Nick Clark · Published April 25, 2026 · PDF

Electric Mobility and Transport: How a Hydrogen-Aluminum Cell Architecture Maps to Vehicle Constraints, and Where It Does Not

Electric vehicles and other mobility platforms impose constraints that stationary storage does not: bounded mass and volume, crash and puncture exposure, cold-weather starts, traction voltages in the hundreds of volts, and a service model built around the road rather than a maintenance bay. This article examines, with deliberate caution, how the cell architecture disclosed as the Hydrogen-Aluminum Energy Cell in U.S. Provisional Application No. 64/055,649 would and would not map onto those constraints. It draws on the same disclosed elements (bulk-equipotential charge retention, hydrogen-metal surface bond storage, asymmetric proton paths, and mechanochemical self-healing) that the energy-storage articles describe, but holds them against mobility's harder boundary conditions.

What This Application Specifies

This application describes how the cell architecture disclosed in U.S. Provisional Application No. 64/055,649, the Hydrogen-Aluminum Energy Cell, would serve as the energy-storage element of an electric mobility platform: a passenger vehicle, a delivery van, a bus, a two-wheeler, light rail, or a marine craft. The disclosed cell stores energy as electron-stabilized hydrogen-metal surface bonds on aluminum-based nanoflakes dispersed through a dual-domain proton-conducting carbon gel, and retains charge by bulk-equipotential saturation of that continuous gel rather than by an internal separator. A mobility integration would assemble these cells into a traction pack, wire them through a battery management system, and couple them to a vehicle's inverter, motor, and regenerative-braking path.

The disclosed architecture, not any single material, is what an integrator would be adopting. The underlying pieces (hydrogen chemisorption on aluminum surfaces, proton-conducting sulfonated carbon gels, boron doping of carbon, mechanochemical repair at strained sites) are established materials science. What the provisional discloses is their combination into a sealed cell with specific governance: flake-to-flake electrostatic isolation, hot-proton charging versus cold-proton discharge through structurally distinct paths, and a thermal envelope deliberately engineered as a safety interlock. The mobility framing here is an enabling deployment of that disclosed architecture, not a new technology.

Concretely, an integrator would specify cells against the modes the disclosure already names. Section 9.1 contemplates standard charging at roughly C/10 to 5C and discharge to a maximum sustained current. Section 9.3 contemplates a high-rate discharge mode at sustained currents in the approximate 10C to 100C band for one to sixty seconds, called out for motor starting and regenerative-braking energy capture. Section 9.10 fixes a single-cell voltage ceiling (approximately 2.5 to 3.0 volts) and routes high-voltage applications through series stacking. A traction pack is precisely such a series stack, scaled to vehicle bus voltages.

Why It Matters

Mobility is the most demanding and least forgiving home for any energy-cell category, which is exactly why it is the honest test case. A vehicle pack must survive crashes, vibration, thermal cycling, and a decade-plus service life while carrying its own mass everywhere it goes. The dominant incumbent chemistry, lithium-ion, carries two structural liabilities that the disclosed architecture addresses at the level of mechanism rather than packaging.

The first is calendar and cycle aging. The disclosure's BACKGROUND notes that conventional cells lose roughly one to five percent of capacity per year at rest, independent of use, and degrade further with cycling. The disclosed cell separates these: at rest it generates no new strain and relies on bond-state stability (Chapter 7), and under cycling it is projected to heal strain through carbon migration to stressed flake sites, a use-positive aging behavior in which cycling does not drive monotonic capacity loss until the auxiliary carbon reservoir nears exhaustion. For a vehicle that sits parked most of its life and then cycles hard, the decoupling of rest aging from use aging is the architecturally interesting claim.

The second is abuse response. Lithium-ion thermal runaway produces flammable organic-solvent vapor. The disclosed cell's breach response (Section 9.12) instead drives oxygen-fed oxidation of the stored energy into non-flammable products (water vapor, aluminum oxide particulates, carbon dioxide). This matters most in a crash, where the difference between a non-flammable and a flammable gas product is the difference between a containable thermal event and a vehicle fire. The disclosure is explicit that the released thermal energy is comparable in magnitude to lithium-ion runaway; the distinction is in character, not in quantity, and that distinction is exactly the one mobility safety engineering cares about.

How It Composes With the Domain

A mobility integration composes with several disclosed elements in a way that fits vehicle dynamics well.

Regenerative braking and launch. Section 9.3's high-rate mode is enabled by the gel's high electronic and ionic conductivity (no separator impedance), the bulk-equipotential architecture (charge can be drawn from any region rather than a localized electrode), and surface-bonded storage (no diffusion-limited intercalation). A braking event dumps a large current transient for a few seconds; a launch pulls one. The disclosure names both regenerative-braking capture and motor starting as targets for this exact mode, which aligns the cell's stated transient envelope with the two highest-power events in a drive cycle.

State-of-charge estimation. Section 9.2 describes a smooth, gradually declining discharge voltage profile arising from the distribution of hydrogen-binding energies across structurally non-uniform flakes, and states that this admits open-circuit-voltage state-of-charge estimation with high accuracy. For a vehicle, a monotonic voltage-versus-charge relationship simplifies the range estimator and reduces dependence on coulomb counting, which drifts. The flat plateaus of some incumbent chemistries make this harder; the disclosed profile is, in this respect, friendlier to a range gauge.

Pack architecture and voltage. Because a single cell is bounded near 2.5 to 3.0 volts (Section 9.10), a traction pack would series-stack many cells to reach a vehicle bus voltage of several hundred volts, with per-cell monitoring, inter-cell isolation, mechanical support, and thermal management. This is conventional pack practice, and the disclosure explicitly prefers series stacking over single-cell high-voltage operation, citing standardized cell construction and per-cell state-of-health monitoring (Section 9.8 contemplates non-destructive microwave or dielectric probing of each cell). The architecture therefore slots into a modular, monitorable pack rather than demanding an exotic high-voltage cell.

Thermal and structural integration. The disclosed aluminum equipotential layer (Section 1.2) also serves as thermal mass and a conduction path between cell interior and exterior, and as electromagnetic shielding. In a vehicle these are not incidental: pack thermal management and electromagnetic compatibility with the inverter are first-order design problems, and a cell whose case participates in both reduces separate engineering. Outer enclosure layers contemplated in the disclosure include carbon-fiber composite for impact resistance and a polymer-rubber compliance layer for vibration, both directly relevant to road loads.

What This Enables

If the disclosed mechanisms behave as projected, a mobility integration could pursue several configurations, each an embodiment of the same architecture tuned to a different platform.

A long-service traction pack. The use-positive aging projection (Chapter 7) and the long calendar-life projection (Chapters 7 and 8 contemplate multi-decade end-of-life horizons, to be determined empirically) point toward a pack treated as durable infrastructure rather than a consumable. A fleet operator running predictable duty cycles (transit buses, delivery vans, taxis) is the natural first adopter, because high cumulative cycling is where use-positive aging, if realized, would matter most.

A high-transient-tolerant hybrid buffer. The 10C-100C transient band suits applications dominated by short, intense power events: a regenerative-braking buffer in a heavy vehicle, a launch-assist cell in a performance two-wheeler, or a frequency-following buffer in a marine or rail auxiliary system. Here the cell is sized for power character rather than for total range.

A crash-tolerant cell for safety-critical platforms. The non-flammable breach response (Section 9.12), combined with the reversible thermal-stall interlock (Section 9.9, in which the cell raises its internal resistance and stalls discharge above roughly 60 to 90 degrees Celsius, then recovers on cooling), composes into a thermal and mechanical safety story aimed squarely at the failure modes regulators and crash-test protocols probe. This is the disclosed architecture's most distinctive mobility value: not necessarily more energy, but a categorically different abuse response.

Chemistry and configuration variants. The disclosure enumerates active metals beyond aluminum (magnesium, zinc, iron, titanium, nickel, and others), flake-loading fractions trading cycle life against energy density, fractal flake generation counts trading synthesis cost against accessible surface area, and an optional boron-doped framework projected to extend cycle life. An integrator could pick a point on these axes per platform: a low-loading, high-cycle cell for a fleet, a higher-loading cell for a range-focused passenger vehicle.

Boundary Conditions

This is the cautious case, and the boundaries are real.

Performance is undisclosed. The provisional is an architecture disclosure, not a built and benchmarked product. No validated energy density, cycle life, fast-charge rate, efficiency, or cost figure exists for a mobility cell. Every range in the disclosure (cycle-count estimates, voltage windows, current bands) is explicitly stated as projected or to be determined empirically. Nothing here should be read as a claim that a vehicle pack achieves any particular range or charge time.

The thermal-stall interlock cuts both ways. Section 9.9's stall is a genuine safety feature: above its tunable threshold the cell raises resistance and stops delivering current, reversibly. But on a vehicle, a cell that stalls under sustained heavy load or in a hot pack is a cell that limits power exactly when an under-sized or under-cooled system demands it. The disclosure frames this candidly as a system-design signal that the application needs more cells or better cooling. For mobility, that means the interlock disciplines pack sizing and thermal design; it does not substitute for them, and a pack designed too close to the stall threshold would brown out under demand.

Cold-weather behavior is unproven and mechanism-sensitive. The disclosed charging path depends on hot-proton kinetics, Grotthuss proton transport through hydrated channels, and conductivity that the disclosure quotes at near-ambient conditions. The provisional does not characterize low-temperature operation. Cold-start performance, the bane of many chemistries, is therefore an open question, not a solved one. An honest integrator would treat sub-freezing operation as a development risk requiring its own testing, possibly with pack pre-heating.

Service does not happen at the roadside. Despite BACKGROUND language about field-serviceable gel replacement, the detailed embodiments are explicit (Sections 1.9 and 8.2) that the operational cell is fully hermetic with no drain or fill ports, because the gel's operational state is established through directional flow during use and cannot be drained and refilled in place without producing a functionally new cell. End-of-life recovery is centralized remanufacturing (Chapter 8), not a service-bay swap. For mobility this means the durability story is real but the maintenance story is centralized: packs return to a facility for material recovery, not for a quick gel refresh. That is a fleet-and-logistics model, not a corner-garage one.

Voltage, mass, and pack overhead are unquantified at the system level. The single-cell voltage ceiling forces long series strings; series strings demand cell-to-cell balancing, isolation monitoring, and management overhead whose mass and complexity the provisional does not address. The disclosed energy content is reported only at the active-material and cell levels in the storage-domain analysis; pack-level specific energy, after enclosure, cooling, structure, and management, is unestablished. Whether a competitive vehicle range results is precisely what prototype testing would have to show.

The materials are prior art; the novelty is the combination. Aluminum hydrogen chemisorption, proton-conducting carbon gels, and mechanochemical healing are not new and are not claimed as new. Any mobility advantage would arise from the disclosed architecture and its governance, not from a basic-science breakthrough, and only to the extent the architecture performs as projected once built.

Disclosure Scope

The technology discussed here is the cell architecture disclosed in U.S. Provisional Application No. 64/055,649. All statements about what the cell does (bulk-equipotential charge retention, hydrogen-metal surface bond storage, asymmetric proton paths, mechanochemical self-healing, the thermal-stall interlock, and the oxygen-driven breach response) trace to that disclosure and are described as architectural capabilities of a provisional filing, not as validated, benchmarked, or production behavior. The electric-mobility framing (vehicle duty cycles, traction-pack architecture, crash and cold-weather constraints, fleet service models, and any regulatory or safety-testing context) is external domain context supplied to illustrate an enabling deployment; it is not part of the patent claims and should not be read as a representation that any vehicle, pack, regulatory approval, or performance figure exists. Underlying materials and physical effects are established prior art; the disclosed novelty lies in their combination, configuration, and governance into a new energy-cell category. No energy-density, range, charge-time, cycle-life, efficiency, or cost figure is claimed.

Hydrogen-Aluminum Energy Cell (/h-al-battery)

All 40 steps → (/inventive-steps)

Sealed electrochemical cell storing energy as reversible covalent hydrogen bonds on carbon electrodes.

Provisional application

PRIMARY TECHNICAL DISCLOSURE

- A Hydrogen-Aluminum Surface-Bond Storage Cell with Bulk-Equipotential Charge Retention (/articles/a-hydrogen-aluminum-surface-bond-storage-cell-with-bulk-equipotential-charge-retention)

SECONDARY TECHNICAL

- Charge Retention by Bulk-Equipotential Saturation Without an Internal Separator (/articles/h-al-battery/bulk-equipotential-charge-retention)
- Storing Energy as Electron-Stabilized Metal-Hydrogen Surface Bonds Formed by Proton-Coupled Electron Transfer (/articles/h-al-battery/hydrogen-metal-surface-bond-storage)
- Electron-Mediated Bond Stability: The Kinetically Trapped Idle State Behind Indefinite Calendar Life (/articles/h-al-battery/electron-mediated-bond-stability)
- Hot-Proton Charging Versus Cold-Proton Discharge: The Bias-Gated Asymmetry That Blocks Self-Charge and Self-Discharge (/articles/h-al-battery/hot-cold-proton-asymmetry)
- Asymmetric Dual-Domain Proton Paths: Separate Ingress and Egress Routes in a Hydrogen-Aluminum Storage Gel (/articles/h-al-battery/asymmetric-dual-domain-paths)
- Hydrophobic Gating: Rejecting Neutral and Molecular Hydrogen While Admitting Only Biased Protons (/articles/h-al-battery/hydrophobic-gating)
- The Storage Gel as a Polarized Electrochemical Switch: Coherent Alignment, Equipotential Locking, and Load-Proportional Discharge (/articles/h-al-battery/gel-polarized-switch)
- Flake-Flake Electrostatic Isolation: DLVO Repulsion as a Self-Discharge Barrier in a Separator-Free Hydrogen-Aluminum Cell (/articles/h-al-battery/flake-electrostatic-isolation)
- Dynamic Flake Expansion: Carbon-Intercalation Wedging to Expose Buried Metal Surface Under Bias (/articles/h-al-battery/dynamic-flake-expansion)
- Hydrogen-Locked Expanded State: Surface-Energy Inversion as a Positive-Feedback Capacity Mechanism (/articles/h-al-battery/hydrogen-locked-expanded-state)
- Secondary Carbon-Hydrogen Storage on Transmuted Intercalated Carbon (/articles/h-al-battery/secondary-carbon-hydrogen-storage)
- Mechanochemical Strain Self-Healing and Use-Positive Aging in a Bulk-Equipotential Hydrogen-Aluminum Cell (/articles/h-al-battery/mechanochemical-self-healing)
- Boron Doping of the Carbon Framework as a Multi-Function Precision Multiplier (/articles/h-al-battery/boron-doping-precision-multiplier)
- The Floating Aluminum Equipotential Extension Layer: A Multifunctional Inner Case for the Bulk-Equipotential Cell (/articles/h-al-battery/aluminum-equipotential-extension-layer)

APPLICATIONS · GENERAL

- Grid-Scale and Renewable-Firming Storage with the Hydrogen-Aluminum Energy Cell (/articles/h-al-battery/grid-scale-storage)
- Building-Integrated and Behind-the-Meter Storage: Putting Energy Cells Inside the Structure With the Hydrogen-Aluminum Energy Cell (/articles/h-al-battery/building-integrated-storage)
- Stationary Backup and UPS Reserve Power for Data Centers, Hospitals, and Telecom (/articles/h-al-battery/backup-and-ups)

- Storage for Microgrids, Islands, and Off-Grid Sites: A Stationary Cell Built From Abundant Materials (/articles/h-al-battery/microgrid-and-off-grid)
- **Electric Mobility and Transport: How a Hydrogen-Aluminum Cell Architecture Maps to Vehicle Constraints, and Where It Does Not (/articles/h-al-battery/ev-and-mobility)**
- Marine and Rail Energy Storage: A Bulk-Equipotential Hydrogen-Aluminum Cell for Mass-Tolerant Heavy Transport (/articles/h-al-battery/marine-and-rail)
- Supply-Chain-Resilient Field Power: An Abundant-Material Energy Cell for Defense and Expeditionary Operations (/articles/h-al-battery/defense-and-field-power)

Hydrogen-Aluminum Energy Cell overview → (/h-al-battery)