Characterizing Nanoparticles

Final phase in this section is important. The purpose of this phase is to measure and characterize aluminium nanoparticle. Initially the samples of nanoparticle are placed in an oven. The aluminium nanoparticles still have remains of kerosene solution. Hence the oven dries out the kerosene solution from the nanoparticle to obtain the highest aluminium composition. The samples are measure according size in nm and material composition [13]. To obtain these data, Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray Spectroscopy (EDAX) used to characterize the shape, size and material composition. The highest reading accuracy were recorded and compared. The discussion written should be in term of size, shape, and composition of aluminium, carbon and oxide. Final step after measure and characterize is to select best parameter. The combination of parameters selected should produce the aluminium nanoparticle in the smallest size. Figure 6 shows flowchart of steps measuring and characterizing nanoparticle.

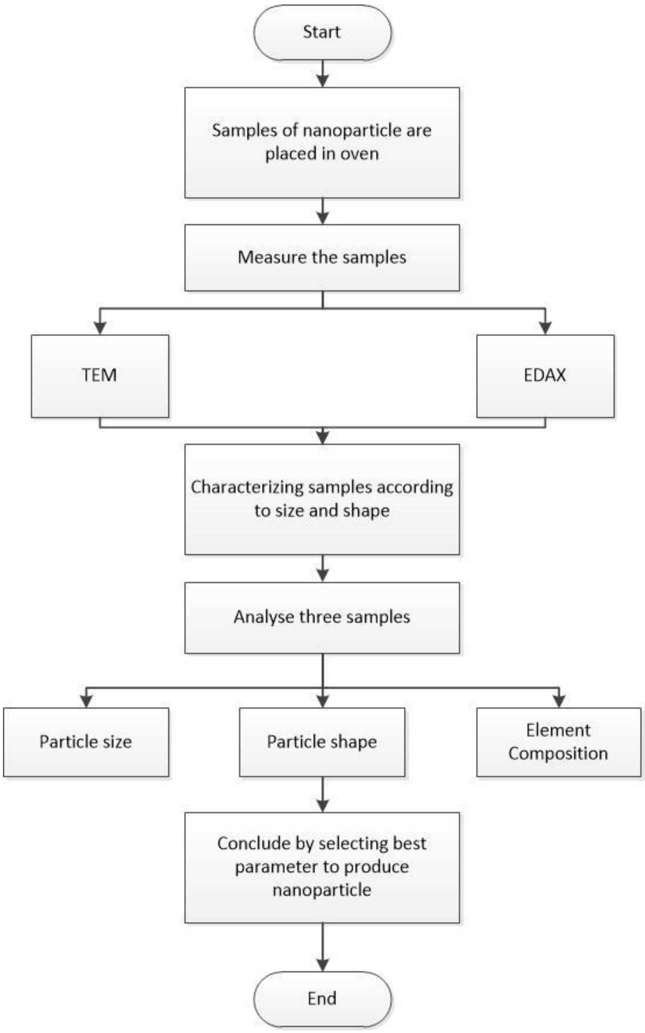

Figure 6: Procedure to measure and characterize aluminium nanoparticle

III. PRELIMINARY RESULTS

Initially result obtained as shown in Figure 7. However, the composition of aluminium nanoparticle in figure below is not yet optimized. Target weight of aluminium must be more than carbon and oxide composition. Figure below shown aluminium have the weight of 39.20% superior compare to other element's weight. The illustration from SEM shows aluminium nanoparticle in coarse shaped. The white spot on the particle is the remains of kerosene solution after dried using oven.

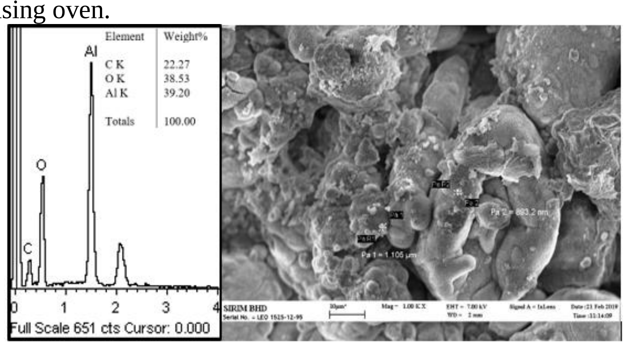

Figure 7: Illustration of Al_2O_3 under SEM and EDAX for observation and composition.

IV. ENHANCEMENT FOR FUTURE RESULT

A suitable combination of parameter needed to obtain higher than 39.20% aluminium simultaneously the percentage of carbon and oxide need to be reduced. The target of this research is to obtain higher weightage of aluminium oxide without any kerosene solution remains. In order to obtain almost high aluminium composition, a better process to separate kerosene solution and aluminium nanoparticle should be used. Since the result obtained shows nanoparticle of 800nm, the target size should be within 1nm to 100nm.

V. CONCLUSION

To conclude, the aluminium nanoparticle produce must be small and able to conduct equal or more electrical current. The purpose of getting high weight of aluminium compared to oxide and current can be achieved if the drying process is carried out longer. The objective of this paper was achieved by the procedure drafted previously using EDM machine that is less tedious and solution than easily to be obtained plus less harmful to human skin. If all this method carried out precisely, the fabrication of aluminium nanoparticle should use up minimal cost compared to other material that are used in battery electrode. The objective of this whole research is to substitute aluminium nanoparticle so that the world aluminium waste can be reduce and make the world green.

ACKNOWLEDGMENT

The authors would like to acknowledge the Universiti Kuala Lumpur (UniKL) for awarding the Short Term Research Grant Scheme (STRG) grant number STR18004.

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