ALUMINUM (ALLOYED WITH INDIUM AND MAGNESIUM) AS ANODES FOR SEAWATER BATTERIES AND CORROSION PROTECTION

IITM Technology Available for Licensing

Problem Statement

- Electrodes of **Batteries used in marine and underwater environments** with seawater need to be **corrosion resistant** without compromising on power delivery.
- **Conventional** seawater batteries rely on materials like magnesium or zinc, which suffer from **high corrosion rates or limited efficiency**.
- Further, these materials **are prone to rapid self-corrosion** increase weight of the battery while being prone to passivation issues that **reduces operational lifespan** and **increasing costs.**
- There is a need for **an improved anode material** that significantly **lowers corrosion** rates while **boosting voltage** output, and **improving efficiency** for extended underwater use.

Intellectual Property

- IITM IDF Ref 2894
- **IN 202441036555 Patent Application**

TRL (Technology Readiness Level)

TRL 4 Technology Validated in Lab

Technology Category/ Market

Category- Energy, Energy Storage and Renewable Energy

Industry Classification:

Manufacture of batteries and accumulators; Fuel Cells; Battery Energy Storage Systems (BESS)

Applications:

In batteries powering deep-ocean sensors and underwater vehicles; sacrificial anodes to protect marine infrastructure; light weight and extended endurance batteries for deep sea exploration.

Market report:

The global Marine Batteries Market was valued at USD 3.49 Billion in 2024 and is projected to grow to USD 15 Billion by 2035 with a CAGR of 14.17%.

Research Lab

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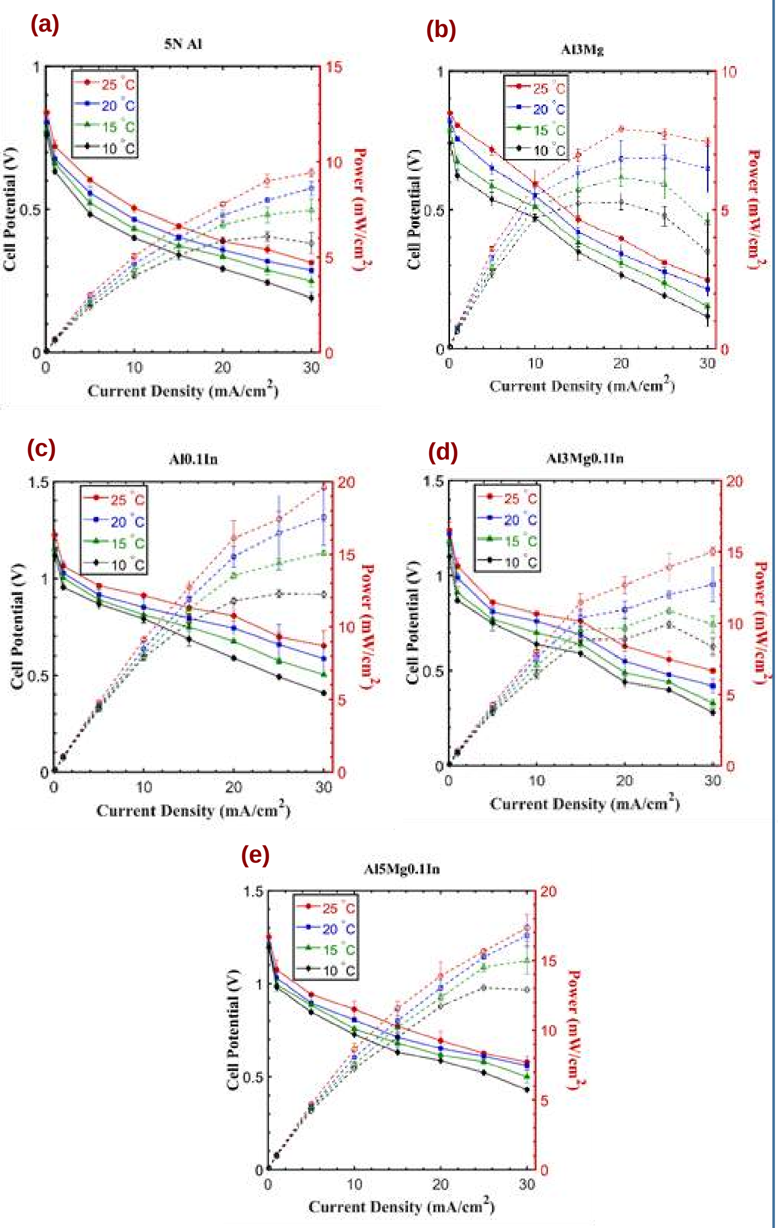

Figure: Cell discharge performance, i.e., I-V and I-P results of (a) 5N Al, (b) Al3Mg, (c) Al0.1In, (d) Al3Mg0.1In, (e) Al5Mg0.1In anode with Pt-C in 3.5 wt% NaCl solution at 10 - 25 °C. The closed markers are the cell potentials, while the open markers are the power values. The results show that the voltage is reduced when the temperature is reduced. When we compare the results of high purity (5N) aluminum anode with Al0.In, i.e**., when indium is added to aluminum, the voltage (at a given temperature) increases. In other words, the performance is better.** Whereas, when Mg is added to aluminum (comparison of Al3Mg with 5N Al), the voltage is reduced, i.e. the performance is poorer.

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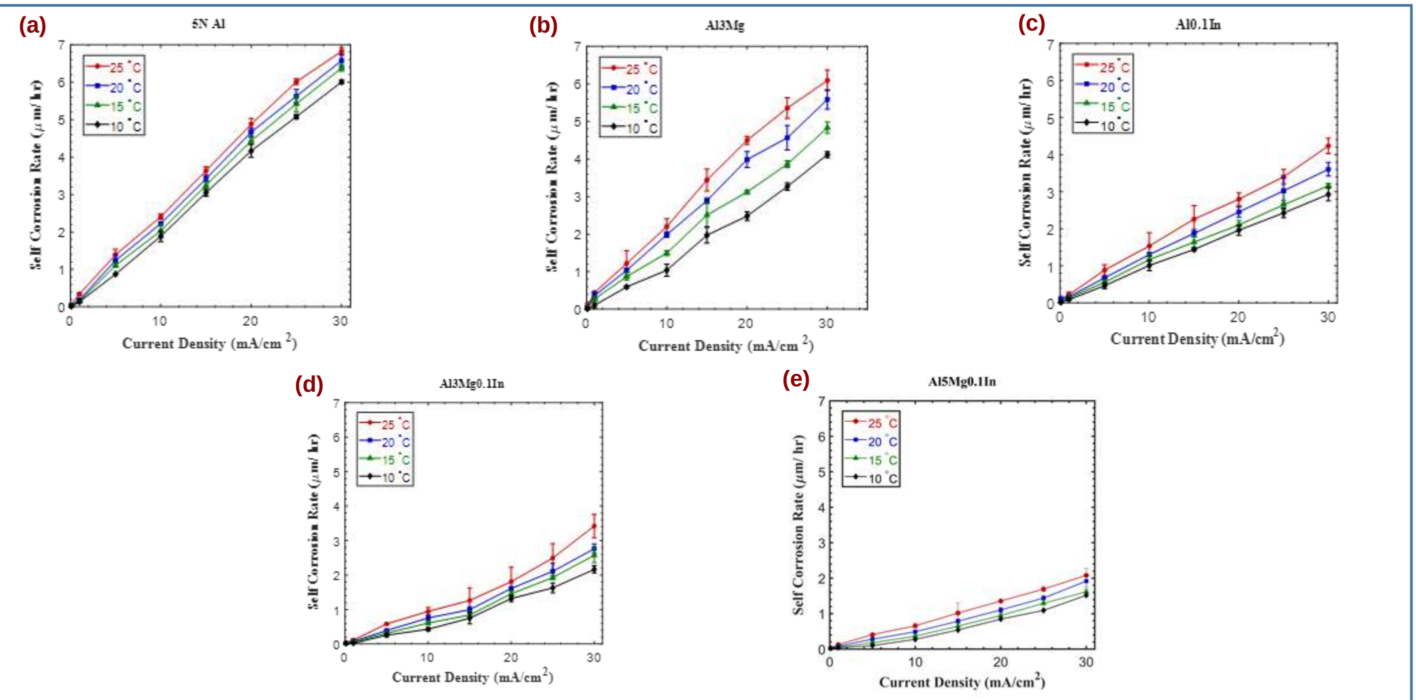

Figure: Self-corrosion rate of (a) 5N Al, (b) Al3Mg, (c) Al0.1In, (d) Al3Mg0.1In, (e) Al5Mg0.1In during battery test in 3.5 wt% NaCl solution at 10-25 °C. The markers represent the experimental results and the lines represent the linear interpolations.

Technology

- The technology uses aluminum doped with indium and magnesium, offering reduced corrosion rates and high voltage output, suitable for seawater batteries and sacrificial anodes in harsh marine and soil environments.
- **The alloy achieves 90% utilization efficiency with low self-corrosion rates (<0.18 μ/h) and excellent discharge potential (1V at 1mA/cm²), ensuring long-term durability in underwater applications.**
- The seawater battery features an open architecture, with a 5 mm cell gap and seawater electrolyte, enabling efficient power generation under extreme oceanic pressure and temperature conditions (10–25°C)
- The anode contains 3–5% magnesium, 0.1% indium, and the remainder aluminum, processed through precision casting and machining to optimize electrochemical performance and longevity.
- Ideal for deep-sea sensors, underwater vehicles, and corrosion protection of marine infrastructure, the invention offers lightweight, cost-effective energy storage and corrosion solutions for challenging environments.

Key Features / Value Proposition

- The invention's aluminum-indium-magnesium alloy significantly reduces self-corrosion rates (e.g., <0.18 μ/h), outperforming traditional anode materials like magnesium and zinc, which exhibit higher corrosion and require frequent replacement in marine environments.
- Incorporating indium boosts the discharge potential to 1V at 1 mA/cm², a notable improvement over magnesium- and zinc-based systems, making it more efficient for energy-intensive underwater applications.
- The synergistic effect of indium and magnesium prevents passivation, ensuring consistent performance and extending battery life in harsh conditions, unlike conventional aluminum alloys that form passive oxide layers, reducing efficiency.
- Aluminum's lower atomic weight and the optimized alloy composition provide higher electron release per unit mass, reducing overall weight and cost compared to magnesium and zinc anodes with similar applications.
- The alloy demonstrates excellent performance across a broad temperature range (10–25°C) and withstands high pressures in deep-sea conditions, where conventional technologies face limitations due to environmental stress.

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