Technology Offer

Sustainable High-Performance Energy Storage: The Solar Battery

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Abstract

This solar battery technology enables direct harvesting and storage of solar energy in a single material, overcoming key limitations of traditional batteries and solar cells. Developed using cyanamide-functionalized polyheptazine-imide (NCN-PHI), the system integrates light absorption and photoinduced electron storage in a monolithic structure. Its ability to decouple energy capture from immediate discharge ensures efficient energy utilization. This solar battery can operate in aqueous environments, offering a practical solution for renewable energy storage and mitigating fluctuations in solar power availability.

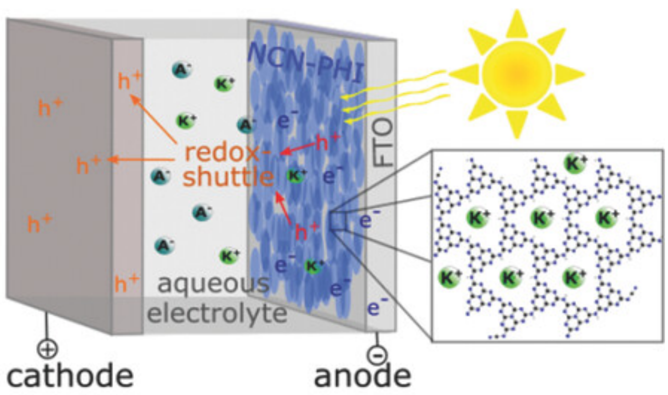

Figure 1: Schematic of the monolithic solar battery: Integration of light harvesting and electron storage within the NCN-PHI material, stabilized by alkali ions in an aqueous electrolyte (Podjaski et al., 2018).

Background

The shift toward renewable energy faces a key challenge: efficient and sustainable energy storage. Solar energy, while abundant, requires reliable storage solutions to compensate for its intermittent availability. Conventional methods rely on separate photovoltaic systems and batteries, leading to energy losses, high costs, and material constraints. Lithium-ion batteries, though widely used, depend on scarce resources and have limited cycle life.

Aqueous battery systems offer a safer alternative but struggle with low energy densities due to the electrochemical limitations of water. Additionally, most current storage technologies require immediate discharge, reducing flexibility. An ideal solution would integrate solar energy capture with direct electrical storage in a single material. Such an approach could improve efficiency, scalability, and sustainability while reducing dependence on fossil-based charging sources.

Technology

This innovative solar battery is based on cyanamide-functionalized polyheptazine-imide (NCN-PHI), a two- or three-dimensional carbon nitride material (Inlet Fig. 1) that uniquely integrates light absorption and energy storage in a single component. Unlike conventional systems, where energy conversion and storage occur separately, NCN-PHI directly captures sunlight, stores the resulting photoinduced electrons, and releases them as electrical energy on demand.

The material functions as a photoanode in an aqueous electrolyte, where light excitation generates electron-hole pairs (Fig. 1). While holes are extracted to a cathode via a redox shuttle, electrons are trapped within the NCN-PHI structure, stabilized by alkali ions such as Na^+, K^+, or Li^+. This mechanism prevents immediate recombination, allowing charge retention for extended periods.

Max-Planck-Innovation GmbH
Arnulfstr. 58
80335 München
www.max-planck-innovation.de

With a high overpotential for hydrogen evolution, NCN-PHI avoids unwanted water reduction, expanding the operational voltage window and improving energy density. The device achieves high durability (Fig. 2) and can be charged using sunlight or conventional electrical methods, demonstrating versatility in energy storage applications.

Advantages

- **Integrated Functionality:** Simultaneous light harvesting and energy storage within a single material.
- **High Performance:** High energy density, long charge retention, and operational stability (Fig. 2).
- **Scalability:** Suitable for large-scale production using cost-effective, abundant materials.
- **Flexibility:** Compatible with multiple ions (e.g., Na^+, K^+, Li^+, and ammonia) in aqueous electrolytes.
- **Environmentally Friendly:** Operates sustainably based on earth-abundant, cost-effective materials.

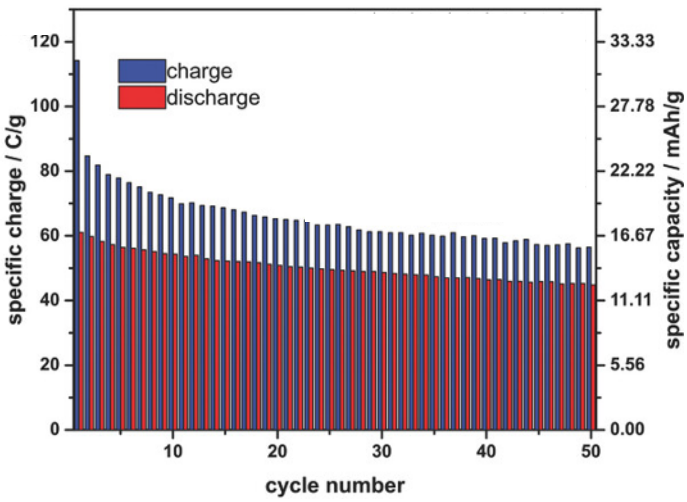

Figure 2: Charge and discharge stability over 50 cycles: Demonstrates the high Coulombic efficiency and durability of the NCN-PHI-based solar battery (Podjaski et al., 2018).

Potential applications

- Storage systems for renewable energy grids to balance supply and demand.
- Solar-powered mobile devices and remote systems.
- Photovoltaic power generation with integrated storage capabilities.
- Advanced energy solutions for off-grid applications.
- Specialized detectors requiring energy storage and release mechanisms.

Patent Information

PCT (*WO2020143912A1*; 09.01.2019), active in EP, JP, US

Publications

Podjaski, F., Kröger, J., & Lotsch, B. V. (2018). Toward an aqueous solar battery: direct electrochemical storage of solar energy in carbon nitrides. *Advanced Materials*, *30*(9), 1705477.

Contact

Dr. Bernd Ctortecka

Senior Patent- & License Manager, Physicist
Phone: +49 (0)89 / 29 09 19 – 20
eMail: ctortecka@max-planck-innovation.de

Max-Planck-Innovation GmbH
Arnulfstr. 58
80335 München
www.max-planck-innovation.de