Preliminary Study of Research and Development of Solid Electrolyte based LTP for Lithium-Ion Batteries

Selly Pratiwi[1], Romie Oktovianus Bura[1], and Evvy Kartini[2]
[1]*Faculty of Defense Technology, Indonesia Defense University, Bogor, Indonesia*
[2]*Center for Science and Technology of Advance Materials, National Nuclear Energy Agency(BATAN) South Tangerang, Indonesia*

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Abstract: Lithium was developed as an energy storage because of various advantages it offers. The development of lithium batteries further increases the density of stored energy, the safety and the endurance in its life cycle. Among the development of a new generation energy storage, the development of all-solid-state batteries is one of the solution to improve batteries with higher safety, energy density and endurance in its life cycle. The development of all-solid-state batteries by converting liquid electrolytes to solid electrolytes has been carried out. Low conductivity of solid electrolytes is a challenge to produce all-solid-state batteries. This paper discusses an overview of the development for solid electrolytes with Lithium Titanium Phosphate (LTP) materials. The discussion includes the correlation between the material, composition, method and conductivity of the solid electrolyte produced. Each material with a different composition has characteristic and expected to increase the conductivity of solid electrolytes and can be used as a method to improve the performance of lithium batteries with solid electrolytes (all- solid-state batteries).

1 INTRODUCTION

Defense Development can never be separated from the development and mastery of Defense Technology. Included in defense technology is technology for defense equipments. Defense equipments are all equipments that are built to support national defense as well as security and public order. Defense equipment is an important factor in the development of national defense whose responsibility is to maintain national defense and sovereignty to national borders on land, sea and air.

Unequal energy availability in Indonesia has frequently been a barrier in military operations, especially for those that are based in border areas. These conditions encourage Indonesia to develop energy storage with higher endurance and energy density, as well as light weight and secure so that it can sustain the energy needs of the equipments used in military operations. The following Figure 1 is roadmap for development of energy storage, especially secondary battery in Indonesia.

The development of secondary/rechargeable battery technology as energy storage in Indonesia itself has been initiated and introduced since 2011; in the current era of 2015-2020 the development of secondary batteries on research and development scale is at a stage where research is carried out more in depth, namely on secondary batteries based on lithium ion and modifications of new electrodes, electrolytes and separators.

Secondary battery that utilizes lithium ions is a promising next generation energy storage because of its high energy density. However, the utilization of lithium ion batteries faces several problems caused by its liquid electrolyte. This happens as liquid electrolytes in lithium ion batteries are vulnerable in terms of safety. In addition, lithium ion batteries themselves is very reactive to water or water vapor, so that the battery assembly is done with minimum use of liquid material or even liquid free.

In anticipation of the possible problems with lithium ion batteries caused by liquid electrolytes, a new form of electrolyte so-called solid electrolyte was developed. Solid electrolytes can be obtained from several types of inorganic materials that possess characteristics of high energy level, high conductivity potential, high levels of security and safety. This paper intends to summarize the potential of glass composite to become Solid Electrolyte on Lithium-ion Battery.

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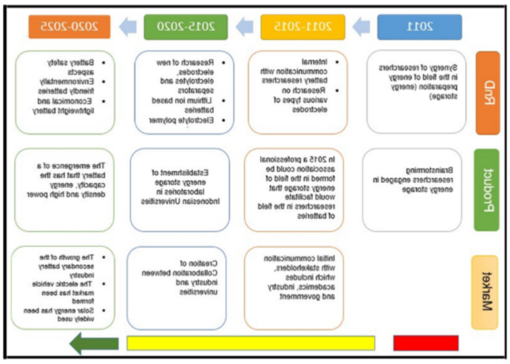

Figure 1: Roadmap of Development for Secondary Battery in Indonesia.

2 LITHIUM ION BATTERY

Development of energy storage technology is not only for devices to be used as energy storage but more to devices that are able to function as energy storage as well as the conversion of the energy it stores, so that the stored energy can be used immediately. The battery is a technology that can be used as an energy storage and converter of electrochemical energy which has many advantages and is being actively developed. In addition, the use of batteries as energy storage and converter can also reduce CO2 gas emissions generated from fossil fuels which may damage the environment. Because of that using batteries as energy storage and converter is deemed appropriate to meet existing energy needs. Related to the statement, batteries in large capacities can be utilized for power grids and electric vehicles.

Lithium ion batteries are included in the secondary battery group, which means these batteries have a reversible chemical process. Reversible electrochemical reaction is a reaction in which the process of converting electrical energy into chemical energy (charging process) and the process of converting chemical energy into electrical energy (discharging process) may be done. The development of lithium ion batteries is carried out due to the many advantages possessed by lithium ion batteries, including its light mass and that lithium material included in the material which is safe to use for electrochemical processes unlike some previous secondary batteries such as Ni-MH and Ni-Cd Lithium is also considered ideal because it has a high oxidation potential. In addition, another advantage possessed by lithium ion batteries is good stability in storing energy so that it has a life time of up to 10 years or more. Researcher from Exxon, M.S. Whittingham. He researched the Electrical properties of Energy Storage and Intercalation Chemistry in 1970. He explained the intercalation process (the process of moving lithium ions from the anode to the cathode and from the cathode to the anode) on the lithium ion battery. In the process of charge and discharge, lithium ion batteries undergo reaction based on the phenomenon of intercalation. The intercalation process on lithium ion batteries can be seen in Figure 2.

Lithium ion batteries are rated as the next generation energy storage technology with its various advantages. The technology can be applied in a variety of devices as energy storage and supply, especially in supporting energy supplies in some defense equipment. Lithium ion batteries are widely used in some defense equipment, especially in defense equipment that requires lengthy operating time such as some military equipments used by special forces, drones, to submarines.

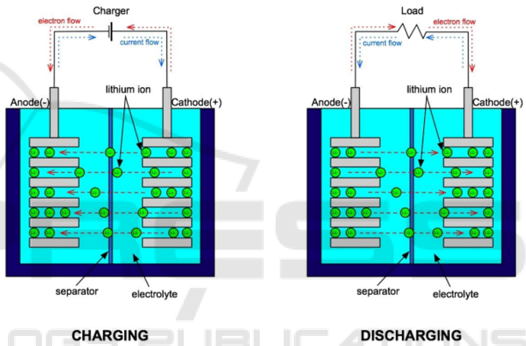

Figure 2: Charge Dan Discharge Lithium Ion Battery.

3 SOLID ELECTROLYTE

A battery is composed of three main components namely anode, cathode and electrolyte. Now in general the lithium ion batteries on the market are composed of carbon graphite as an anode, lithium cobalt as a cathode and electrolyte which is still in the form of liquid or gel. The vulnerability of liquid electrolytes, especially in terms of durability and safety makes the need for development of this battery element. The development of Solid Electrolytes is considered to be a solution to the current lithium battery problem caused by the electrolyte which is still in the form of liquid or gel.

Solid electrolyte itself has the potential to be used in various types of electronic equipment with various advantages, namely it is more resistant to high temperatures, good resistance to impact and vibration and does not cause leakage.

Solid Electrolyte can be obtained from various types of inorganic materials which have high conductivity, safety and security values. One material that is widely investigated as a constituent of Solid Electrolytes is glass material. The use of glass material in the manufacture of Solid Electrolytes has several advantages, among other things is that it is easily formed in a variety of shapes and sizes and has a relatively lower melting temperature. However, behind the advantages of this glass material, the conductivity value of glass material itself is relatively low. Therefore, the glass material used in the manufacture of solid electrolytes still needs to be modified by the addition of other materials to increase the conductivity value.

Glass materials such as Li3PO4 Lithium-Phosphate have a low conductivity value of ~ 10-9S / m. However, the addition of lithium ions to the lithium-phosphate bond can increase the conductivity value. The synthesis results obtained from the addition of lithium ions to the Li3PO4 bond are Li4P2O7 with a higher conductivity value of ~ 3.85x10-5 S / cm. Glass-based Solid Electrolytes continue to experience development and modification to increase the conductivity values of these Solid Electrolytes.

Modifications to solid electrolytes include the development of Lithium Titanium Phosphate (LTP)-based solid electrolytes. Several studies are reported to have modified the Li2O-P2O5 system by adding oxides such as Al2O3, TiO2, GeO2 and SiO2 to increase the ion conductivity of solid electrolyte material.

4 RESULTS AND DISCUSSION

Solid Lithium Titanium Phosphate (LTP) based electrolyte is considered to be one of the solid electrolytes that have good stability potential at room temperature. Lithium Titanium Phosphate (LTP) has chemical characteristics that are stable, non-flammable and the waste produced is classified as environmentally friendly. Therefore Lithium Titanium Phosphate (LTP) material is being considered to be used as the basis for making solid electrolytes as a constituent of lithium ion batteries. Besides that, the characteristic needed by lithium ion batteries is high conductive capability at room temperature, but Lithium Titanium Phosphate (LTP) material has relatively lower conductivity at room temperature due to high barriers in grain boundary. Higher porosity causes lithium ions to travel greater distances between grains so that the ionic conductivity is low. Modifying Lithium Titanium Phosphate (LTP) with trivalent atom doping tends to reduce the porosity of Lithium Titanium Phosphate (LTP) and will certainly increase the value of Lithium Titanium Phosphate (LTP) conductivity and can meet the criteria as solid electrolytes for lithium ion batteries.

Some modifications to Lithium Titanium Phosphate (LTP) with the addition of doping in the form of trivalent atoms have been carried out. Among them are the addition of Aluminum (Al), Vanadium (V), Gallium (Ga) atoms. Besides using trivalent atoms as doping in the modification of Lithium Titanium Phosphate (LTP), there are also doping additions in the form of Liquid Ion ([BMIM] [BF4]), addition of Li3BO3 Glass. The use of lithium salt as doping has also been done, the lithium salt group including LiI. The addition of lithium salt to glass-based solid electrolytes has been carried out and has succeeded in increasing the conductivity value up to 10-4S / cm.

The use of doping is considered helpful in increasing the value of conductivity in the results of solid electrolyte synthesis. In addition to modifying the material by adding doping to the synthesis material, the method used can also affect the conductivity value of the solid electrolytes produced. The Solid State Reaction method is a method that is deemed appropriate to be used to synthesize a solid material with a solid reacted at the melting temperature of each material. Solid state reaction is a method used to synthesize inorganic and organic compounds. Solid stated also has the advantage that the method is simple and does not use many precursors. The use of appropriate methods can increase the conductivity of the synthesis results, especially in the use of the right temperature in the synthesis process.

The production of Lithium Titanium Phosphate (LTP) based electrolytes can be done through various methods and raw materials. Certainly, the modifications made at the research and development stage aims to improve the quality of the solid electrolytes produced. The development of solid electrolytes in the research and development process can be seen in Figure 3.

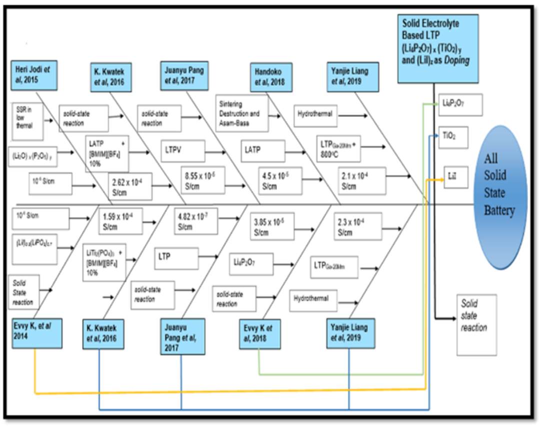

Figure 3: This caption has one line so it is centered.

The diagram above is the result of a Preliminary Study conducted by the author in the development of solid electrolytes by reviewing material modifications, the method used and the conductivity value resulting from each synthesis result. Based on the diagram, the authors assume that for further development Lithium Titanium Phosphate (LTP) materials can be obtained from Li4P2O7 and TiO2 using LiI Doping. Meanwhile, the synthesis method used can use the solid state reaction method.

5 CONCLUSIONS

Lithium-ion Batteries bear several vulnerabilities caused by its liquid electrolytes, especially in terms of safety and life cycle. To anticipate this vulnerability, solid electrolytes were developed as a substitute for liquid electrolytes and t lithium ion batteries into an all-solid state battery. Solid electrolytes can be obtained from several inorganic materials which have the characteristics of high conductivity values at room temperature and stable electrochemical properties and have a high level of security. Based on the preliminary study conducted in this paper, Lithium Titanium Phosphate has good potential by modifying the appropriate synthesis method and the addition of doping. To be used as a basis for solid electrolytes in lithium ion batteries.

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