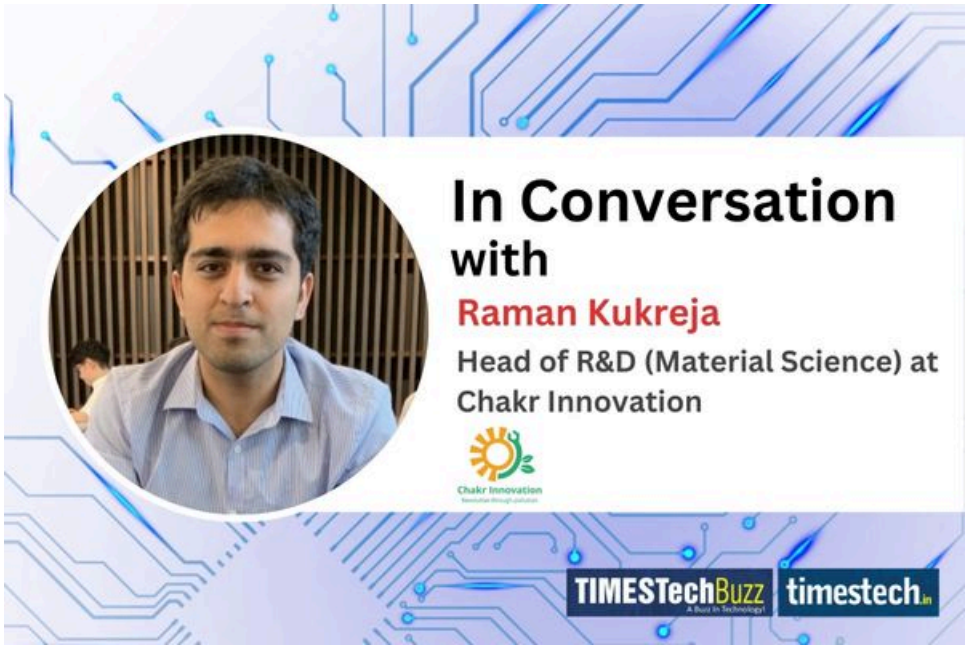
Aluminium-Air Batteries: Transforming Energy Storage with Chakr Innovation

By **Kajal Mehra** - December 6, 2024



In an interview with *TimesTech*, Raman Kukreja, Head of R&D (Material Science) at Chakr Innovation, discusses the revolutionary aluminium-air battery technology. He highlights its unparalleled energy density, safety, and recyclability, paving the way for sustainable energy solutions. Kukreja elaborates on its transformative potential across electric mobility, drones, and energy storage, aligning with India's Atmanirbhar Bharat initiative and net-zero goals.

Read the full interview here:

TimesTech: Could you provide an overview of aluminum-air battery technology and explain its working principle? What makes it a revolutionary advancement in energy storage solutions?

Raman: The chemistry employed in batteries determines their performance and safety (storage and usage). Aluminum-air chemistry is both highly energy dense and safe to

utilize. The chemistry employed in batteries determines their performance and safety (storage and usage). Aluminum-air chemistry is both highly energy dense and safe to utilize this is because Aluminum is one of the most energy dense materials and safe to handle. In Aluminum-air batteries, redox reactions transform the chemical energy held in aluminum to electricity, much like in any other electrochemical cell or battery. While the Aluminum oxidizes in the oxidation reaction, Oxygen which comes from air is reduced in the reduction reaction. Thus, this chemistry inherently enables a safe, energy dense battery for any type of application. Although extensive research has been done on Aluminum-air batteries for a very long time, challenges faced are on two major fronts, energy wastage due to side reactions resulting in low actually available energy per unit weight of Aluminum consumed (energy density) and a sluggish time rate of extraction of energy per unit weight or volume (power density). We have been able to address these challenges with robust R&D by innovation in development of advanced materials (for the anode, electrolyte and cathode) and the processes used in making them. This combined with the best packing method gives us a high performing Aluminum-Air cell/battery. Unlike electrical recharging, Aluminum-air batteries need a mechanical recharge once the aluminum is completely consumed during electrical discharge. During a mechanical recharge, the used Aluminum plates need to be replaced by new plates. Our innovative battery design enables this mechanical recharge in ~~3~~ to 5 minutes, ensuring that the customer experience remains very similar to a conventional refueling at a fuel station of vehicles in a mobility application.

Additionally, the consumed Aluminum can be extracted in-situ from the electrolyte and can be easily converted back to new Alumin~~u~~m plates through Bayers and Hall-Heroult process. These processes are traditionally being used in the Aluminum production industry. Contrary to contemporary battery chemistries, this step of material recovery helps ~~in~~ ensuring a circular economy without any safety concerns linked with the disposal of toxic material in the environment, additionally, no flammable material is used in these batteries. On the contrary, the electrolyte used is aqueous (water) based and this battery can douse a fire.

All this translates to a safer solution with longer range, almost 3 to 4 times of that of contemporary batteries, when it comes to electric mobility applications. In stationary energy storage applications, it gives a longer backup-time, almost 3-4 times of that of contemporary batteries. The thermal management systems required are also simpler and cheaper. Moreover, as these batteries employ mechanical recharging compared to electrical recharging, they would be useful in expanding electric mobility and complement other renewable energy sources in stationary energy storage in remote locations and regions with a very unreliable electricity grid. Hence, these batteries would, in turn, aid quicker adoption of electric mobility without the requirement of establishment of a robust electricity distribution grid and charging infrastructure.

Our Aluminum-air batteries have been independently validated by esteemed institutions worldwide, including the Indian Institute of Technology Bombay (IIT Mumbai), International Centre for Automotive Technology (ICAT), Automotive Research Association of India (ARAI), and IDIADA (Spanish automotive certification agency). The BOPT (Battery Operated Pallet Trucks) has proven to be a promising product, marking a significant difference in its commercial pilots. Users have experienced enhanced operational efficiency Our BOPTs (Battery Operated Pallet Trucks) are designed to boost efficiency and productivity by making material handling faster and easier. Equipped with

safety features like automatic brakes, emergency stop buttons, and low-maintenance hydraulic systems, they prioritize workplace safety. With reduced maintenance needs compared to traditional pallet trucks or forklifts, BOPTs also lower maintenance costs. As an eco-friendly solution, they produce zero emissions, helping reduce your carbon footprint. Cost-effective and easy to operate with minimal training, BOPTs are compact, allowing for smooth maneuvering in narrow aisles. Their sturdy platforms ensure operator comfort for extended working hours, and their versatility makes them ideal for a wide range of material handling applications. Additionally, we are extending the technology to 2-wheelers (bikes, scooters, etc.) and drones, offering valuable use cases that complement and enhance the overall offering.

TimesTech: What are the key performance metrics of aluminum-air batteries, and how do they compare to traditional lithium-ion batteries in terms of efficiency, longevity, and performance?

Raman: The main performance metrics for the battery are energy density (which translates to range), charging time, safety, and sustainability. In these measurements, here's how aluminum air batteries compare to typical lithium-ion batteries three-to-four-fold increase in range compared over lithium-ion batteries. Secondly, reduced charging/ swapping downtime to 3-5 minutes. (Compared to the long charging time of hours). Thirdly, improved safety features due to non-flammable substance. (Can douse fires instead of causing them) Fourthly, Complete recyclability, supporting sustainable practices.

Since every battery has some pros and cons, all battery chemistries have found their own space in the wide spectrum of energy market (not all applications use Lithium ion batteries for e.g. the starter motor batteries in vehicles are still lead acid). As a result in the automotive space, we don't consider Lithium ion to be a comparable substance. Instead of contemplating the advantages of ~~this~~ battery (especially in terms of charging time being like ICE) we see ICE (internal combustion engine) vehicle as competitor and compared to that:

- The expected operational cost is much lower than ICE and like that of Lithium ion batteries.
- Since, in these batteries, the fuel (which is Aluminum and other components are non-flammable, transfer and storage becomes much easier and safer.
- The most abundant metal in Earth's crust is Aluminum thus it has the potential to make India self-reliant in terms of energy storage

TimesTech: In what ways do you foresee aluminum-air batteries transforming the commercial vehicle industry and other targeted applications? What potential challenges might arise during this transition?

Raman: The first targeted application which has a promising future is BOPT. Battery Operated Palletizers (BOPT) are revolutionizing the material handling industry by offering an eco-friendly, cost-effective, and efficient solution. Powered by batteries, BOPTs reduce dependency on traditional fuels, lowering operational costs and minimizing the carbon footprint. These systems enhance productivity by speeding up material movement, reducing downtime, and ensuring safer, more accurate handling. BOPTs are portable,

versatile, and adaptable to various environments, including both indoor and outdoor settings, making them ideal for industries like retail, manufacturing, and food processing. Their autonomous navigation and smart integration with warehouse management systems improve operational efficiency, while also minimizing risks associated with manual handling, such as injuries and human errors. BOPTs are designed for scalability, providing businesses with a long-term return on investment through lower maintenance and energy costs. As industries continue to prioritize automation and sustainability, BOPTs will play a key role in transforming material handling, offering a promising future for logistics and manufacturing operations.

Electric vehicles (EVs) are gaining popularity for their lower operational costs and sustainability. However, lithium-ion EVs face challenges like limited range and long charging times, making intercity travel difficult. Aluminum-air battery EVs, with three times the range and low-cost swapping stations, could address these issues, making them ideal for commercial and intercity use while promoting energy self-sufficiency.

Aluminum-air batteries also show promises for drones, energy storage, and medical devices due to their safety. However, challenges like efficient aluminum extraction and ensuring consistent fuel quality need to be addressed for broader adoption.

TimesTech: How does aluminum-air technology address the cost-efficiency concerns of energy storage systems, and what role does it play in extending the range of electric vehicles?

Raman: Capital cost associated with this technology is expected to be 30% lower than current Lithium-ion powered EVs. Additionally, the operational cost is similar (much lower than ICE) thus making it an obvious choice. Since this technology is energy dense, Aluminum air powered vehicles can have 3x range of current Li-ion EVs.

TimesTech: What makes aluminum a sustainable and cost-effective alternative to rare materials like lithium? Could you elaborate on its abundance, recyclability, and potential for creating a circular economy?

Raman: Other than Aluminum being available abundantly, it can be recycled over and over again without any loss of quality. Aluminum is one of the most recycled materials on earth. Almost 75 per cent of the 1.5 billion tonnes of Aluminum ever produced is still in use today. (Source: https://international-aluminium.org/work-areas/recycling/). Since this and other Aluminum making processes are already available, this will help in making the adoption of Aluminum air easier. And as answered before Aluminum can easily be recycled back through traditionally available methods and the energy required in this process can be taken from renewable resources like solar panels and wind farms. This will both mitigate carbon emission and address the electrification challenge.

TimesTech: How can the adoption of aluminum-air battery technology reduce India's reliance on imported energy storage materials, and what impact could this have on the domestic manufacturing sector?

Raman: Cells used in making the lithium-ion batteries in EVs right now are all imported not only the manufacturing technology but even the raw materials (like Lithium, cobalt etc.) and its processing both is not available in India (majority of All three is owned by

China, raw material ores, processing and Lithium ion cell manufacturing). So the current scenario is such that if we shift majorly towards EV the level of imports will remain same or get higher, reduced oil imports will go towards Lithium-ion imports. India is the 6th and 9th largest country in terms of Aluminum production and reserves in World, respectively (https://en.wikipedia.org/wiki/Bauxite). Also since cell technology is also of India, once the aluminum air battery reaches market it will boost domestic manufacturing sector for all: mining, processing, and manufacturing of Aluminum air battery. Thus overall, this technology aligns with the goal of "Atmanirbhar Bharat"

TimesTech: Aluminum-air technology aligns with India's Make in India initiative and net-zero goals. How do you envision this innovation contributing to the country's green energy transition and its broader sustainability goals?

Raman: As mentioned earlier, the aluminium-air technology stands out as a fully recyclable solution, with its recycling energy needs met through renewable sources. This not only accelerates the global green energy transition but also aligns seamlessly with the United Nations' Sustainable Development Goals (SDGs), particularly **Affordable and Clean Energy (SDG 7)** and **Responsible Consumption and Production (SDG 12)**. Moreover, its potential to revolutionize domestic manufacturing will drive rapid job creation, contributing to **No Poverty (SDG 1)** and **Industry, Innovation, and Infrastructure (SDG 9)**. By fostering equitable economic opportunities and sustainable industrial growth, the technology also addresses **Reduced Inequalities (SDG 10)** and supports the development of **Sustainable Cities and Communities (SDG 11)**. Through collaborations and partnerships, it plays a pivotal role in advancing **Partnerships for the Goals (SDG 17)**. This innovation is not just a breakthrough in clean energy but a transformative leap toward a more inclusive, sustainable, and resilient future.

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