



**TOWARDS A SUSTAINABLE FUTURE** FOR ENERGY STORAGE

**INTERNATIONAL SOCIETY FOR ENERGY AND SUSTAINABILITY RESEARCH/** KUMARAGURU COLLEGE OF TECHNOLOGY INDIA

## **BIOMIMICRY AND** BATTERIES

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## SUSTAINABILITY IN BATTERY TECHNOLOGY





DEMAND FOR ENERGY STORAGE



SUSTAINABLE BATTERIES

# ENVIRONMENTAL

## RAW MATERIAL EXTRACTION

#### DISPOSAL



#### RECYCLING







## ADVICE FROM THE EXPERTS

NATURE DOESN'T HAVE BATTERIES,YET IT SOLVES SIMIL PROBLEMS

ALL THE EXISTING AND DOCUMENTED NATURE-INSPIRED BATTERY INVENTIONS NOT LIMITED ON THE SOLUTION CONCERNING A SPECIFIC BATTERY COMPONENT



METHODOLOGY

DESCRIPTIVE REVIEW

## SCOPING & LIMITATIONS



## WHAT IS BIOMIMICRY?

A practice that learns from and mimics the strategies found in nature to solve human design challenges Challenge Lack of biocompatible, mechanically flexible batteries for implants

## ELECRTIC EEL- INSPIRED FLEXIBLE & BIOCOMPATIBLE BATTERIES





Gradients of ions between miniature polyacrylamide hydrogel compartments

Thomas B. H. Schroeder, Anirvan Guha et al. An electric-eel-inspired soft power source from stacked hydrogels

next generation of pacemakers, prosthetics & medical implants'

**'To drive the** 

## Challenge Li-ion batteries take up 20% of the carrying capacity and overall weight of a robot

## MAMMALIAN FAT TISSUES **INSPIRED STRUCTURAL BATTERIES**



times as much capacity than the typical single lithium-ion battery is achieved

#### Carbon-based aramid nanofibers

Mingqiang Wang, Drew Vecchio et al. Biomorphic structural batteries for robotics



Challenge Structural batteries are heavy, short-lived, or unsafe

## CARTILAGE INSPIRED STRUCTURAL BATTERIES



capacity is achieved by a zinc battery with a cartilage-like solid electrolyte for more than 100 cycles

1. Mingqiang Wang, Drew Vecchio et al. Biomorphic structural batteries for robotics



A perfect prototype for an iontransporting material in batteries Challenge To precisely control their molecular structure of Synthetic polymers

## SPIDER-WEB INSPIRED HIGH PERFORMANCE ANODE



Yuqiang Jin, Haocheng Yuan et al. Bio-inspired spider-web-like membranes with a hierarchical structure for high performance lithium/sodium ion battery electrodes

'It selfassembles at the nanoscale which is very beneficial for the proton conductivity'

#### Structural degradation & instability of Si in Li-ion batteries

## POMEGRANATE-INSPIRED HIERARCHICAL STRUCTURED SILICON ANODE



Liu, N., Lu, Z., Zhao, J. et al. A pomegranate-inspired nanoscale design for large-volume-change lithium battery anodes.

SMALLER, LIGHTER AND MORE POWERFUL BATTERIES

Challenge Costly and more efficient nanoscale materials for Li ion batteries

## CHITON TEETH - INSPIRED NANOSCALE MATERIAL FOR LI-ION BATTERIES



production costs'

Daniel Nocera, Caltech's Nate Lewis et al. Integrated transcriptomic and proteomic analyses of a molecular mechanism of radular teeth biomineralization in Cryptochiton stelleri

1. Hydrated iron oxide crystals nucleation 2. Conversion to magnetic iron oxide 3. Parallel rods along these organic fibers

## **'Engineering nanocrystals** can be grown at significantly lower temperatures, lower

### Challenge Self-assembled molecular templates to produce hierarchical carbon materials

## UNICELLULAR ALGAE- INSPIRED CARBON ANODES





## Self-assembled molecular templates

Liu, N., Lu, Z., Zhao, J. et al. A pomegranate-inspired nanoscale design for large-volume-change lithium battery anodes.



of the original capacity is retained, even when the current density is increased 600-fold

## Challenge Sodium-ion batteries are heavier & cannot handle the high voltage levels

## MAMMALIAN BONE- INSPIRED SPONGE-LIKE BATTERY ARCHITECTURE





Sodium cathode material called NVP (Na3V2(PO4)3)

Kang Ho Shin, Sul Ki Park et al. Biomimetic composite architecture achieves ultrahigh rate capability and cycling life of sodium ion battery cathodes



of its capacity is maintained after 10,000 cycles of discharging and recharging

## Challenge Biodegradable yet

efficient batteries

## SUGAR FUELED BATTERY





Zhu, Z., Kin Tam, T., Sun, F. et al. A high-energy-density sugar biobattery based on a synthetic enzymatic pathway



#### times last longer than current lithiumion batteries

#### BATTERY DESIGN



#### SHAPE

#### BATTERY FABRICATION



#### BATTERY RECYCLING





#### PROPOSED APPROACH





HOW NATURE, recycles? produces? make materials? harvests energy? stores energy? transports energy?

## CALL FOR ACTION!

NON-FLAMMABLE NON-TOXIC INEXPENSIVE MODULAR ECO-FRIENDLY CONDUCIVE TO LIFE RECYCLABLE



BILLION YAEARS OF RESEARCH & DEVELOPMENT



## HOW TO USE BIOMIMICRY AS A DESIGN TOOL?



#### biomimicry functions like nature

biomorphism <sup>Iooks like nature</sup> bioutilization

https://biomimicry.org/

## WAY FORWARD

## We just have to look around! HOW WILL NATURE SOLVE THIS?

#### lt's time to ask nature.

Innovation Inspired by Nature

Innovation Inspired by Nature

 ${\sf Q}$  asknature.org





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https://asknature.org/