Nick Clark · Published 2026-06-29 · PDF

Charge Retention by Bulk-Equipotential Saturation Without an Internal Separator

This article documents bulk-equipotential charge retention, a secondary inventive step of the Hydrogen-Aluminum Energy Cell disclosed in U.S. Provisional Application No. 64/055,649, by which a cell holds its charge with no internal separator at all. Every conventional rechargeable cell instead relies on an internal separator to hold its charge: an anode and a cathode sit at different electrochemical potentials, and the only barrier preventing them from short-circuiting internally is the separator's electronic insulation. Any breach of that separator produces self-discharge, and the separator's integrity becomes the load-bearing determinant of cell safety and cycle life. The disclosed cell takes a different approach. Its interior is a single continuous electronically and ionically conductive gel of metal nanoflakes, with no internal separator, membrane, or barrier between the two current collectors. Charge is retained instead by bulk-equipotential saturation: in the charged state with no external load, the gel's own conductivity equalizes every flake to the same electrochemical potential, so no internal gradient exists to drive electrons from one region to another. The cell holds its charge not by being insulated against current flow but by being internally saturated to the point that no driving force for internal current exists at all.

The Separator as the Load-Bearing Component

Conventional rechargeable cells share a common architectural assumption. An anode and a cathode held at distinct electrochemical potentials are kept apart by an ion-conducting but electronically insulating barrier: the separator, the membrane, or the solid-electrolyte phase. That barrier is the load-bearing mechanism for charge retention. The anode sits at a lower electrochemical potential than the cathode, and the only thing preventing internal current from flowing between them is the separator's electronic insulation. Any breach of the separator results in self-discharge. Because the separator is what stands between a charged cell and an internal short, its failure modes are the principal determinants of cell safety and cycle life across the incumbent industry.

This article describes how the disclosed cell retains charge without any such internal separator, membrane, or barrier between its two current collectors.

A Continuous Conductive Gel, No Internal Separator

The disclosed cell retains stored electrical charge in the absence of any internal separator, internal membrane, or internal electronic-insulating barrier between its two current collectors. Its interior is a continuous gel medium that is both electronically and ionically conductive, mechanically continuous from one terminal to the other. Charge retention is achieved instead through bulk-equipotential saturation of that continuous gel medium.

This inverts an assumption built into conventional cell design. Internal electron conductivity throughout the bulk, which in a conventional cell would constitute an internal short and is normally engineered against, is here present by design and is part of how the cell works.

The Equipotential State of the Charged Cell

In the charged state with no external load connected, the metal nanoflake population is in an equipotential condition: substantially all flakes are at the same electrochemical potential, and no electrochemical-potential gradient exists across the gel volume. This condition is reached automatically through the gel's electronic and ionic conductivity. Any local potential difference between two regions of the gel volume is rapidly equalized through that conductivity, with the equilibration timescale being short relative to the cell's operating timescales.

In the equipotential condition, no internal driving force exists for charge to redistribute within the cell. The cell is internally at rest despite holding stored chemical energy in the metal-hydrogen bonds at the flake surfaces.

Saturation, Not Insulation, Prevents Self-Discharge

The equipotential condition prevents internal self-discharge by removing the driving force that would otherwise transfer electrons from one electrode to another within the cell. In a conventional rechargeable cell, the anode is at lower electrochemical potential than the cathode, and the only barrier to internal current is the separator's electronic insulation. In the disclosed cell, no such internal potential difference exists: every metal nanoflake is at the same potential as every other, and there is no internal terminus for electron flow other than the locations the electrons already occupy.

The distinction is the heart of the mechanism. The cell holds its charge not by being insulated against current flow but by being internally saturated to the point that no driving force for current flow exists. There is nowhere for the charge to go.

Asymmetry Created Only by External Circuit Closure

The equipotential condition is broken only by closure of an external circuit between the first and second terminals through an external load. Closing that circuit creates an asymmetric electron path: electrons may exit the cell at one terminal, traverse the external load, and re-enter the cell at the opposite terminal. This asymmetric path establishes a potential gradient across the gel volume. The regions near the exit terminal become depleted of electrons and drop in potential, while the regions near the entry terminal become enriched and rise in potential.

That gradient drives internal redistribution of stored charge toward the exit terminal, where the electrons are released to the external load. The cell discharges only as fast as the external load admits. In the limiting case of an open circuit, the cell does not discharge at all. Because both terminals are electrically equivalent in the absence of applied bias, the cell has no defined anode and cathode in the conventional sense; the terminals are differentiated only by the asymmetric path established when an external circuit closes.

How This Differs from Conventional Charge Retention

The bulk-equipotential charge retention principle is distinct from conventional charge retention in several specific ways disclosed in the filing:

- Absence of an internal electron-insulating separator, which in conventional cells is the load-bearing component for charge retention.
- Presence of internal electron conductivity throughout the bulk gel, which in conventional cells would constitute an internal short and is normally engineered against.
- Charge retention by saturation rather than by insulation, in which the storage capacity is set by the integrated bond-state population of the metal nanoflakes; the conductivity of the gel is irrelevant to retention.

- Absence of a defined anode and cathode in the conventional sense, with both terminals being electrically equivalent in the absence of applied bias and differentiated only by the asymmetric path established by external circuit closure.
- Retention of charge in distributed bond-state form across the entire flake population rather than in a separated electrode-pair form, with that distributed form admitting more uniform thermal management, mechanical stress distribution, and aging characteristics than conventional separated-electrode cells.

Relationship to the Equipotential Case and Storage State

The charge-retention principle is reinforced by other disclosed architectural elements. An electrically conductive aluminum layer at the inner surface of the enclosure floats at the gel's bulk equipotential potential rather than being driven to a fixed terminal potential, extending the equipotential volume of the cell to include the enclosure layer. Because that layer sits at the gel's own potential, the filing describes it as suppressing leakage through the enclosure dielectric.

The same equipotential condition stabilizes the cell's storage state more broadly. In the equipotential storage state, no current flows in either direction, and the absence of any internal potential gradient admits no driving force to randomize established flake-surface configurations; the gel retains its state until an external circuit closes. The filing also notes that this principle constrains other components: the stress-activated conductive additive must be held below its percolation loading, because an additive loading high enough to form a percolating conductive network at rest would compromise the bulk-equipotential charge retention principle.

Disclosed Performance Framing

The filing presents charge retention as the basis for a long-term storage mode in which the cell is charged to a target state-of-charge and held without external load for extended periods. It attributes the expected storage durability to the bulk-equipotential charge retention principle together with the absence of internal degradation chemistries operating at rest. The filing states that actual long-term storage performance is to be determined empirically through long-duration testing, and that the disclosed mechanisms admit projected calendar self-discharge rates well below 1 percent per year, with the precise value dependent on engineering implementation. That figure is stated in the filing as a projection, not a measured result, and is the only retention-rate number the disclosure provides.

Disclosure Scope

This article describes the bulk-equipotential charge retention mechanism as disclosed in U.S. Provisional Application No. 64/055,649. Every mechanism, term, and numeric value above traces to that filing. The provisional is an early-stage disclosure that recites concepts and mechanisms, frequently without specific numbers; the single retention-rate figure cited here is presented in the filing as a projection dependent on engineering implementation and subject to empirical verification through long-duration testing.

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)

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