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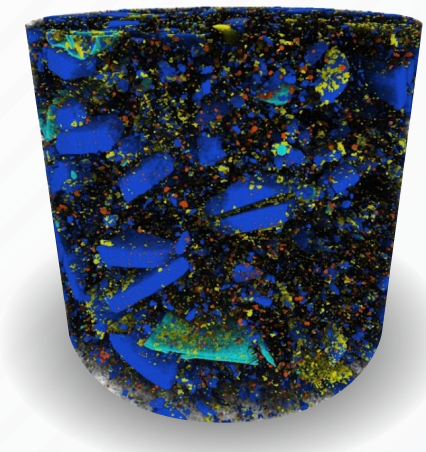
NATURE'S BLUEPRINT: ENGINEERING BIODEGRADABLE BATTERIES AND CLEAN WATER SYSTEMS

The Global Challenge and Bio-Based Solutions

The Resource Crisis We Face

Our planet extracted 93 billion tons of resources in 2015, yet only a tiny fraction returns to the economy. The rest ends up in landfills or polluting our environment. With billions lacking access to clean water and electricity, we need sustainable solutions that work within Earth's limits.



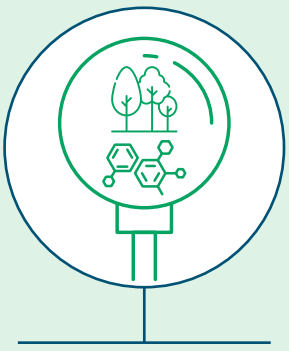
3D rendering of powdered black mass (recycled battery) materials. Microscopic data acquired by ZEISS VersaXRM, segmentation and rendering by Dragonfly. Blue represents the NMC cathode materials, turquoise the Cu foil, red the LFP cathode, green the Al foil, yellow the polymer separator, and black the graphite anode.

NMC: nickel manganese cobalt oxide; Cu: copper;
LFP: lithium iron phosphate; AI: aluminium

The Promise of Bio-Based Materials

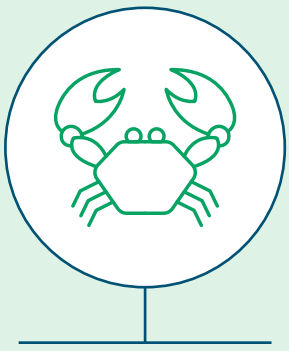
Nature provides abundant, renewable materials that can replace petroleum-based products in critical applications. These materials—primarily cellulose, chitin/chitosan, and lignin—offer unique advantages: they're biodegradable, locally available, and can be engineered for specific functions.

Key Bio-Materials Showcase:



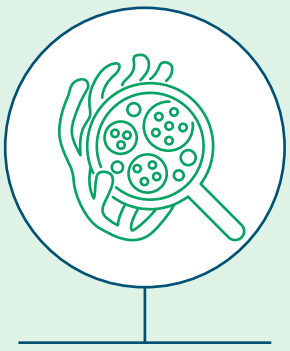
Cellulose

Earth's most abundant polymer from plants and trees



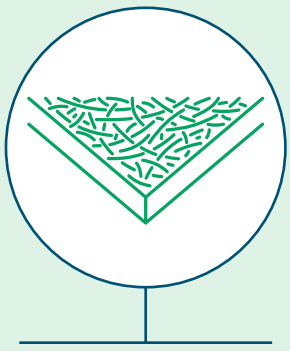
Chitin/Chitosan

From crustacean shells and mushrooms



Algae-based polymers

Fast-growing marine resources



Wood components

Complex structures with multiple applications

Revolutionary Battery Technologies

Bio-Based Battery Components

Traditional batteries rely on non-renewable materials and toxic components. Researchers have successfully replaced key battery parts with bio-materials, achieving remarkable performance while maintaining sustainability.

Breakthrough Achievements

Cellulose separators
Outperform commercial options, lasting 4,000+ hours vs. 600 hours

Chitosan gel electrolytes
Enable 10,000 charge cycles in zinc-ion batteries

Mushroom-derived components
Simple kitchen blender processing for scalable production

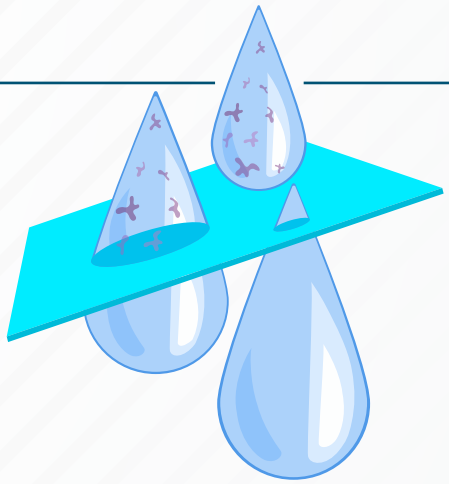
Transient Batteries: Disappearing on Demand

Imagine batteries that work perfectly until you want them to disappear. These "transient" batteries maintain full performance but can be triggered to biodegrade when their job is done—ideal for temporary medical implants or environmental sensors.

How It Works

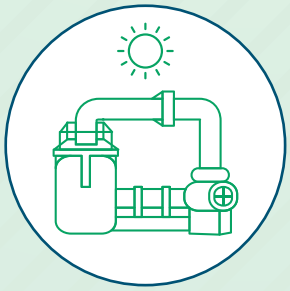
1. Battery operates normally with bio-based components
2. Water or heat trigger activates degradation
3. Materials dissolve into non-toxic byproducts
4. 50% degradation achieved in just 9 weeks

Water Purification Innovations



Multi-Functional Water Treatment Systems

Bio-based materials excel at removing diverse contaminants from water from pharmaceutical residues to forever chemicals (PFAS: per- and polyfluoroalkyl substances) and microplastics.

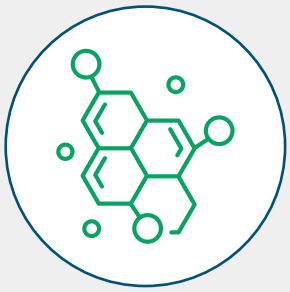


Photocatalytic Treatment

Cellulose cryogels embedded with titanium dioxide use sunlight to break down organic pollutants. The porous structure maximizes contact between contaminants and the photocatalyst, achieving complete degradation of pharmaceuticals like paracetamol.

PFAS and Microplastic Capture

Two of our most persistent pollutants now have bio-based solutions



PFAS Removal System

- Chitosan gels achieve 400–500 mg/g removal capacity
- Magnetic nanoparticles enable easy recovery
- Maintains performance across pH ranges
- Fully recyclable for multiple uses

Microplastic Aggregation

- Modified wood captures plastics from 24 nm to 10 µm
- Creates visible aggregates that settle naturally
- Captured plastics can be pressed into construction boards
- Converts waste into useful materials

Measuring Success and Scaling Up

Environmental Impact Assessment

Using Life Cycle Assessment, researchers quantified the true sustainability of these bio-materials across multiple categories.

Carbon Footprint Winners

- Cellulose pulp: lowest overall impact
- Minimal processing = maximum sustainability
- Some bio batteries show negative carbon footprint (carbon storing)

The Path Forward: Challenges and Opportunities

Current Challenges

- Scale-up: moving from lab bench to industrial production
- Cost parity: achieving competitive pricing at scale
- Performance consistency: maintaining quality across batches
- Regulatory approval: navigating new material certifications

Near-Term Applications (2–5 Years):

- Temporary medical devices
- Agricultural sensors
- Single-use electronics
- Water treatment facilities

Long-Term Vision (5–10 Years):

- Grid-scale energy storage
- Municipal water treatment systems
- Fully compostable consumer electronics
- Closed-loop manufacturing

The Circular Economy in Action

These technologies demonstrate that we can create high-performance materials that work with nature's cycles rather than against them. By using renewable resources, designing for degradability, and creating value from waste, we're building the foundation for a truly sustainable future.

"From 93 billion tons extracted to zero waste—bio-materials make the impossible possible."

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Further Resources

Wiley Event: Register for free to watch the recording of:

Renewable Materials for Sustainable Energy Storage and Environmental Remediation

Webinar Microscopy for Battery Research

Microplastics and Nanoplastics Analysis Imaging Solutions from ZEISS

For more information about Zeiss solutions, and to find the right system for your needs, please visit:

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