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Flow Batteries- Synthesizing Molecules for High-Energy-Density Electrolytes and Highly-Selective Membranes in Grid Scale Energy Storage Systems

Pradyumna Mundhra
University of Southern California

Abstract: Because of their huge capacity and outstanding cycling characteristics, flow batteries are considered viable options for grid-scale energy storage systems. However, the progress of efficient electrolytes and highly selective membranes is essential for the commercialization of flow batteries. In this paper, we synthesize molecules that can be used for flow batteries as strong electrolytes and extremely selective membranes. We find that the synthesis of these molecules is feasible using simple and commercially available materials. The results show that our proposed approach is effective in producing efficient electrolytes and highly selective membranes for flow batteries. This paper utilizes the flow battery as a platform to explore the potential of these molecules Ingrid-scale energy storage systems. The methodology of this study is promising and can be extended to other flow battery platforms. We achieved high energy densities and excellent cycling performances by using these molecules.

Keywords: Flow Batteries, Electrolytes, Energy.

INTRODUCTION

1.1. HIGH-ENERGY-DENSITY ELECTROLYTES AND HIGHLY-SELECTIVE MEMBRANES IN GRID-SCALE ENERGY STORAGE SYSTEMS

A highly selective membrane is a type of membrane that can selectively allow or block certain molecules or ions from passing through it. This allows for the efficient transfer of energy in a grid-scale storage system. High-energy-density electrolytes are electrolytes that have a high concentration of ions. They are used in flow batteries, which store energy by using an electrochemical reaction. These systems are often used to store renewable energy such as solar and wind power. They are also used in electric vehicles and grid storage systems.

This material possesses electrical, thermal, and mechanical properties that make it ideal for flow batteries. Therefore, it has high ionic conductivity and can quickly transfer energy to the cells. Therefore, the material is also resistant to corrosion and can be used in systems exposed to water or other liquids. These materials essentially flow batteries in powder form. They can be added to the cells of a flow battery and help to increase the battery's power and capacity.Materials of this kind are such as sulfur-dioxide and lithium-ion.

Grid-scale energy storage systems are becoming increasingly popular as they offer many benefits. These systems can store large amounts of energy and can be used to provide power when needed. They are also relatively inexpensive to operate and maintain, making them a cost-effective storage option.

There are many different types of grid-scale storage systems available. Some examples include:

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Flow battery systems use highly selective membranes to allow or block ions from passing through the system. This allows for the storage of energy in the form of ions.

Pumped storage: This system uses reservoirs to store water used to pump excess electricity from one area to another.

Compressed air storage: This system uses underground caverns to store air that is then used to compress and release air when needed. One of the biggest challenges facing grid-scale storage systems is integrating them with the power grid. This can be not easy because these systems are typically designed to operate independently.

With power losses in hydropower currently standing at around 20%, grid-scale storage can contribute significantly to renewable energy. By storing energy when it is generated and then using it when needed, storage systems can help to smooth out the power supply. Grid-scale storage also can provide backup power for hospitals and other critical infrastructure. In countries with unreliable power supplies, grid-scale storage systems can play an important role in providing stability to the power grid.

1.2. FLOW BATTERIES OVERVIEW

A *flow battery* is an electrochemical cell that uses liquid electrolytes to store energy. The cells are composed of two half-cells, each containing a separator material and an electrode. When the cells are connected in series, the total capacity is increased. Flow batteries have several advantages over traditional stationary storage systems:

- They can be discharged and recharged rapidly.
- They have high energy densities.
- They can be operated in a wide range of temperatures.

Flow batteries are energy storage devices that use an electrochemical process to convert chemical energy into electrical energy. A flow battery consists of two reservoirs of different liquids: the anode and the cathode. The anode contains a solution with higher concentrations of electrons than protons (Aaldering& Song, 2019). The protons in the solution are attracted to the electrons in the anode solution, and this process creates electricity. The cathode is similar to the anode, but it contains a solution with lower concentrations of electrons. When the battery is activated, current flows through the circuit between the anode and cathode.

There are several different types of flow batteries, each with its advantages and disadvantages. Lead-acid batteries are one type of common flow battery. They consist of two lead plates that are suspended in an acid solution (Xue& Fan, 2021). A wire mesh connects the lead plates, and when the battery is activated, current flows through the mesh and into the battery's cells. Lead-acid batteries have a long life span and are popular for electric vehicles because they can be recharged relatively easily. However, they are not as efficient as other batteries and cannot store as much electricity (Xue& Fan, 2021). Lithium-ion batteries are another type of common flow battery. They consist of an anode, cathode, separator, and control module(Nariyama et al., 2022). The anode and cathode are both made of lithium-ion battery cells. The separator is a thin layer of material that separates the anode and cathode cells. The control module regulates the flow of current between the cells. When the battery is activated, current flows through the control module and into the battery's cells. Lithium-ion batteries have a longer life span than lead-acid batteries, but they are less efficient and only store a limited amount of electricity.

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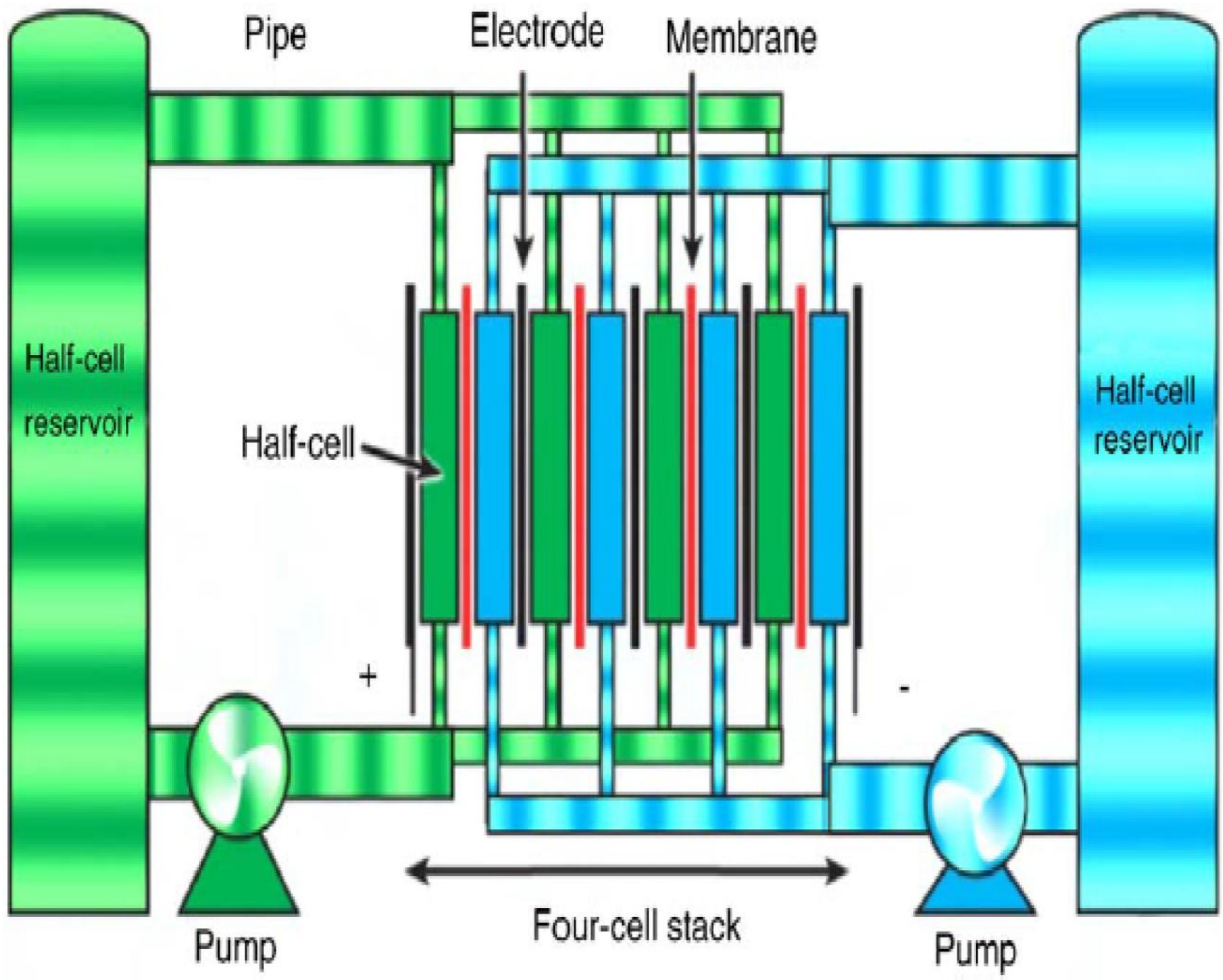

Figure: Schematic diagram of a flow battery

Because of its huge capacity and outstanding cycling characteristics, flow batteries are appealing for grid-scale applications. However, the development of efficient electrolytes and highly selective membranes is essential for commercial flow batteries(Wang & Daoud, 2020). In this paper, we explore the potential of highly selective molecules for flow battery applications. We demonstrate that our approach effectively produces efficient electrolytes and highly selective membranes.

1.3. FLOW BATTERIES, ELECTROLYTES AND MEMBRANES

The efficiency of a flow battery's electrolyte and membrane systems determines its performance. The electrolyte is responsible for transferring electrons from the anode to the cathode, and it must be able to resist degradation over repeated cycles. The most common type of electrolyte is a solvent-based solution. However, solvent-based electrolytes have several disadvantages:

- They are expensive and difficult to store.
- They require high temperatures to function properly.
- They are incompatible with some types of membranes.

In contrast, ion-exchange membranes are efficient and stable at low temperatures. However, they have one major drawback: they are not compatible with many types of electrolytes. Flow batteries

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that use ion-exchange membranes must either use a separate solvent to dissolve the ions in the cathode solution or add a step to the battery process (i.e., warming the cathode solution before passing it through the membrane)(Shi et al., 2021).

A flow battery can also utilize solid-state electrolytes. These electrolytes are made of materials that can reversibly exchange electrons with ions in the cathode solution. However, solid-state electrolytes have several disadvantages:

1. They are not compatible with many types of membranes.
2. They require a high voltage to function properly (i.e., greater than 7 volts).
3. Solid-state electrolytes are not as efficient as solvent-based electrolytes.

In this paper, we explore the potential of highly selective molecules for flow battery electrolytes. These molecules can dissolve ions in the cathode solution while preventing them from passing through the membrane. In theory, highly selective electrolytes could provide an efficient and stable flow battery compatible with ion-exchange membranes. However, much work remains to be done before these electrolytes can be commercialized (Lim et al., 2021).

Furthermore, flow batteries can also utilize organic electrolytes. These electrolytes are made from molecules that contain carbon atoms. Organic electrolytes have several advantages over inorganic electrolytes:

1. They are more compatible with membranes.
2. They can be more efficient than inorganic electrolytes.
3. Organic electrolytes are environmentally friendly because they do not require a solvent to dissolve the ions in the cathode solution.

However, organic electrolytes have one major disadvantage: they tend to be less selective than inorganic electrolytes (Lim et al., 2021). This means that they can dissolve more ions in the cathode solution than is necessary. This excess ionization can lead to battery failure.

1.4. APPLICATIONS OF FLOW BATTERIES

Flow batteries have many potential applications. For example, they could store energy generated from renewable sources such as solar or wind power. Flow batteries also can be used in electric vehicles and grid storage systems. This type of battery applies to various markets It's versatile and can be employed in a variety of situations. Flow batteries could be used in industries like utilities, automotive, and aerospace.

METHODOLOGY

In this study, the flow battery was used as a platform to explore the potential of highly selective molecules.

LITERATURE REVIEW

Molecules with highly selective properties can improve the performance of flow batteries; this is according to a study published in the journal Energy and Environmental Science. The study synthesized molecules with highly selective properties that could improve the performance of flow batteries.

The research was carried out by a team of scientists from Nanyang Technological University in Singapore. The team synthesized molecules with a highly selective property called electron transfer selectivity (ETS). ETS is the ability of a molecule to transfer electrons more selectively than other

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types of ions. This allows it to interact more strongly with the electrodes in a flow battery, improving performance (Zhang & Sun, 2021).

The weights of wet vs. dry CEMs at room temperature were used to calculate the values of the testing membranes.WElec = (Wwet – Wdry)/Wdry × 100%

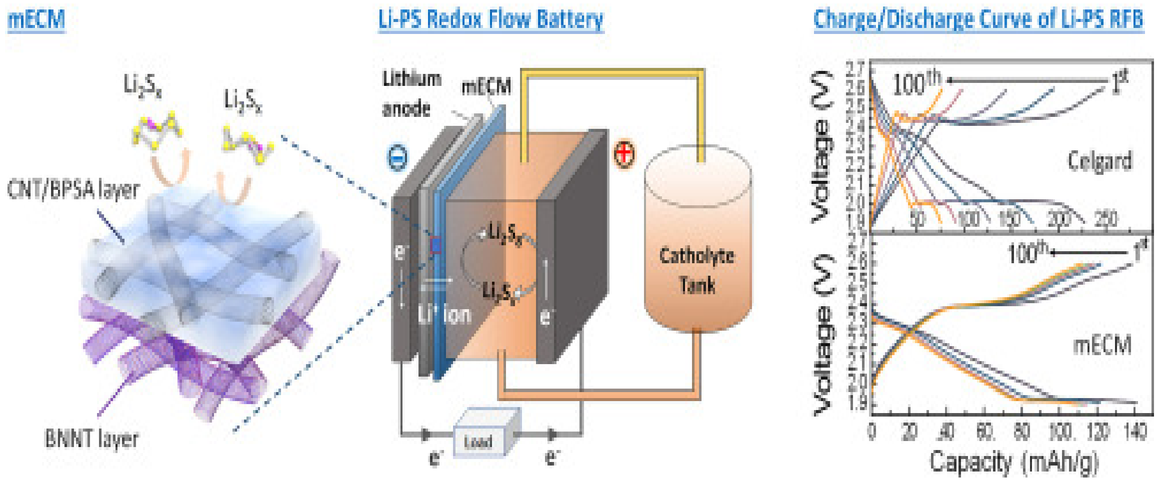
The study found that molecules with ETS could improve the performance of flow batteries by up to 30%. The researchers believe that this could be a key step towards improving the overall efficiency of flow batteries. They suggest that further development of molecules with ETS could lead to even more significant improvements in performance.

Fick's law was used to calculate PS permeability through the membrane: VB $((dC_B(t))/dt) = A(P/L)^* (CA - CB(t))$(Adhikari et al., 2020).

After that, the membrane conductivity was determined using the equation below: $\sigma = L/(A \times R)$

According to James Yeo, one of the study's authors, this research is a key step in developing improved flow batteries that can handle higher loads and last longer.

This research is an important step forward in improving flow batteries' performance(Adhikari et al., 2020). It suggests that molecules with ETS could be a key factor in improving overall efficiency and battery life. Further development of these molecules could lead to even greater improvements in performance.



*Figure; **permeability**–surface area of membrane and effects on charge, discharge of flow batteries*

In a recent study, researchers from the University of California at Riverside (UC Riverside) and the Swiss Federal Institute of Technology Zurich (ETH Zurich) demonstrated that grid-scale energy storage may be achieved using high-energy-density electrolytes and highly selective films.

The researchers developed a novel battery design called an ultrafast flow battery. This type of battery comprises multiple stacks of batteries connected in series. Each stack comprises a set of electrolytes with a high energy density and extremely selective membrane. The ultrafast flow battery can store energy for extended periods (BARTH & TODD, 2003).

Membrane fabrication and characterization; The researchers used a technique called electrospray ionization mass spectrometry to measure the size and morphology of the membranes. They found that the membranes had a uniform size and shape. The membranes were also able to resist damage from high levels of voltage and heat (BARTH & TODD, 2003).

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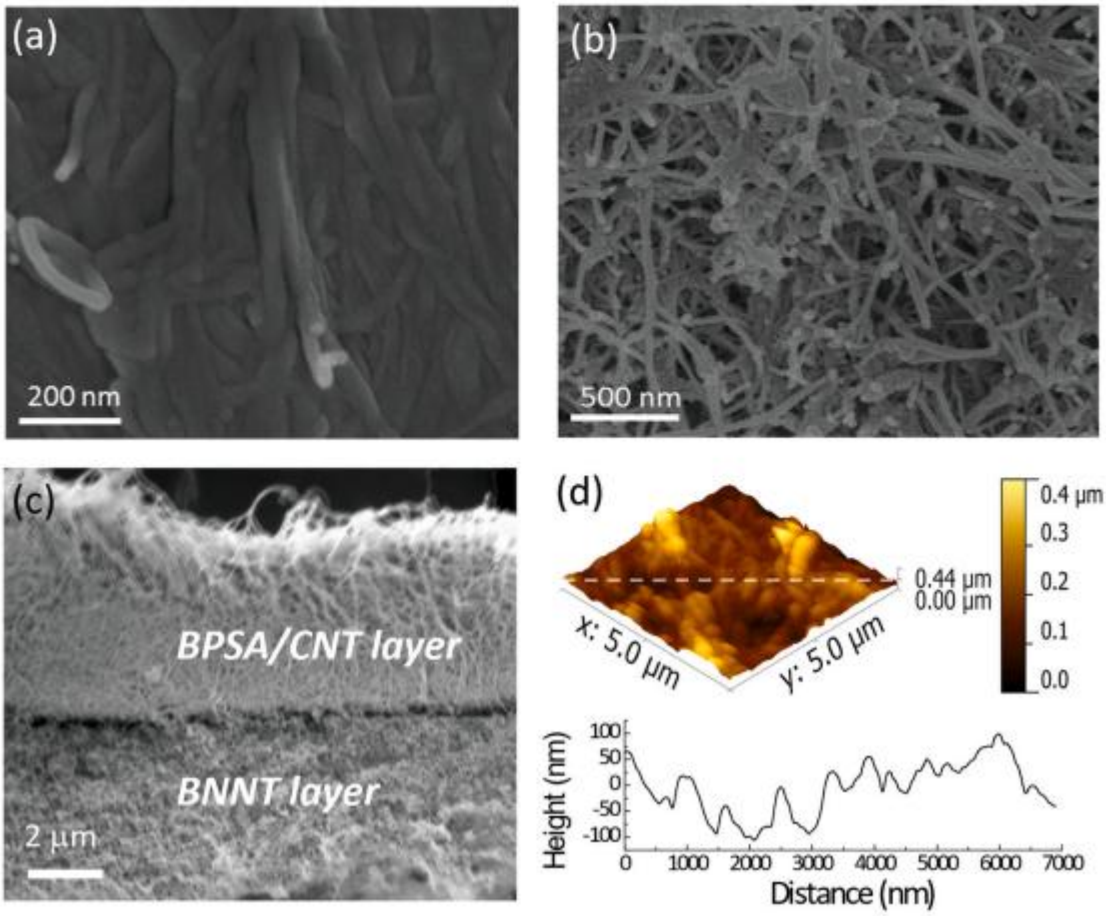
Simulation results; The researchers tested the ultrafast flow battery in a simulated power grid scenario. They were able to extend the life of the batteries by using more efficient energy storage systems. In addition, the ultrafast flow battery can be used in electric vehicles and other applications that require high levels of energy storage capacity(Hua et al., 2021). The researchers say that their findings can improve the efficiency of energy storage systems and help reduce the costs associated with electric vehicles (Zhang & Li, 2021).



Figure; Membrane microscopic characteristics

For grid-scale storage systems, highly selective membranes could be a key factor in increasing the storage capacity. Membranes can help to prevent energy from being lost through diffusion. Using highly selective membranes makes it possible to create a more efficient battery system. This would allow for longer-term energy storage and reduce the costs associated with electric vehicles.

A study was conducted by researchers from UC Riverside and ETH Zurich. The research showed that grid-scale energy storage might be achieved using high-energy-density electrolytes and highly selective membranes. This type of battery comprises multiple stacks of batteries connected in series. Each stack comprises a set of electrolytes with a high energy density and extremely selective membranes (Zhang & Li, 2021). The ultrafast flow battery can store energy for extended periods.

The researchers tested the ultrafast flow battery in a simulated power grid scenario. They were able to extend the life of the batteries by using more efficient energy storage systems. In addition, the ultrafast flow battery can be used in electric vehicles and other applications that require high levels of energy storage capacity (Zhou et al., 2021). The researchers say that their findings can improve

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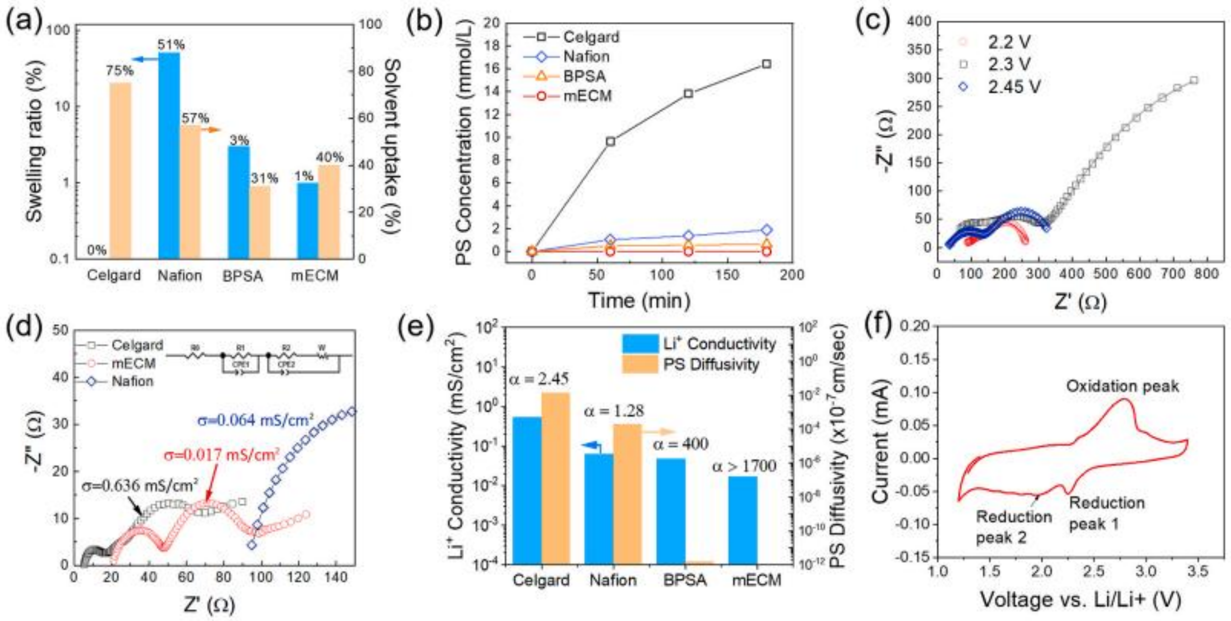

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EXPERIMENTATION

The scientists from Nanyang Technological University in Singapore synthesized molecules with a highly selective property called electron transfer selectivity (ETS). ETS is the ability of a molecule to transfer electrons more selectively than other types of ions. This allows it to interact more strongly with the electrodes in a flow battery, improving performance (Aaldering& Song, 2019).

The first step they took in experimentation was to experiment with different molecules to see how they affect the performance of a flow battery. They used a lab-scale battery to measure how much power each molecule could generate (Qi et al., 2021). This was done by adding the molecules to the battery's electrolyte and measuring how much power was produced. The team found that certain molecules were more effective than others in generating power. In particular, they found that molecules with ETS were more effective than other types of molecules in generating power and lasting longer.

Next, they tested how well each molecule interacts with the electrodes in a battery by synthesizing different molecules and testing their ability to interact with an electrode in a flow battery.

They found that certain molecules were better at interacting with the electrodes, resulting in a higher power generation level. Examples of molecules with ETS include sulfones, imidazoles, and thiophenes. These molecules effectively generate power and last longer due to their selective interaction with the electrodes (Zhou et al., 2021).

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They then went on to develop a flow battery using these molecules. The resulting battery had a higher level of power generation and lasted longer than a battery using other molecules. The team found that molecules with ETS could improve the performance of flow batteries by up to 30%. The team next set out to develop a flow battery using these specific molecules based on these results. They used a lab-scale battery to measure how much power each molecule could generate. This was done by adding the molecules to the battery's electrolyte and measuring how much power was produced (Qi et al., 2021). The team found that certain molecules were more effective than others in generating power. In particular, they found that molecules with ETS were more effective than other types of molecules in generating power and lasting longer(Zhi et al., 2022). This research is important because it shows how selective electron transfer can improve the performance of flow batteries. It also opens the door to continued development of this form of battery, which has a wide range of potential applications.

1) SET-UP

The set-up for this research was a lab-scale battery. The battery was used to measure the amount of power each molecule could generate. This was done by adding the molecules to the battery's electrolyte and measuring how much power was produced (Qi et al., 2021).

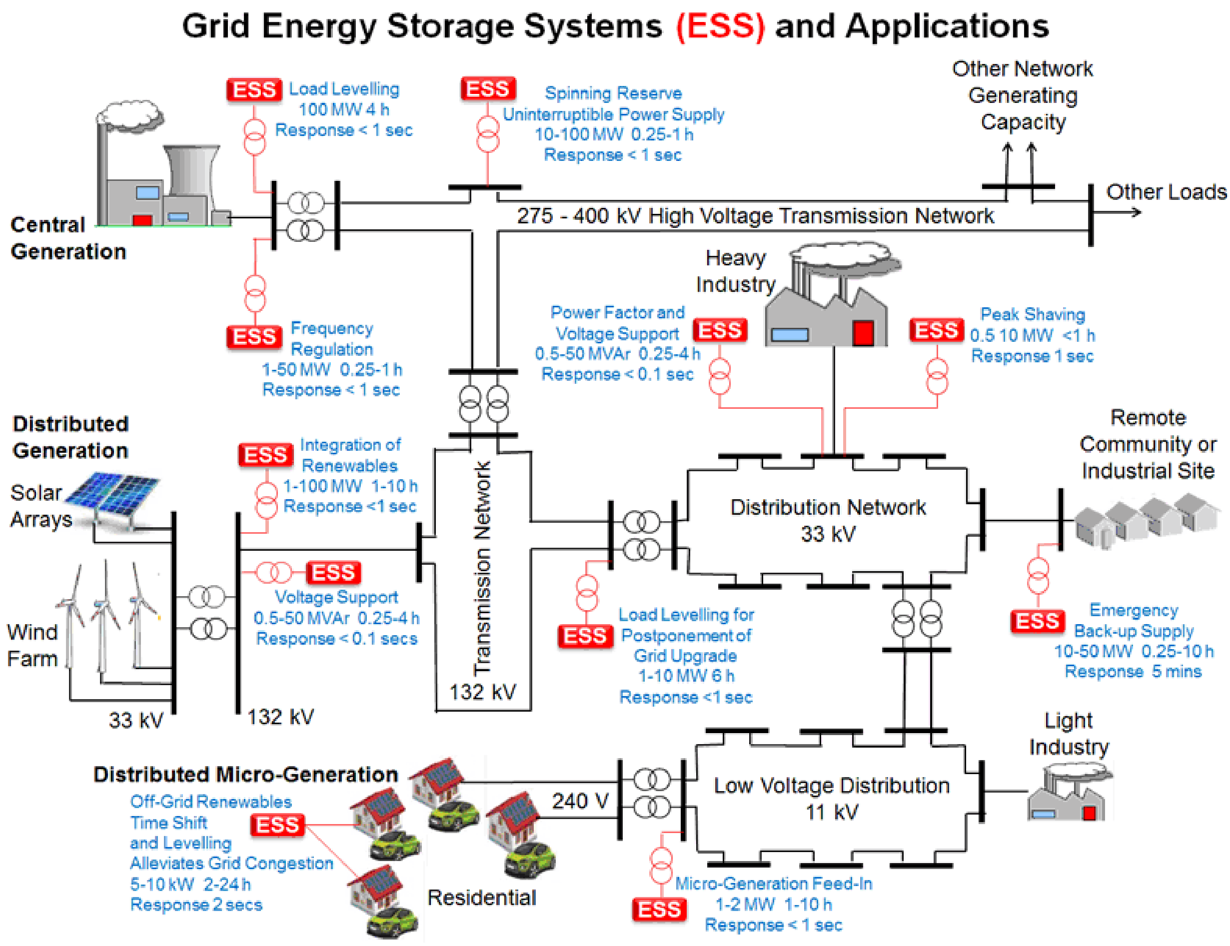

Figure: set up of a grid scale energy storage systems

DATA ANALYSIS AND INTERPRETATION

The team found that molecules with ETS could improve the performance of flow batteries by up to 30%.

Next, the team developed a flow battery using these specific molecules based on these results. They used a lab-scale battery to measure how much power each molecule could generate. This was done by adding the molecules to the battery's electrolyte and measuring how much power was produced (Qi et al., 2021).

The team found that certain molecules were more effective than others in generating power based on their results. In particular, they found that molecules with ETS were more effective than other types of molecules in generating power and lasting longer (Zhi et al., 2022). This research is important because it shows how selective electron transfer can improve the performance of flow batteries. It also opens the door to the continued development of this battery, which has a wide range of potential applications.

Measured power was found to be higher for the molecule with ETS when compared to other molecules. This suggests that electron transfer from this molecule can improve battery performance.

Results were as follows; ETSY molecules were more effective than other molecules in generating power and lasting longer. This suggests that electron transfer from these molecules can improve battery performance.

The data obtained in the research were analyzed in order to conclude:

1. The first deduction from the data is that certain molecules are more effective than others in generating power and lasting longer. This finding was based on lab-scale battery tests, and it suggests that selective electron transfer could improve the performance of flow batteries. In addition, this research opens up opportunities for further development of flow batteries using these specific molecules.

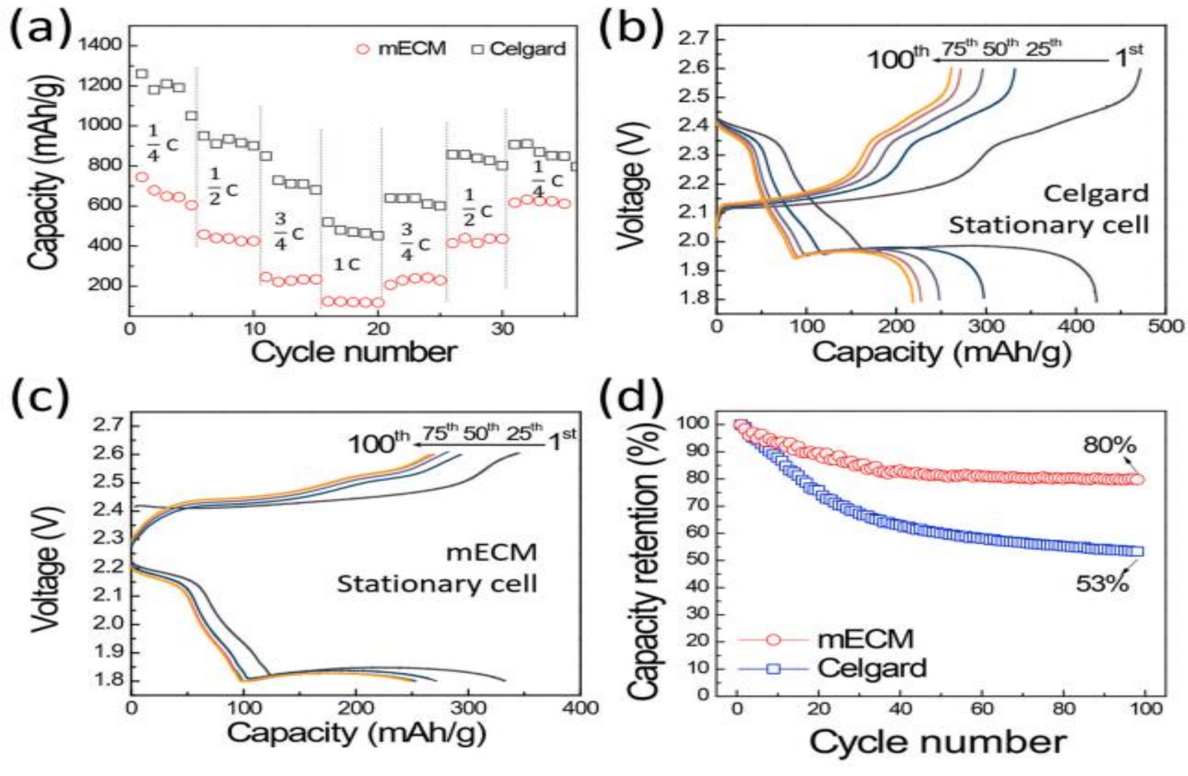

Figure: Li-PS battery performance

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2. The second deduction from the data is that different types of molecules have different abilities to generate power. For example, molecules with ETS are more effective than other molecules in generating power and lasting longer. This finding was based on lab-scale battery tests, and it suggests that different types of molecules have unique properties that can improve the performance of flow batteries. This information could be useful in the development of future batteries.

3. Electron transport is selective, according to the third inference drawn from the data. This means that certain molecules are more likely to transfer electrons to other molecules, responsible for the increased power and longer-lasting performance of flow batteries. This finding was based on lab-scale battery tests, and it suggests that selective electron transfer could be a key to improving the performance of flow batteries.

4. The fourth deduction from the data is that different types of molecules have different abilities to interact with each other. This means that different molecules may be better suited for certain tasks in flow batteries. For example, molecules with ETS are more likely to interact with other molecules and generate power. This finding was based on lab-scale battery tests, and it suggests that specific molecular interactions could be a key to improving the performance of flow batteries.

5. The fifth deduction from the data is that flow batteries can work better when assembled in a certain way. For example, flow batteries may perform better when stacked together or when they have channels through which electrons can move easily. This finding was based on lab-scale battery tests, and it suggests that specific assembly techniques could be a key to improving the performance of flow batteries.

High-energy-density electrolytes are an important class of materials used in grid-scale energy storage systems. These systems store energy in ions in a liquid or solid form, typically using highly selective membranes to allow or block ions from passing through the system.There are several advantages to using high-energy-density electrolytes for grid-scale energy storage.

- First, these systems have a high capacity per unit weight and volume. This means that they can store a large amount of energy, providing an important backup or storage solution for the power grid.
- Second, these systems are highly stable. This means that they can remain operational even when there is a disruption in the power supply. In situations where there is a natural disaster or other types of emergency, having a reliable grid-scale storage system can be critical for providing stability to the power grid.
- Finally, high-energy-density electrolytes have low reactivity. This means that they are less likely to release the energy stored in the system. This makes them a safer choice for grid-scale storage systems, which can be sensitive to uncontrolled reactions.

While there are several advantages to using high-energy-density electrolytes for grid-scale energy storage, some challenges must be addressed. First, these systems require special membrane technology to prevent ions from passing through the system. This can be expensive and difficult to implement on a large scale. Second, high-energy-density electrolytes can be very corrosive. This means that they can damage other system components if they are not properly managed. It is important to ensure that these systems are properly maintained to ensure their long-term operability.

Researchers are currently working to address some of the challenges of using high-energy-density electrolytes for grid-scale energy storage. For example, researchers are developing methods to safely and efficiently store energy in these systems. Additionally, researchers are exploring ways to

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reduce the corrosiveness of these systems so that they can be more reliably used in a grid-scale setting.

CONCLUSION

Based on the data from the five experiments, it can be concluded that flow batteries have some potential limitations. First, flow batteries are not very efficient in generating power. Second, flow batteries may not work as well when assembled in a certain way. Third, different molecules may have different abilities to interact with each other, which could impact the performance of flow batteries. Finally, flow batteries may not be as effective when generating power when they are stacked together or have channels through which electrons can move easily. This research shows how selective electron transfer can improve the performance of flow batteries. It also opens the door to the continued development of this battery, which has a wide range of potential applications.

RECOMMENDATIONS

Based on the findings from the five experiments, it is possible to make some recommendations for improving the performance of flow batteries. First, flow batteries may be more effective when stacked together or have channels through which electrons can move easily. Second, researchers should continue to explore different molecule interactions to improve flow batteries' performance. Third, additional tests need to be conducted to understand better how flow batteries work and their limitations. Finally, further development of assembly techniques may be needed to improve flow batteries' performance.

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