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Neutrosophic Battery: An Introduction to High-Performance Battery Configuration

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ABSTRACT Nowadays, great effort has been focused on various kinds of batteries commonly referred to as electric energy storage systems (EESS), such as lithium-related batteries, sodium-related batteries, zinc-related batteries, aluminum-related batteries and so on. Some cathodes can be used for these batteries, such as sulfur, oxygen, layered compounds. In the present article, let us consider the basic battery configuration, i.e. they are mostly composed of cathode and anode metals. Such a classic system can be considered as "two elements" model. Based on Neutrosophic Logic as developed by one of us (FS), we consider in this paper that actually we can extend it further to become a Neutrosophic battery system, consists of three-elements (or may be more), i.e. cathode-anode-catalyst system. The catalytic electrolyte method is found to be significant to achieve high-performance battery.

KEYWORDS Neutrosophic Battery, Electric Energy Storage Systems (EESS)

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INTRODUCTION

As it is known, the majority of energy usage in the world is predominated by fossil fuels. But it has resulted in many environmental problems, including ozone layers problem. Renewable energy sources have been promoted as an alternative to such fossil fuel sources. Among many kinds of renewable energy sources, solar energy has become the most favorite in many countries, along with water and wind. They are called WWS (wind, water, solar) energy. [4] Although it is still quite debatable, there is growing acceptance of potential contribution of renewable energy sources. Even there *are known projections* that renewable energy sources can be sufficient to meet future energy demands. See for instance Mark Jacobson's book from Stanford University [5]. Among those plentitude alternatives of renewable energy types, it is known that "Sun, wind and tides have huge potential in providing us electricity in an environmental-friendly way." However, as Jianmin Ma et al., wrote: Its intermittency and non-dispatchability are major reasons preventing full-scale adoption of renewable energy generation. Energy storage systems will enable this adoption by enabling a constant and high-quality electricity supply from these systems, see [7]. But which storage technology should be considered? That is one of significant questions to be asked now-a-days. Nowadays, great effort has been focused on various kinds of batteries to store energy, lithium-related batteries, sodium- related batteries, zinc-related batteries, aluminum-related batteries and so on. Some cathodes can be used for these batteries, such as sulfur, oxygen, layered compounds. Now, let us consider the basic battery configuration, as composed of cathode and anode metals. Such a classic system can be considered as ″two elements″ model. Based on Neutrosophic Logic as developed by one of us (FS), we consider in this paper that actually we can extend it further to become a Neutrosophic battery system, consists of three-elements (or may be more), i.e. cathode-anode-catalyst system. The catalytic electrolyte method is found to be significant to achieve high-performance battery. Moreover, recently there is also research on ″*interface engineering*.″ Therefore, the classic model of cathode- anode can still be improved further. This article is an introduction to this fast growing field in (physics-) chemistry engineering.

PROSPECT OF BATTERIES FOR ENERGY STORAGE

Let us cite from Nadeem *et al*.'s paper at IEEE Access: ″It is an exciting time for power systems as there are many ground-breaking changes happening simultaneously. There is a global consensus in increasing the share of re-newable energy-based generation in the overall mix, transitioning to a more environmental-friendly transportation with electric vehicles as well as liberalizing the electricity markets, much to the distaste of traditional utility companies.″

The generation affects distribution networks, renewables introduce intermittency, and liberalized markets need more competitive operation with the existing assets. All of these challenges require using some sort of storage device to develop viable power system operation solutions. There are different types of storage systems with different costs, operation characteristics, and potential applications. Understanding these is vital for the future design of power systems whether it be for short-term transient operation or long-term generation planning.″[6] For instance, if we consider batteries for Large Scale EESS, then one obvious consideration is how to find quite abundance source in nature as well as cheap material. The effective use of electricity from renewable sources requires large-scale stationary electrical energy storage systems (EESS) with rechargeable high-energy-density, cheap batteries. While batteries using lithium, cadmium, lead-acid etc. have been widely used, notably there is an alternative source e.g. salt-water which is quite abundant in nature and known as electrolytes. In a recent paper, we reported a series of preliminary experiments on potential use of salt-water as cheap source of renewable battery with various kind of metals as anode and cathode.[4] Interestingly, a report by PreScouter (2018) also mentioned salt-water battery as one of potentially disruptive battery technologies.[2] They also wrote some key insights, such as follows: ″Numerous chemistries are being developed to directly counter some of the disadvantages of Li-ion batteries, namely the high cost and sourcing for the raw materials, as well as degradation of the caused by dendrite formation in the solid-electrolyte interphase. Most of these technologies are still in either the prototype or research phase, and may not appear on the commercial market until at least 5-10 years from now (with notable exceptions, e.g. silicon-based chemistries). Most of these technologies are aiming to reduce the cost of energy storage and point to new opportunities in the energy sector.″[2] Nonetheless, such a choice of salt-water battery (in German: ″*salzwasser batterie*″), is not without hurdles. One of such a hurdle is low voltage produced in salt-water (EES) system. That is why nowadays we begin to consider several potential catalytic materials. Such a hurdle actually also leads us to the following new scheme of "Neutrosophic battery system," as we are going to discuss in subsequent section.

INTRODUCING NEUTROSOPHICBATTERY SYSTEM

As we wrote in Introduction section, let us consider basic battery configuration, as composed of ″cathode″ and ″anode″ metals. Such a classic system can be considered as ″two elements″ model. Based on Neutrosophic Logic as developed by one of us, FS [3], we consider in this paper that actually we can extend it further to become a Neutrosophic battery system, consists of three-elements (or may be more), i.e. cathode-anode-catalyst system. Definition of catalyst (/kad()lst/): ″a substance that increases the rate of a chemical reaction without itself un-dergoing any permanent chemical change.″

According to Merriam-Webster dic- tionary: ”a substance that enables a chemical reaction to proceed at a usually faster rate or under different conditions (as at a lower temperature) than otherwise possible.” (cf. https://www.merriam-webster.com/dictionary/catalyst). The catalytic electrolyte method is found to be significant to achieve high-performance battery configurations. Moreover, recently there is also research on “interface engineering.” Therefore, the classic model of cathode-anode system can still be improved further. Although the use of catalyst was more known in fuel-cell research, see for instance [8], but recently it begins to be explored for applications in battery research, see for instance [9]. We admit that the proposed term ”Neutrosophic battery” is still schematic as for now, but let us see the following diagram of configurations used in high-performance battery experiments, as follows (Figure 1).

Alternatively, one may consider the fourth element as extension of catalytic method to improve performance, i.e. interface. It is sometimes called as interface engineering; an example is as shown in the following diagram (Figure 2).

It is our hope that the above diagrams make clear what is the implication of the proposed new term ”Neutrosophic battery” in actual experiments. It can be expected that high-performance battery research in the future shall include these additional elements.

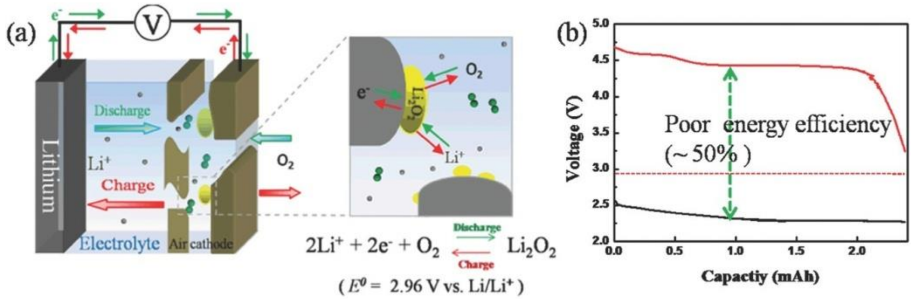

Figure 1: Sample configuration of electrocatalyst, from Chang’s paper

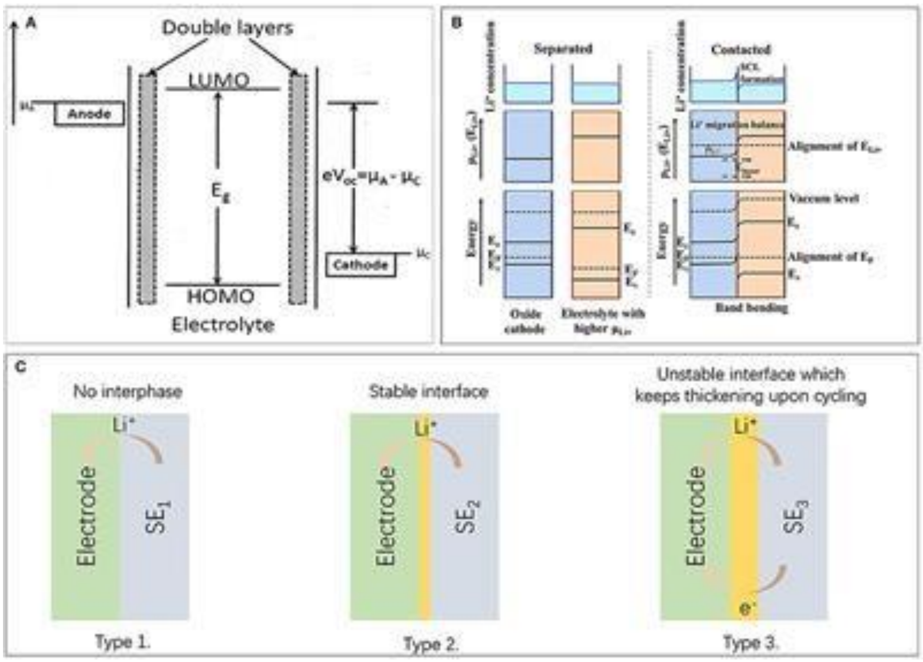

Figure 2: An example of interface in battery experiment.

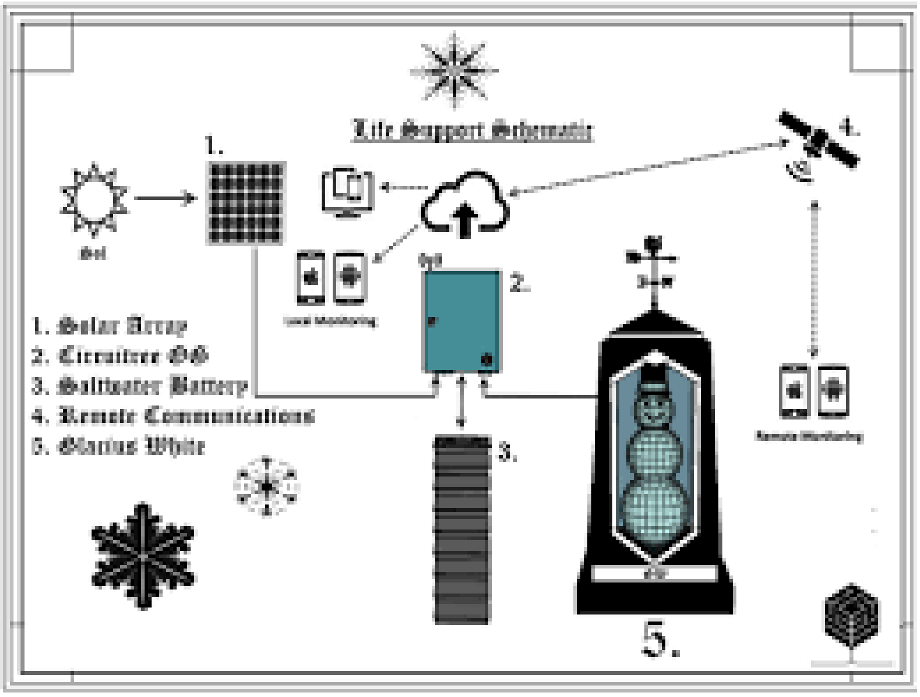

Figure 3: Example of Aquion Salt-Water battery for remote support.

COMMENTS ON INDUSTRIAL APPLICATIONS

As far as we can find in recent literatures, there are a number of companies which already put salt-water batteries into practical applications, including Aquion, SoNick, and also GreenRock. Nonetheless, there is news that it appears that Aquion battery went bankrupt then it restarts again recently. What is interesting here is that SWB (salt- water battery can also be used for powering off-grid house). See the following diagrams.

CONCLUDING REMARKS

There is growing acceptance of renewable energy contribution to meet world energy demands. However, intermittency problem of WWS requires solution to stabilize that intermittency i.e. battery as energy storage (EESS). Considering basic battery configuration, as composed of ″cathode″ and ″anode″ metals. Such a classic system can be considered as ″two elements″ model. Based on Neutrosophic Logic as developed by one of us (FS), we consider in this paper that actually we can extend it further to become a Neutrosophic battery system, consists of three-elements (or may be more), i.e. cathode-anode-catalyst system. The catalytic electrolyte method is found to be significant to achieve high-performance battery. Moreover, recently there is also research on "interface engineering." Therefore, the classic model of cathode-anode system can still be improved further. We admit that the proposed term ″Neutrosophic battery″ is still schematic as for now, but we cited several other configurations used in high-performance battery experiments. It is our hope that the above diagrams make clear what is the implication of the proposed new term ″Neutrosophic battery″ in actual experiments. To conclude, it can be expected that high-performance battery research in the future shall include these additional elements. We hope that this introductory article can be found useful for young physicists/chemistry scientists.

Figure 4: Salt-water battery can power off-grid house.

Figure 5: A Swedish school implements salt-water battery. Source: *PV Magazine*.

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