High-Performance Dual-Gradient Li-S Battery Electrodes for Fast-Charging and Long-Life Applications

A dual-gradient lithium-sulfur electrode architecture that enables high energy density, fast charging, and long cycle life for EVs, UAVs, and grid storage applications.

EV battery engineers and cell makers struggle to deliver high energy at high mass loadings without severe capacity fade, uneven sulfur utilization, and throughput losses during fast charge/discharge; current Li-S cathodes bottleneck production lines and fail durability targets. This technology introduces a dual-gradient Li-S electrode architecture that synchronizes sulfur redox reactions across the electrode thickness, reducing polarization and maintaining structural integrity at high current densities without relying on slurry-cast methods that break down under scale. Unlike today's catalyst-tweaked or simply structured cathodes, the correlated gradients (pore/active material) create a fundamentally different reaction environment that keeps the whole electrode participating, enabling both high areal capacity and high-rate operation. Compared with incumbent Li-S approaches, demonstrated performance shows higher areal capacities, stable cycling beyond 1,000 cycles at multi-C rates, and fast-charge capability; where head-to-head cost and reliability data are still emerging, benefits are expected to include lower $/kWh via longer life and better sulfur utilization. The technology has been validated at lab-prototype level in coin and pouch cells with practical performance data under relevant conditions (including sub-zero operation). If adopted, it could unlock lighter, higher-energy packs for EVs, UAVs, and grid modules while fitting into existing assembly formats after modest process adaptation.

Technology Validation:

Lab prototypes (coin and pouch cells) achieved areal capacities above 20 mAh/cmÂ^2 at low rates and maintained high capacities at up to 5C, with ~82% capacity retention after ~1,100 cycles at 4C; pouch cells demonstrated ~403 Wh/kg and stable operation at -10 Â°C. Testing was performed under controlled lab conditions with application-relevant current densities and

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mass loadings, indicating robustness of synchronized redox behavior.

Advantages:

- High throughput & rate capability: Stable performance at multi-C rates without rapid polarization buildup or localized failure.

- Long cycle life at high mass loading: Maintains capacity and structural integrity beyond 1,000 cycles where typical Li-S cathodes fade early.

- Integration-ready formats: Compatible with coin, pouch, and cylindrical cells; assembly aligns with existing battery lines after modest adaptation.

- Scalable architecture: Additive manufacturing + thermal treatment pathways are customizable and support repeatable electrode quality.

- Low-temperature resilience: Demonstrated operation at sub-zero temperatures to extend use into aerospace/defense and cold-weather EVs.

Applications:

- UAV endurance packs: Lightweight, high-energy modules for long-range autonomous flight (deployed by aerospace/UAV integrators).

- EV fast-charge cathodes: High-mass-loading Li-S cells for passenger/commercial EV programs seeking step-change energy density.

- Grid-scale storage modules: High-energy racks for renewable integration where cycle life and cost/kWh drive LCOE.

- Portable/industrial devices: Extended-life batteries for field instrumentation and medical/industrial handhelds

TRL: 4

Intellectual Property:

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