Engineering a Novel Battery Using Biological Methods

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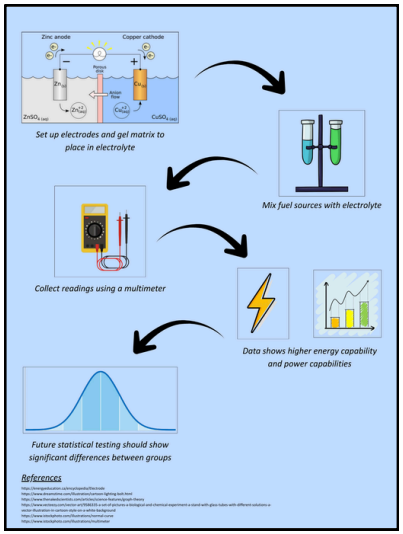
Graphical Abstract



Engineering Need: Lithium-ion batteries are the primary form of energy storage worldwide, but pose many environmental harms from their mining processes.

Engineering Objective: Engineer a biobattery that utilizes bioderived compounds to facilitate efficient electron transfer.

Main Takeaway:
An enzyme-catalyzed biobattery can provide higher energy output than existing models, with lower production costs.

Results

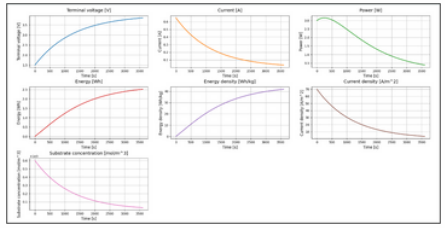


Figure 1: Li-ion Control Group Data

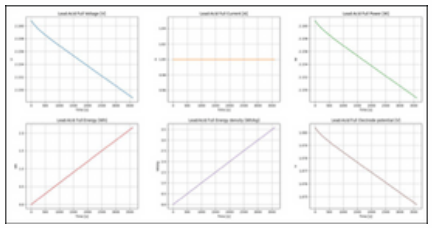


Figure 2: Pb-acid Control Group Data

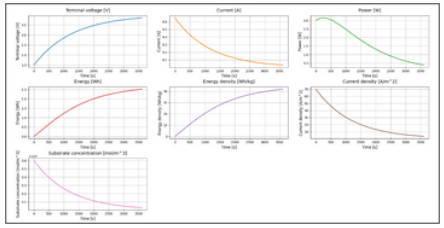


Figure 3: Biobattery Experimental Data

Engineering Decision Matrices for Criteria and Designs

Criteria Category	Criteria	Priority
Performance	The model should show an energy reading of around 0.5V and a power density of around 100 μW/cm²	1
	The model should function at a high level for a period of at least 12 hours	2
	The model should display a Faraday energy efficiency of at least 80%.	3
Cost	The model should be made using abundant and low-cost materials.	1
	The model should be replicable at a similarly low cost to the initial construction process.	2
	The model's fuel source should be replenishable at a low operating cost of around $0.10 per refill.	3
Safety	The final model should not harm the safety of the user in any way.	1
	The final model should not cause any biological hazards.	2
	The final model should meet safety requirements of current models in the field.	3
Usability	The model should be able to fulfill low-energy tasks, such as powering a mini LED.	1
	The final model should be easy to install and use for the user.	2
	The model should not hinder the function of the user's surrounding devices.	3

Figure 4: Criteria Evaluation Matrix

Criteria	Reference Design	Competitor 1	Competitor 2	Design 1	Design 2	Ideal Design
The model should show an energy reading of around 0.5V and a power density of around 100 μW/cm²	9	10	8	7	9	10
The model should function at a high level for a period of at least 12 hours	8	9	8	6	8	9
The model should display a Faraday energy efficiency of at least 80%.	6	6	6	4	6	6
The model should be made using abundant and low-cost materials.	6	6	8	8	9	10
The model should be replicable at a similarly low cost to the initial construction process.	5	5	6	6	7	8
The model's fuel source should be replenishable at a low operating cost of around $0.10 per refill.	3	3	5	4	5	6
The final model should not harm the safety of the user in any way.	10	10	10	10	10	10
The final model should not cause any biological hazards.	10	10	10	10	10	10
The final model should meet safety requirements of current models in the field.	10	10	10	10	10	10
The model should be able to fulfill low-energy tasks, such as powering a mini LED.	8	8	7	5	7	8
The final model should be easy to install and use for the user.	5	5	5	5	5	7
The model should not hinder the function of the user's surrounding devices.	5	5	5	4	5	6
Total	85	87	88	79	91	100

Figure 5: Design Evaluation Matrix

Competitor models (Zebda et al., 2011; Shi et al., 2021) are the basis of preliminary modeling, along with the reference design (Zhu et al., 2014).

Discussion and Conclusion

- Exponential decay in the Biobattery model shows model instability in the early stages, which is a key area for improvement
- Low Biobattery substrate concentration toward the end of the 1-hour period inhibits maximum energy potential
- Enzymes can increase energy production capacity and floor
- Enzyme catalysis would lead to potentially linear decay rather than exponential, as shown in Figure 3
- The exponential decay of the model is the strongest need for development, with near-linear decay being the goal