

Building-Integrated and Behind-the-Meter Storage: Putting Energy Cells Inside the Structure With the Hydrogen-Aluminum Energy Cell

Behind-the-meter and building-integrated storage forces an awkward choice: a flammable battery cabinet bolted to the wall of an occupied space, or a separate code-segregated room that buildings rarely have to spare. This application is built on the Hydrogen-Aluminum Energy Cell, disclosed in U.S. Provisional Application No. 64/055,649, whose separator-free, equipotential, surface-bonded architecture changes what a cell can safely share a wall, floor, or facade with. It composes with the credentialed-surfaces energy-storage property-surface as a separate, external attestation layer rather than a property of the cell itself.

What This Application Specifies

This application describes how the architecture disclosed in U.S. Provisional Application No. 64/055,649, the Hydrogen-Aluminum Energy Cell, would serve building-integrated and behind-the-meter storage: configurations where the building structure itself (a wall cavity, a floor slab, a facade panel, a foundation void, a rooftop curb) hosts the storage cell rather than the cell living in a dedicated, fire-rated cabinet or a segregated equipment room.

The home invention is a sealed electrochemical cell built from established materials science arranged in a way the provisional treats as a new category. As disclosed, the cell holds charge through bulk-equipotential saturation of a continuous electronically and ionically conductive carbon gel, with no internal separator, no internal membrane, and no internal barrier between its two carbon current collectors other than the gel itself. Energy is stored as electron-stabilized hydrogen-metal surface bonds on a population of aluminum-based nanoflakes dispersed through that gel, not as a charged liquid electrolyte sitting between electrodes at different potentials. The provisional further discloses an aluminum equipotential extension layer lining the enclosure, which the disclosure describes as floating at the gel potential and serving simultaneously as an oxygen barrier (through its natural oxide passivation), a Faraday shield, and a thermal conduction path.

The domain contribution here is not new chemistry. It is the recognition that these disclosed architectural properties, taken together, relax the constraints that normally force a battery into its own segregated, flammable enclosure, and therefore let the structure host it. The attestation question (who certifies that a given embedded cell is what it claims to be, in what state, owned by whom) is handled separately and externally, as described under "How It Composes."

Why It Matters

Behind-the-meter storage is the load-shifting, backup, and self-consumption battery that sits on the customer side of the utility meter: in homes, in commercial basements, on the sides of buildings. The market problem is physical, not just economic.

Conventional intercalation chemistries carry a flammable liquid or gel electrolyte and a charged-cathode active material that can release oxygen under thermal abuse, which is why deployment is governed by stringent siting rules, listed enclosures, fire-rated separations, and clearance requirements. Standards such as UL 9540 and UL 9540A for

energy storage systems and thermal-runaway propagation, and the installation provisions in NFPA 855, exist precisely because the cell is treated as a fire source that must be isolated from people.

That isolation requirement is what prevents the structure from hosting the cell. You cannot pour an intercalation cell into a load-bearing wall cavity, because the cavity is not a fire-rated, vented, serviceable enclosure and the wall is full of people on the other side. So the storage ends up in a cabinet that consumes floor area, demands setbacks, and is often the hardest part of any retrofit to approve.

The Hydrogen-Aluminum Energy Cell, as disclosed, attacks the root constraint rather than the cabinet. The provisional discloses a heat-triggered programmable discharge stall: at elevated temperatures the rate of controlled carbon-framework failure exceeds the rate of mechanochemical healing, internal resistance climbs monotonically, and the cell progressively stalls discharge regardless of external load demand, a behavior the disclosure describes as reversible upon cooling and explicitly contrasts with the irreversible thermal-runaway mode of conventional lithium-ion cells. The disclosure further describes an enclosure engineered to exclude molecular oxygen ingress below roughly 10 parts per million, with the active metal being aluminum (an abundant, low-cost, low-mass material) rather than a charged transition-metal oxide. A cell whose disclosed abuse response is to stall and cool rather than to propagate is a fundamentally different thing to put inside a structure.

How It Composes With the Domain

Building-integration is an enabling implementation of several disclosed properties at once, plus one external layer.

The structure can be the enclosure host. Because the disclosed cell carries no internal separator and stores energy in the bulk gel rather than across a stacked electrode pair, the provisional describes it as tolerant of varied cell geometry and

admits an enclosure whose outer construction is conventional engineering material selected per deployment environment, including carbon-fiber composite for structural integrity, a polymer-rubber compliance layer for strain absorption, and a finish layer for cosmetic or regulatory marking. In a building context the host can therefore be a facade spandrel panel, a floor void, a parapet curb, or a prefabricated wall module, with the disclosed multi-layer enclosure providing the hermetic boundary inside the architectural assembly.

Equipotential operation suits embedded, hard-to-reach placement. The disclosed charge-retention principle is saturation, not insulation: with no external load the flake population sits at one potential and there is no internal driving force for self-discharge. The disclosure projects long-term-storage and calendar-stability behavior that, if realized, suits an embedded cell that may be charged seasonally and left at rest, exactly the duty cycle of a backup or self-consumption asset buried in a wall.

Shielding and thermal coupling are already in the architecture. The disclosed aluminum equipotential extension layer functions as a Faraday cage and as a thermal conduction path from interior to exterior. Embedded in a structure, that disclosed layer couples cell heat into the surrounding mass for passive thermal management and shields the cell interior from the electromagnetic environment of an occupied building, both without separate engineering added on top.

High-rate and series-stacking give building-scale ratings. The disclosed high-rate mode (sustained high-C bursts attributed to the absence of separator impedance and to bulk-equipotential draw from any region) supports building loads such as motor starting and grid-frequency response, while the disclosed single-cell voltage ceiling is accommodated by series stacking of standardized cells to reach building or grid system voltages. A facade or floor can host many standardized cells wired into a building-scale array.

Non-invasive state-of-health fits sealed-in placement. Crucially for a cell you cannot easily reach, the provision discloses microwave/radar dielectric state-of-health monitoring at roughly 1 to 30 gigahertz, which it describes as penetrating the aluminum layer at characteristic skin depths and reading gel and degradation status without disassembly or interruption of operation. An embedded cell can be interrogated through the structure.

Attestation is the separate, external layer. The structure-as-host arrangement answers the physical question (where the cell lives) but not the trust question (which cell this is, what state it is in, who owns the stored energy, and whether a meter or a grid program should believe those claims). That trust question is composed in from the credentialed-surfaces energy-storage property-surface, treated here as a distinct attestation layer that binds an identity and a verifiable state record to the embedded asset. It draws on the disclosed monitoring as a measured input but is not itself part of the cell architecture or the present disclosure. The cell provides a readable physical state; the credentialed-surfaces layer is what turns that reading into an attested, transferable claim about a specific structure-embedded asset. Keeping these layers separate is deliberate: the cell's enabling properties are technology disclosed in 64/055,649, while the property-surface attestation is governance and credentialing applied on top.

What This Enables

Concretely, the composition enables embodiments such as:

- **Wall- and floor-integrated residential storage**, where prefabricated structural modules arrive with cells already embedded, eliminating the wall-mounted cabinet and its setbacks while the credentialed-surfaces layer attests each module's identity and state to the home energy controller.

- **Facade and curtain-wall storage** for commercial buildings, where spandrel panels or rainscreen cavities host series-stacked cells, turning otherwise inert envelope area into behind-the-meter capacity that is interrogated through the panel by dielectric monitoring.
- **Foundation and floor-slab thermal-coupled arrays**, exploiting the disclosed aluminum-layer thermal path to sink heat into structural mass during high-rate operation.
- **Long-duration backup embedded in infrastructure**, leveraging the disclosed long-term-storage mode for resilience assets that are charged and held, with the attestation layer providing an auditable ownership and state-of-charge record for grid programs.
- **Standardized embedded modules with service-by-remanufacture**, where the disclosed end-of-life path of centralized cell remanufacturing (rather than in-place field service) lets the structure stay intact while modules are swapped on a predictive schedule informed by the disclosed monitoring.

The throughline is that the safety and observability properties the provisional discloses are exactly the properties that let a cell stop being a segregated fire object and start being a structural inhabitant.

Boundary Conditions

The honest limits matter here. The Hydrogen-Aluminum Energy Cell is disclosed in a provisional application as an architecture. It has not, on the record of that disclosure, been built, validated, benchmarked, or certified. No energy density, cycle life, calendar life, efficiency, charge rate, or cost figure should be inferred from this article; the provisional itself describes aging behavior, long-term-storage performance, and self-discharge as projected from the disclosed mechanisms and to be determined empirically through prototype testing. The thermal-stall safety behavior and the dielectric monitoring are disclosed mechanisms, not certified results.

The underlying materials science is prior art. Hydrogen chemisorption on aluminum surfaces, proton-conducting sulfonated carbon gels, electrochemical exfoliation of metal nanoflakes, mechanochemical effects, and boron doping of carbon are all established and characterized in published research. The provisional locates novelty in the combination, architecture, and resulting category, not in any newly discovered material, bond, or physical effect, and nothing in this article should be read as claiming otherwise.

The building-integration framing is a domain application, not a claim that the cell is rated for any specific structural or fire code today. Real deployment of a structure-hosted cell would require the relevant listings and installation approvals (for example under UL 9540 and the provisions of NFPA 855, as applicable in a given jurisdiction), which are conformity-assessment outcomes external to a provisional disclosure. The disclosed stall behavior is described as a safety interlock, not as a substitute for code compliance. Regulatory and standards references are named only as real domain facts; they do not represent any assessment performed on the disclosed cell.

The credentialed-surfaces attestation layer is described here as external context. Its mechanisms, guarantees, and governance are not part of U.S. Provisional Application No. 64/055,649 and are not claimed here; it is presented as a separate layer that consumes the cell's disclosed readable state, not as a feature of the cell.

Disclosure Scope

The energy-storage technology described in this article is disclosed in U.S. Provisional Application No. 64/055,649, the Hydrogen-Aluminum Energy Cell, and all statements about what the cell does (its separator-free bulk-equipotential charge retention, hydrogen-metal surface-bond storage, aluminum equipotential extension layer, heat-triggered discharge stall, microwave/radar state-of-health monitoring, series stacking, and remanufacture-based service) trace to that disclosure as an architecture, not as a built or benchmarked product. The building-integrated and behind-the-meter

deployment scenarios, the market problem, the structural host embodiments, and the standards and regulatory references are external domain context offered to show enabling implementations, and are not patent claims. The credentialed-surfaces energy-storage property-surface is referenced as a separate, external attestation layer that composes with the cell; it is not within the scope of 64/055,649 and is not claimed here. No performance figures are disclosed or implied.

Hydrogen-Aluminum Energy Cell ([/h-al-battery](#)) All 40 steps → ([/inventive-steps](#))

al-battery

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 \(/articles/h-al-battery/gel-polarized-switch\)](/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 \(/articles/h-al-battery/flake-electrostatic-isolation\)](/articles/h-al-battery/flake-electrostatic-isolation).
- [Dynamic Flake Expansion: Carbon-Intercalation Wedging to Expose Buried Metal Surface Under Bias \(/articles/h-al-battery/dynamic-flake-expansion\)](/articles/h-al-battery/dynamic-flake-expansion).
- [Hydrogen-Locked Expanded State: Surface-Energy Inversion as a Positive-Feedback Capacity Mechanism \(/articles/h-al-battery/hydrogen-locked-expanded-state\)](/articles/h-al-battery/hydrogen-locked-expanded-state).
- [Secondary Carbon-Hydrogen Storage on Transmuted Intercalated Carbon \(/articles/h-al-battery/secondary-carbon-hydrogen-storage\)](/articles/h-al-battery/secondary-carbon-hydrogen-storage).
- [Mechanochemical Strain Self-Healing and Use-Positive Aging in a Bulk-Equipotential Hydrogen-Aluminum Cell \(/articles/h-al-battery/mechanochemical-self-healing\)](/articles/h-al-battery/mechanochemical-self-healing).
- [Boron Doping of the Carbon Framework as a Multi-Function Precision Multiplier \(/articles/h-al-battery/boron-doping-precision-multiplier\)](/articles/h-al-battery/boron-doping-precision-multiplier).
- [The Floating Aluminum Equipotential Extension Layer: A Multifunctional Inner Case for the Bulk-Equipotential Cell \(/articles/h-al-battery/aluminum-equipotential-extension-layer\)](/articles/h-al-battery/aluminum-equipotential-extension-layer).

APPLICATIONS · GENERAL

- [Grid-Scale and Renewable-Firming Storage with the Hydrogen-Aluminum Energy Cell \(/articles/h-al-battery/grid-scale-storage\)](/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 \(/articles/h-al-battery/building-integrated-storage\)](/articles/h-al-battery/building-integrated-storage)**
- [Stationary Backup and UPS Reserve Power for Data Centers, Hospitals, and Telecom \(/articles/h-al-battery/backup-and-ups\)](/articles/h-al-battery/backup-and-ups).
- [Storage for Microgrids, Islands, and Off-Grid Sites: A Stationary Cell Built From Abundant Materials \(/articles/h-al-battery/microgrid-and-off-grid\)](/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 \(/articles/h-al-battery/ev-and-mobility\)](/articles/h-al-battery/ev-and-mobility).
- [Marine and Rail Energy Storage: A Bulk-Equipotential Hydrogen-Aluminum Cell for Mass-Tolerant Heavy Transport \(/articles/h-al-battery/marine-and-rail\)](/articles/h-al-battery/marine-and-rail).
- [Supply-Chain-Resilient Field Power: An Abundant-Material Energy Cell for Defense and Expeditionary Operations \(/articles/h-al-battery/defense-and-field-power\)](/articles/h-al-battery/defense-and-field-power).

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