

Pioneering Energy Innovations

Discovering HKUST Energy Technologies in:

Energy Harvesting

Energy Efficiency

Energy Storage



About The Hong Kong University of Science and Technology

The Hong Kong University of Science and Technology (HKUST) (<https://hkust.edu.hk/>) is a world-class research intensive university that focuses on science, technology and business as well as humanities and social science.

HKUST offers an international campus, and a holistic and interdisciplinary pedagogy to nurture well-rounded graduates with global vision, a strong entrepreneurial spirit and innovative thinking. Over 80% of our research work were rated “Internationally excellent” or “world leading” in the Research Assessment Exercise 2020 of Hong Kong’s University Grants Committee. We were ranked 2nd in Times Higher Education’s Young University Rankings 2023, and our graduates were ranked 30th worldwide and among the best from universities from Asia in Global Employability University Ranking and Survey 2022.

As of early 2023, HKUST members have founded 1,645 active start-ups, including 9 Unicorns and 11 exits (IPO or M&A), generating economic impact worth over HK\$400billion. InvestHK cited QS World University Rankings by Subject 2021 to demonstrate the performance of five world’s top 100 local universities in several innovation-centric areas, among which HKUST ranked top in four engineering and materials science subjects.

Foreword

In an era where sustainability and environmental stewardship have become paramount, innovative solutions have emerged to address our growing energy demands while reducing our carbon footprint. The research and development community at the Hong Kong University of Science and Technology is devoted to driving this goal and revolutionizing the way to power our world.

This booklet showcased a collection of novel and groundbreaking technologies to reshape the energy landscape. It is structured in three major sub-sections namely energy storage, energy efficient system, and energy harvesting. From advancements in renewable energy to breakthroughs in battery, each section will uncover the potential of HKUST technologies in bringing innovative collaborations and cultivating collective success within the energy industry.

Let's pave the way towards a cleaner and more sustainable future!

Energy Storage

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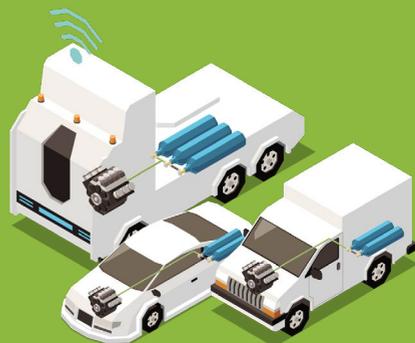
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Consumable and Inert Aluminium Composite Flakes for Hydrogen Generation



Technology

HKUST develops an activated Aluminium (Al) flake with nanometric thickness and surface defects. The surface defects such as skin cracks allow this flake composition and cassettes to efficiently and safely generate hydrogen in water.

The invented Al flake overcomes the restrictions of conventional product which either contains heavy metals or requires an activator and is usually flammable or even explosive. The Al flake is the perfect candidate for safe hydrogen storage and delivery.



Potential Applications

- ▶ Hydrogen transportation
- ▶ Hydrogen generation



Advantages

- ▶ **Safe and controllable**
- ▶ **Low cost**
- ▶ **No heavy metals**



Inventor

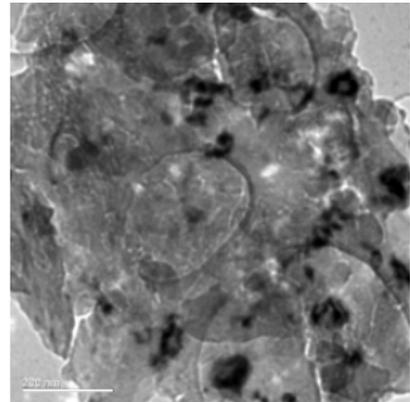
Professor Yui Bun CHAN
Department of Civil and Environmental Engineering



Intellectual Properties

US Patent Application No.: 18/066314
CN Patent Application No.: 202211626523.8
HK Patent Application in-progress

Microimage of the activated Al flakes



Property	Unit	Commercial Product 1	Commercial Product 2	HKUST invention
Requires an activator		Yes	No	No
Heavy metals	wt%	0	3-7	0
Hydrogen Yield	%	~100	93	~94
H ₂ generation rate		Slow	Rapid	Slow - Moderate
Fire safety		Flammable	Explosive	Non-Flammable
Estimated Cost		Very Low	High	Low

A New Aluminium Nanoporous Composite with High Thermal Conductivity



Technology

HKUST invents a new nanoporous Aluminium (Al) composite by a novel production method. The composite exhibits the following properties:

- ▶ Open maze-like pore nanochannels
- ▶ Developed surface area ($3\text{-}7\text{m}^2/\text{g}$)
- ▶ Inner pore surface: AlN and Al_2O_3
- ▶ Fracture strain up to 0.5

It has excellent thermal conductivity that enables a wide range of potential applications in thermal storage or management.



Potential Applications

- ▶ Building/ furniture materials
- ▶ Heat sink
- ▶ Container for phase change materials used in thermal energy storage system



Advantages

- ▶ Good thermal conductivity
 - Up to $60\text{W}/\text{mK}$ vs $50\text{W}/\text{mK}$ (Conventional Al Foam)
- ▶ Good compressive strength
 - Up to 530MPa with only $1/3$ weight of steel



Inventor

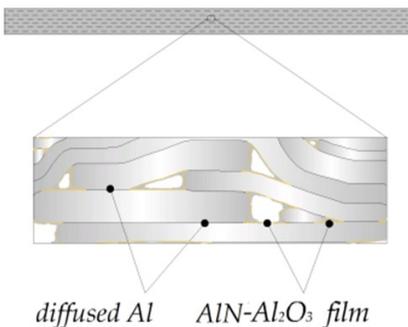
Professor Yui Bun CHAN
Department of Civil and Environmental Engineering



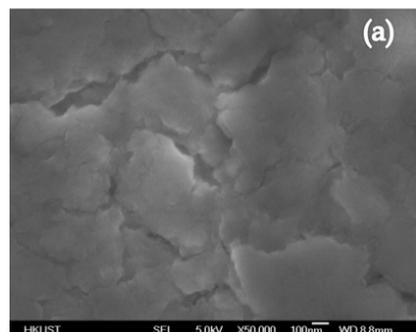
Intellectual Properties

CN Patent Application No.:
ZL201780063431.4

The invented nanoporous Al composite



The nanoporous Al composite



Highly Rechargeable Alkaline Zn Batteries



Technology

Alkaline Zn batteries have been powering consumer electronics for decades with their high safety, low cost, and moderate energy density. Attempts to make Zn batteries rechargeable have been hindered by the poor cycle life of Zn anodes and heavy side reactions.

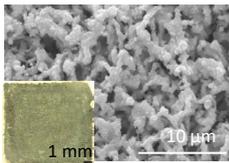
HKUST addresses the challenge via two synergistic approaches. A free-standing, nanoporous (NP) Zn anode is developed to stabilize the metal network to withstand long cycles at a deep depth of discharge (DoD). A super-alkaline electrolyte is designed to suppress side reactions while maintaining high ionic conductivity via hydroxide structural diffusion. The two enable a stable energy density of 110Wh/kg for a Ni-Zn battery, among the best reported.



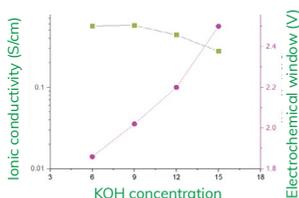
Potential Applications

Grid-scale electricity storage, e.g., backup power

Nanoporous Zn anode



Super-alkaline electrolyte



Advantages

- ▶ Safe and non-flammable
- ▶ Low cost
- ▶ Mature manufacturing method
- ▶ Recyclable



Inventor

Professor Qing CHEN
Department of Mechanical and
Aerospace Engineering
Department of Chemistry

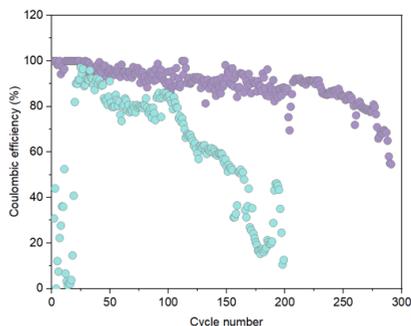


Intellectual Properties

US Patent Application No.: 17/933657 ;
63/509286
CN Patent Application No.:
202111506478.8

Efficiency (capacity) vs. cycle number

Comparing the invented battery (purple) against the state-of-the-art Ni-Zn battery (tested at 40% DoD, 25 mA/cm² current density, as a coin cell)



Non-Flammable Electrolyte for Solid-State Battery



Technology

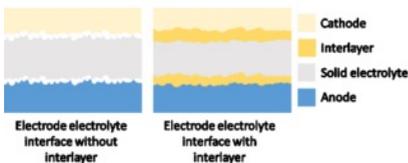
Conventional Li-ion/Na-ion batteries use organic liquid electrolytes, which induces safety concerns including high flammability, corrosivity and toxicity. When temperature reaches 60°C, conventional electrolyte decomposes and forms non-conductive layer that prevents charging and discharging, and even leaks and catches fire.

In view of these issues, HKUST research team presents a novel technology of solid-state electrolyte, composed of ceramic and polymer with interlayers to improve the electrode-electrolyte contact. The stable fully solid structure is leakage-free, possessing wonderful ionic conductivity and reduced resistance.



Potential Applications

- ▶ Solid State batteries
- ▶ Wearable electronics
- ▶ IoT sensors



Advantages

- ▶ Electrochemically stable up to 4.5V
- ▶ High Ionic Conductivity (Greater than 10^{-4} Scm^{-1} at room temperature)
- ▶ Enhanced interfacial contact, resistance reduction by 20 times
- ▶ Fully Solid Structure: Light, compact and leakage-free
- ▶ Wide working temperature window (-30°C to 80°C)
- ▶ Highly flexible
- ▶ High cycling capability (>1000 with 99% capacity retention)
- ▶ Non-Flammable



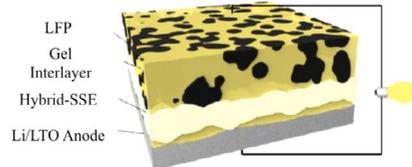
Inventor

Professor Francesco CIUCCI
Department of Mechanical and
Aerospace Engineering



Intellectual Properties

US Patent Application No.: 17/721378
CN Patent Application No.:
ZL201910502091.1



Strength in thinness: Ultra-Strong Polymer Nanofilm for Cutting-Edge Applications

Technology

Self-supporting and porous polymer nanofilms at thicknesses of ~100 nm are enabler materials for a myriad of cutting edge technologies. The nanofilm is **thinner than a human hair and yet over 25 times stronger than that of stainless steel with the same mass**. Among all the known ultra-thin films, the nanofilm is the strongest and highly transparent, while being thin and porous at the same time.

Potential Applications

- ▶ Energy: Flexible ultrathin batteries, high-energy-density capacitors
- ▶ Filtration: Water purification, air filtration, nanofiltration
- ▶ Electronics: Flexible display, wearable device
- ▶ Healthcare: Antibacterial film, skin sensor

Advantages

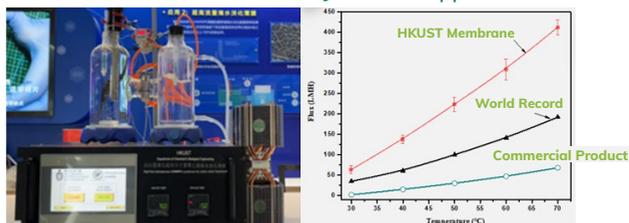
- ▶ Ultra-thin
- ▶ High mechanical strength
- ▶ High transparency
- ▶ High gas permeability
- ▶ Tunable porous properties
- ▶ Free-standing and self-supporting

Inventor

Professor Ping GAO
Department of Chemical and Biological Engineering

Intellectual Properties

US Patent No.: 11389772 ; 11623184
CN Patent No.: ZL201780071319.5 ;
ZL201880081876.X ;
ZL201910926929.X
HK Patent No.: HK40028642
US Patent Application No.: 16/346338 ;
18/245641
CN Patent Application No.:
201880045114.4 ; 202180059284.X
HK Patent Application No.:
62023074997.5
JP Patent Application No.: 2023-517271



The nanofilm's adjustable porous property has made it the world's most potent polymeric membrane for membrane distillation desalination



A Novel Framework Supported Solid Electrolyte Film Possessing Good Mechanical Strength and Ionic Conductivity



Technology

Solid electrolytes offer the advantages of enhanced safety, higher energy density, and wider operating temperature range over traditional liquid electrolytes. However, conventional solid electrolytes used in solid-state batteries have the restrictions of a tradeoff between mechanical strength and ionic conductivity.

To tackle the bottleneck of the technology, HKUST developed an ultrathin polymer framework supported solid electrolyte composite with excellent ionic conductance, superior mechanical strength, and great flexibility for all-solid-state batteries.



Potential Applications

- ▶ Solid-state battery design and manufacturing



Advantages

- ▶ Ultrathin
- ▶ Small resistance
- ▶ Strong and durable



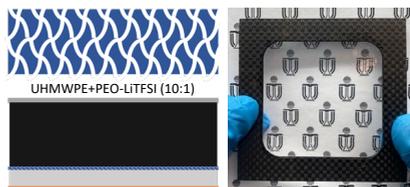
Inventor

Professor Ping GAO, Professor Minhua SHAO
Department of Chemical and Biological Engineering



Intellectual Properties

US Patent Application No.: 17/225356
CN Patent Application No.: 202110394002.3



Full cell

	UHMWPE	Celgard
Tensile strength	380 Mpa	80 Mpa
Thickness	3 μm	24 μm

Cycling performance of the all-solid-state battery having the framework supported solid-state electrolyte film

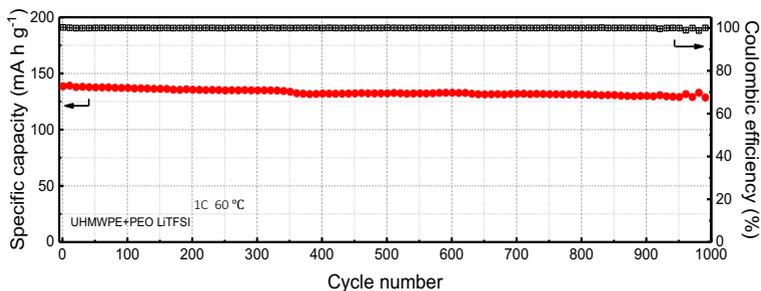


Photo-Rechargeable Lead-Free Perovskite Li-ion Batteries

Technology

HKUST developed a lithium-ion solar photo battery using lead-free perovskite nanocrystals in the active layer, which can be charged upon exposure to a white light source and demonstrates bi-functionality in energy harvesting and storage in a single-device architecture.

The photoactive material is non-toxic and can be easily solution processed under ambient temperature. It can be assembled into a coin cell photo-battery, hence is a highly compact candidate suitable for small electronics power applications.

Potential Applications

- ▶ Small electronic devices battery application e.g. calculators, hygrometers, LEDs

Advantages

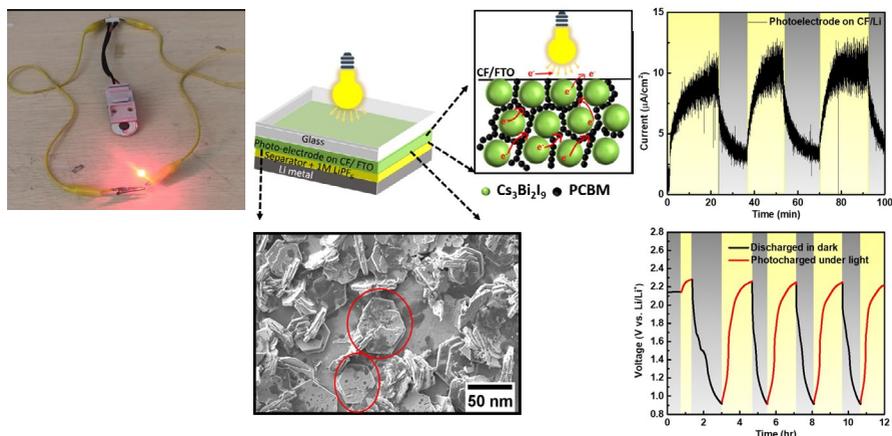
- ▶ High charge/discharge specific capacity up to 400 mAhg^{-1}
- ▶ Efficient charging is possible at 1 sun and lower
- ▶ Completely non-toxic and environmentally stable
- ▶ Bi-functionality: Energy harvesting and storage in a single-device architecture

Inventor

Professor Jonathan Eugene HALPERT
Department of Chemistry

Intellectual Properties

CN Patent Application No.:
202210168608.X



New Strategy to Fabricate a Solid-State Electrolyte with Exceptional Ionic Conductivity

Technology

Developing next generation lithium battery with high energy density and improved safety is critical. To advance the technology, a good solid-state electrolyte (SSE) which offers safety and electrochemical stability with good processing ability and high conductivity is crucially needed.

HKUST is devoted to work on this topic, and here presents an optimized composite SSE from a new strategy of fabrication, which possess good properties:

- ▶ High ionic conductivity : 1.25 mS cm^{-1}
- ▶ Li^+ transference number (t_{Li^+}) : 0.82

A full coin cell prototype was fabricated and demonstrated satisfactory performance.

Potential Applications

- ▶ Electrolyte for Lithium-Metal Battery

Advantages

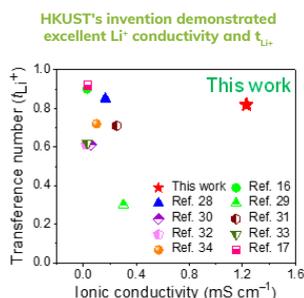
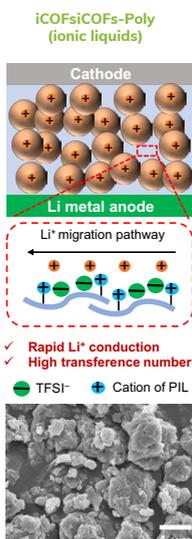
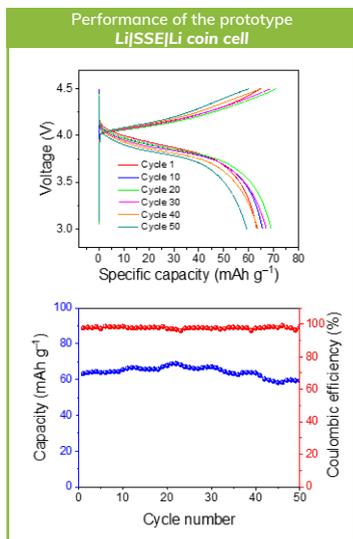
- ▶ High Li^+ conduction
- ▶ Superior ionic conductivity over $10^{-3} \text{ S cm}^{-1}$

Inventor

Professor Yoonseob KIM
Department of Chemical and Biological Engineering

Intellectual Properties

US Patent Application No.: 63/379145
CN and HK Patent Application in-progress



Novel Cathode Materials for Durable Lithium-ion Batteries with High Energy Density

Technology

While various kinds of lithium battery cathode materials have been developed, the energy densities of this class of materials are limited. This innovation presents a durable nickel-rich cathode materials that significantly improves the energy density for lithium-ion batteries.

Potential Applications

- ▶ Electric vehicles
- ▶ Electric tools
- ▶ Electric bikes
- ▶ Drones and more

Advantages

- ▶ High energy density
- ▶ Superior power density
- ▶ Longer cycling life

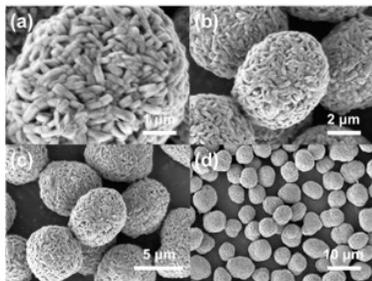
Inventor

Professor Minhua SHAO
Department of DEPARTMENT of Chemical and Biological Engineering

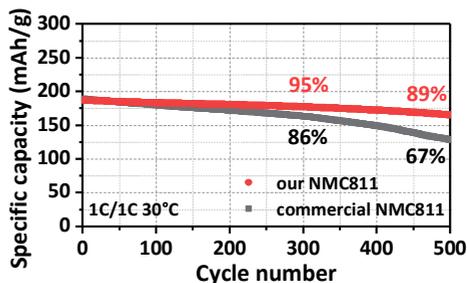
Intellectual Properties

CN Patent Application No.:
201980094484.1

Material Innovation - NMC 811



Improvement of cycling performance



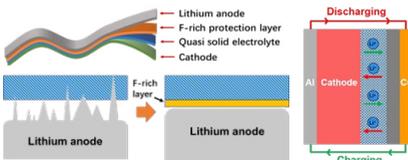
Fluoride-Rich Protective Layer for Enhanced Stability and Safety of Solid-State Lithium Battery



Technology

Solid-state lithium batteries (SSLBs) is prone to lithium dendrite formation at room-temperature, thereby lowering the ionic conductance and the overall battery performance. As such, reducing the operating temperature are essential to suppress the lithium dendrite formation.

To overcome this challenge, HKUST has developed a fluoride-rich layer constructed between the lithium metal and the electrolyte membrane to protect the lithium metal anode to realize the room temperature operation of SSLB, thereby greatly extending the battery life while maintaining optimal capacity.



Potential Applications

- ▶ IOT
- ▶ Electric vehicles
- ▶ Electric bikes
- ▶ Drones and more



Advantages

- ▶ Enhanced stability and safety profile for SSLBs
- ▶ Greatly extends the battery life (> 1600 cycles at room temperature)
- ▶ High battery capacity retention (> 86% after 1600 cycles)



Inventor

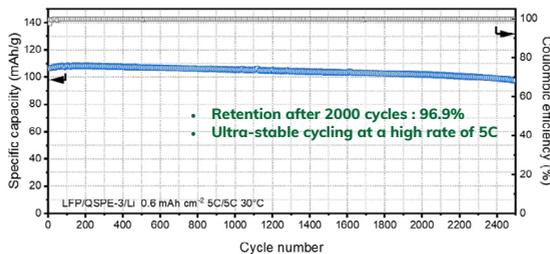
Professor Minhua SHAO
Department of Department of Chemical and Biological Engineering



Intellectual Properties

CN Patent Application No.:
202310170567.2

Performance of the invention with the protection of fluoride-rich layer



Highly Active and Cost-Effective Catalysts for Hydrogen Evolution Reactions in Electrolyzers



Technology

Electrolyzer is an energy conversion device that converts electricity to hydrogen through electrolysis in order to store intermittent renewable energy in a chemical form efficiently. Currently, the hydrogen evolution reactions (HER) in electrolyzer needs costly platinum-based nanomaterials as catalysts.

HKUST has developed an alternative catalyst consisting of palladium and ruthenium alloys, which demonstrates a higher activity level compared with platinum. As the cost of palladium and ruthenium is only 1/4 and 1/20 of platinum respectively, this catalyst replacement reduced the cost of electrolyzers significantly.



Potential Applications

- ▶ Electrolyzer



Advantages

- ▶ Low cost
- ▶ High catalytic activity level



Inventor

Professor Minhua SHAO
Department of Chemical and Biological Engineering

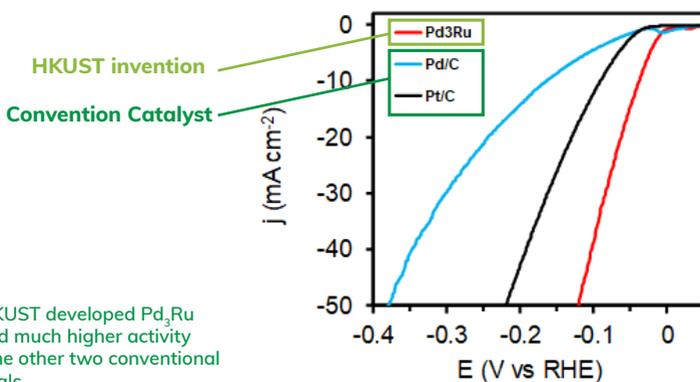


Intellectual Properties

US Patent No.: 11192091

Comparison of current density

(as a function of potential versus Reversible Hydrogen Electrode)



- ★ The HKUST developed Pd₃Ru showed much higher activity than the other two conventional materials.

Lightweight & Durable EV Battery Enclosure by Fiber Metal Laminate Composites



Technology

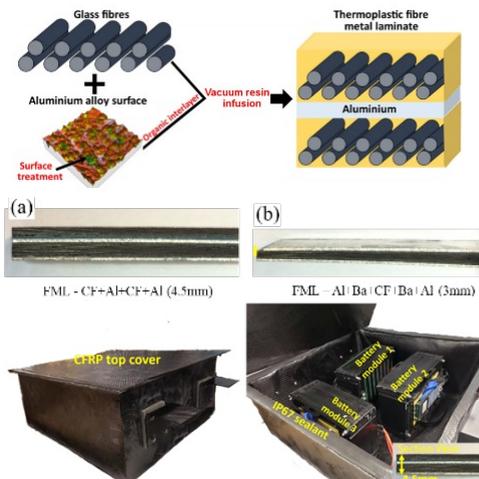
A lightweight battery enclosure with excellent impact resistance and IP rating and EMI shielding is invented by a HKUST research team. The enclosure is fabricated by multi-layer Fiber Metal Laminate (FML), combining tough metal and lightweight FRP to achieve superior mechanical performances. Compared with steel, the composite material reduces ~69% of weight.

The hybridized structure with versatile design exhibits great endurance with the configuration of fiber bridging of fatigue cracks and the residual stress capability between metal layers and composite lamina.



Potential Applications

- ▶ Battery casing for EV or other parts in vehicles



Advantages

- ▶ Lightweight, enabled by green manufacturing
- ▶ High impact resistance, stiffness
- ▶ High fatigue resistance
- ▶ Excellent corrosion resistance
- ▶ Great EMI shielding
- ▶ High flaming resistance



Inventor

Professor Jinglei YANG
Department of Mechanical and Aerospace Engineering



Intellectual Properties

US Patent Application No.: 17/577007



Self-Humidifying Membrane for Fuel Cell Application

Technology

Maintaining optimal balance of humidity is crucial for optimal proton exchange membrane fuel cell (PEMFC) performance. This supports the ionic conductivity of the membrane, allowing the efficient movement of protons (H⁺) between electrodes. HKUST develops technologies to enable self-humidifying fuel cell without the need of external humidification, thereby overcoming one of the major existing limitations that restricts the development of PEMFC.

The invented membrane shows remarkable thermal stability. The absence of external humidifier makes fuel cell smaller and compact and brings higher fuel utilization efficiency.

Potential Applications

- Fuel Cell

Advantages

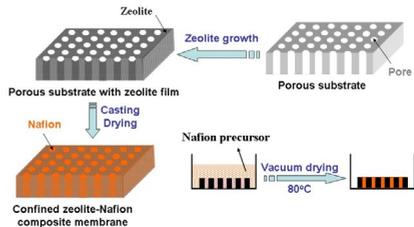
- Compact fuel cell design
- Good thermal stability
- High power density

Inventor

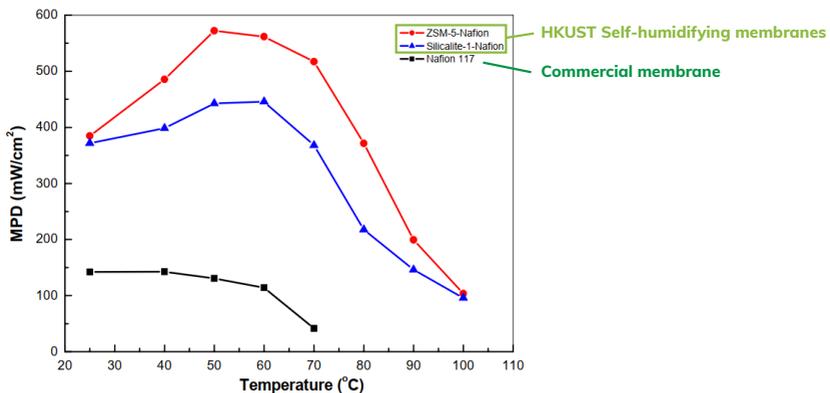
Professor King Lun YEUNG
Department of Chemical and Biological Engineering

Intellectual Properties

US Patent No.: 9077014; 9048471
CN Patent No.: ZL201210091103.4



Comparison of Maximum Power Density (MPD) output from fuel cells prepared from commercial and self-humidifying membranes at different operating temperature



High Performance Electrodes for Redox Flow Batteries Applications



Technology

HKUST presents a series of breakthrough in electrodes for redox flow batteries, achieving excellent battery performance and stability:

- ▶ A gradient negative electrode design promoting uniform distribution of reactants, suppressing dendrite formation and increasing discharge capacity and cycling stability.
- ▶ A room-temperature and zero-energy activated electrode with a simple and safe preparation method
- ▶ A multiscale porous electrode formed by spinning, interweaving, or entangling the carbon fibers; achieves high specific surface area, high catalytic activity, high permeability, and good mass-transport properties.



Potential Applications

- ▶ Design and manufacturing of electrodes for redox flow batteries



Advantages

- ▶ Up to 6x zinc deposition capacity per unit area vs conventional electrode
- ▶ Achieve an energy efficiency of >80%
- ▶ Durable as >1000 operating hours
- ▶ Coulombic efficiency $\geq 98\%$



Inventor

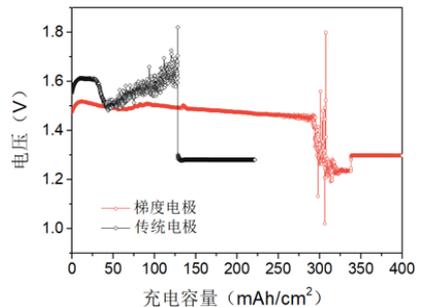
Professor Tianshou ZHAO
Department of Mechanical and
Aerospace Engineering



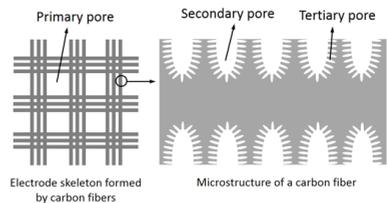
Intellectual Properties

CN Patent No.: ZL201710960189.2 ;
ZL201810194427.8 ; ZL201911396050.5

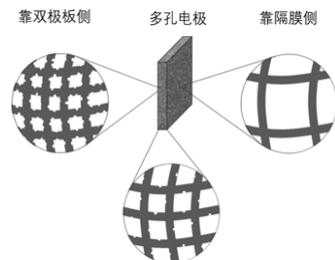
Charge capacity and cycling stability improved with HKUST's gradient negative electrode design compared with conventional electrode configuration



The schematic of the multiscale porous electrode



The schematic of the gradient negative electrode



Optimizing Performance by Electrode Selection for Vanadium Flow Battery



Technology

Vanadium Flow Batteries (VFBs) are widely used in the wind and solar power industry as energy storage devices to achieve continuous output to the power grid.

HKUST develops an advanced electrode selection method in which a single cell is first assembled to test the electrochemical impedance spectroscopy (EIS) and polarization curves. After that, the electrochemical activities, electronic conductivities, and mass transfer abilities of electrodes are evaluated based on the EIS and polarization results. The charge/discharge performance of VFBs is further examined under different operating conditions. The electrode that enables optimal battery performance can be found by analyzing the established electrode database.



Potential Applications

- ▶ Electrode screening for optimal performance of VFBs



Advantages

- ▶ Effective to reach performance optimization, enabling tailored VFB design based on different operating conditions.



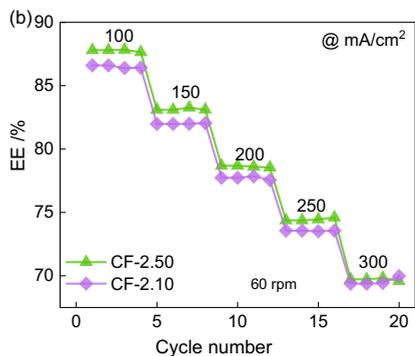
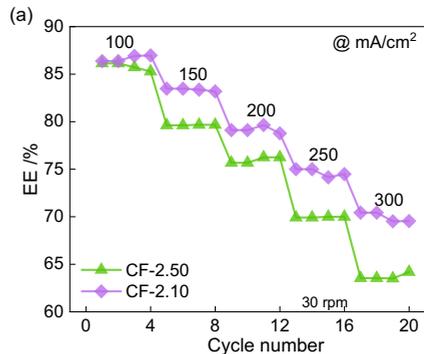
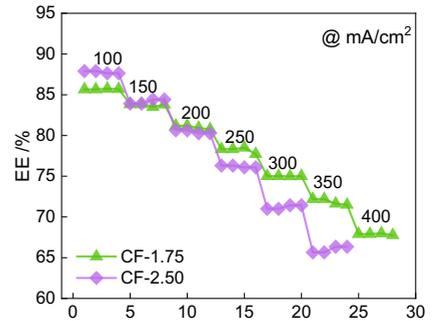
Inventor

Professor Tianshou ZHAO
Department of Mechanical and
Aerospace Engineering



Intellectual Properties

CN Patent Application No.:
202211101811.1



EE: energy efficiency

All-Rounded Performance Improvements for Vanadium Flow Battery



Technology

HKUST has developed a series of technologies to improve the performance of vanadium flow battery (VFB), tackling the performance depreciation and bottleneck issues from different angles. The technologies include:

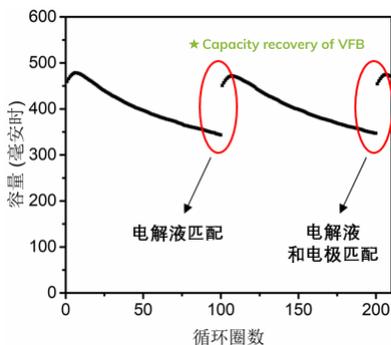
- ▶ Shifting of the concentration of active ions in the vanadium electrolyte by simple diluting method for better voltage efficiency
- ▶ A new flow field arrangement by a bipolar plate caved with bifurcate flow field to obtain uniform electrolyte distribution along branch channels
- ▶ An online method to recover the capacity and efficiency of a VFB to nearly 100% after long-term cycling by a novel mixed liquid treatment on the catholyte and anolyte



Potential Applications

- ▶ Vanadium flow batteries
- ▶ Wind and solar energy harvesting systems

VFB capacity can be recovered to ~100% after long-term cycling by HKUST's novel treatment to the catholyte and anolyte



Advantages

- ▶ Enhanced performance and endurance



Inventor

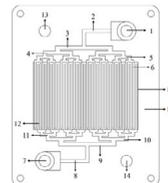
Professor Tianshou ZHAO
Department of Mechanical and
Aerospace Engineering



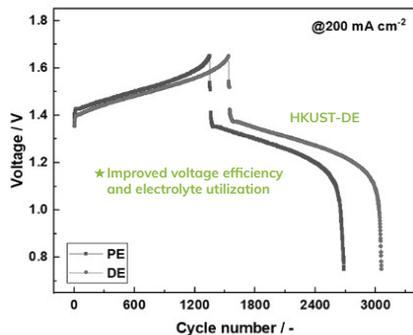
Intellectual Properties

CN Patent Application No.:
202010201043.1 ; 202111028529.0 ;
202210347593.3

Schematic of the flow field arrangement by bipolar plate



Comparison of voltage efficiency between existing Pristine Electrolyte and HKUST's Diluted Electrolyte



PE: pristine electrolyte
DE: diluted electrolyte

Integrated Configuration for Solid-State Lithium-Air Battery System



Technology

Solid-state lithium-air battery aims to combine the advantages of solid-state batteries with the high theoretical energy density potential of lithium-air batteries. HKUST integrates the electrolyte and cathode of lithium-air battery by a glass ceramic material LAMP.

The integrated electrolyte and cathode are connected seamlessly by a sintering process at high temperatures. With the new integrated design and the novel preparation method, the battery system achieves ultrathin electrolyte layer and drastically reduces the internal resistance, while also demonstrating excellent performance and stability.



Potential Applications

- ▶ Lithium-Air battery design and manufacturing



Advantages

- ▶ Ultrathin electrolyte layer : from conventional $\sim 150\text{-}600\mu\text{m}$ to $30\mu\text{m}$
-> Extremely low internal resistance
- ▶ Increased interface between electrolyte and cathode by 300 times-> increased power density
- ▶ High discharge capacity up to 18000mAh/g with a rate capability of 13mA/cm^2
- ▶ Excellent stability



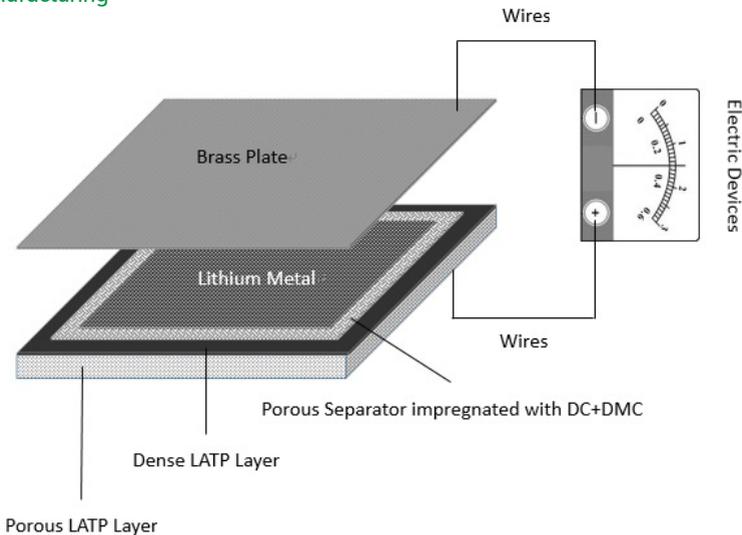
Inventor

Professor Tianshou ZHAO
Department of Mechanical and
Aerospace Engineering



Intellectual Properties

CN Patent No.: ZL201511010194.4



An Integrated Cathode/ Electrolyte Solid-State Lithium Battery (SSLB) of High Energy Density



Technology

HKUST opens up a new avenue in developing a facile, low-cost, and safe Solid-State Lithium Battery (SSLB) exhibit high performance by a novel manufacturing method.

The invented SSLB contains an integrated cathode/ultrathin composite solid electrolyte layer and a cathode layer. The integrated design between the electrolyte and cathode layer greatly improves the interface contact between the electrode and the solid electrolyte, thereby reducing internal resistance.

Moreover, the ultrathin composite solid electrolyte is reinforced by porous polymer scaffold, offering good overall mechanical strength.



Potential Applications

- ▶ Design and production of Solid-State Lithium Battery (SSLB)



Advantages

- ▶ Simplified the conventional manufacturing processes of SSLB
- ▶ Low battery internal resistance
- ▶ Compact in size with the ultrathin electrolyte (<math><20\mu\text{m}</math>)
- ▶ Superior mechanical strength



Inventor

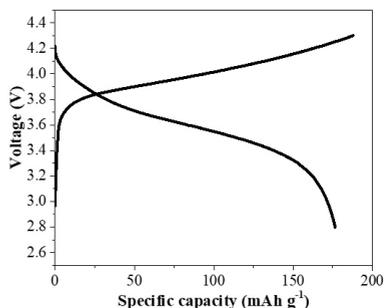
Professor Tianshou ZHAO
Department of Mechanical and
Aerospace Engineering



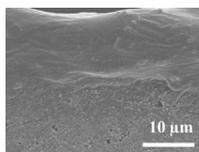
Intellectual Properties

CN Patent Application No.:
202110536488.X

The charge-discharge curve of the SSLB



SEM image of the cross-section of the integrated cathode/ultrathin composite solid electrolyte layer



- 1 Ultrathin composite solid electrolyte layer
- 2 Cathode layer

A 3-Dimensional Ordered Macro-Microporous Sulfur Host for Cathode Design of Li-Sulfur Batteries



Technology

Li-S batteries have a limitation of very severe capacity decay because of the polysulfide generated during the electrochemical reaction process that dissolves into the electrolyte and diffuses to the anode side reacting with the lithium metal.

HKUST built a 3-Dimensional ordered macro-microporous sulfur host derived from Metal Organic Framework (MOF) as the cathode materials which can work under a high sulfur content. This enables a significant elimination of the capacity decay, as well as decrease the mass transport resistance compared with conventional microporous or mesoporous sulfur hosts.



Potential Applications

- ▶ Cathode design of Li-S batteries
- ▶ Coin-cell for small electronics



Advantages

- ▶ Great capacity at high current density:
Demonstrates specific capacity of 683.3 mAh g^{-1} at high current density 5.0 C
- ▶ Great endurance
- ▶ Increase the lifetime of Li-S batteries



Inventor

Professor Tianshou ZHAO
Department of Mechanical and
Aerospace Engineering



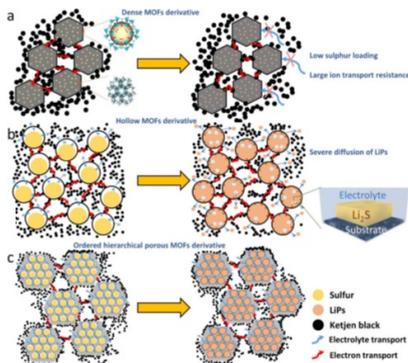
Intellectual Properties

CN Patent Application No.:
202010196322.3

Battery Performance (Test Result)

Battery Capacity	Current Density	Cycles
83%	1.0C	>300 cycles
80.2%	2.0C	1000 cycles
50.8%	5.0C	1000 cycles

Schematic of the structure of the interpenetrated polymer network (IPN) membranes



A Highly Effective Heat Dissipation Film for Lithium-Ion Battery



Technology

To enhance battery performance and safety of lithium-ion battery, HKUST designs and produces a composite heat dissipation film composed of a thermal conductive network and hydrogel. The heat dissipation film features superior properties:

- ▶ High thermal conductivity
- ▶ High water content with preserved water content
- ▶ Very flexible with good mechanical strength



Potential Applications

- ▶ Lithium-ion battery thermal management



Advantages

- ▶ Fits to different shapes of Li-ion batteries
- ▶ Abundant raw material and low cost
- ▶ Easily degradable and environmentally friendly



Inventors

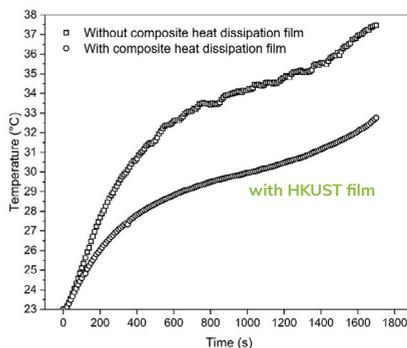
Professor Tianshou ZHAO,
Professor Jianbo XU
Department of Mechanical and
Aerospace Engineering



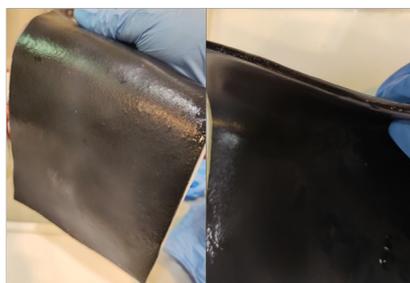
Intellectual Properties

CN Patent Application No.:
202210366976.5

Performance of the composite heat dissipation film on a 25Ah pouch Li-ion battery



The outlook of composite heat dissipation film





Energy Efficient System

Smart Polymer Processing Plant (S-P ³) - Open Collaborative Intelligent Platform	P.27
Energy Saving Kettle with Heat Exchanger	P.28
Ultrathin Vapour Chamber for Electronics Heat Dissipation	P.29
Green-House-Gas-free Elastocaloric Cooling/Heating Technology - Materials and Devices.....	P.30
Nano-enabled Circular Technologies for Sustainable and Negative Carbon Lifestyle	P.31
A Sustainable Evaporative Cooling Coating within a Broad Range of Relative Humidity	P.32

Smart Polymer Processing Plant (S-P³) - Open Collaborative Intelligent Platform



Technology

The next-generation intelligent injection molding with real-time material and quality monitoring has been developed using breakthrough sensors, award-winning control algorithms for superior precision, and a dedicated big-data system for intelligent collaboration.

Key Technology Edge:

- ▶ Breakthrough and world-first sensor for capturing material and quality changes in real-time
- ▶ Award-winning control algorithms for superior precision injection molding
- ▶ Dedicated big-data open system for collaborative intelligent molding



Potential Applications

- ▶ A smart sensor for a huge injection mold market of 14 million molds annually for Mainland China alone
- ▶ A smart control system for millions of production lines
- ▶ The world's first real intelligent system platform for thousand polymer processing plants with collaborative development applications



Advantages

- ▶ Energy and cost-saving
- ▶ Reduces waste materials
- ▶ Improves polymer product quality
- ▶ Real-time quality monitoring
- ▶ Collaborative intelligent molding



Inventor

Professor Furong GAO
Department of Chemical and Biological Engineering

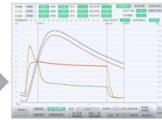


Intellectual Properties

CN Patent No. : ZL201520916639.4 ; ZL201920788422.8 ; ZL201510762903.8

In-Mold Capacitive Sensor System

long-life sensor tip



Intelligent signal interpretation software



曾获本领域最高水平国际年会SPE ANTEC 唯一最佳注册论文奖

High-precision capacitive signal transmitter

Parameters	Typical System by Mainland China suppliers	Typical System by Europe, USA and Japan suppliers	HKUST CPPS Smart Control System
Temperature overshoot	5-30 °C	2-5 °C	1 °C
Precision of temperature control (at steady state)	Approx. 2 °C	Approx. 1 °C	0.5 °C
Precision of mold positioning	2-5mm	Approx. 0.5mm	0.25mm
Injection speed	Open Loop control	Closed Loop Control (Cost intensive)	Closed Loop Control (Low Cost)
Packing Pressure	Open Loop control	Closed Loop Control (Cost intensive)	Closed Loop Control (Low Cost)



Energy Saving Kettle with Heat Exchanger



Technology

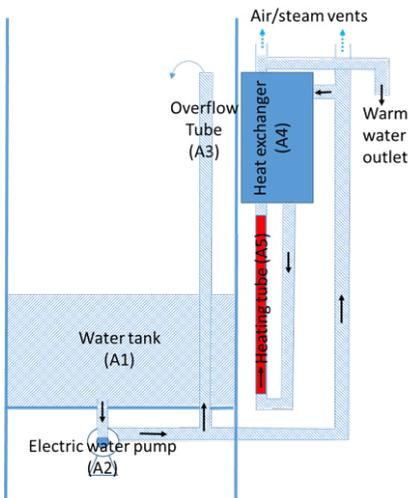
Water boiling is a very large market in both household and commercial or industrial sectors. Conventional water kettle boils water to the boiling point and one needs to cool down the water to drinkable temperature, which is time and energy inefficient.

HKUST has developed a simple and smart invention that can deliver boiled water at a decent drinkable temperature, achieving time, cost and energy-saving purposes.



Potential Applications

- ▶ Industrial-grade water boilers
- ▶ Domestic water boilers
- ▶ Drinking water dispatch system in restaurants, offices, etc



Advantages

- ▶ Power reduction up to 75%
- ▶ Time-saving
- ▶ Simple and low-cost
- ▶ Variations of the system can be achieved easily to fit for different purposes



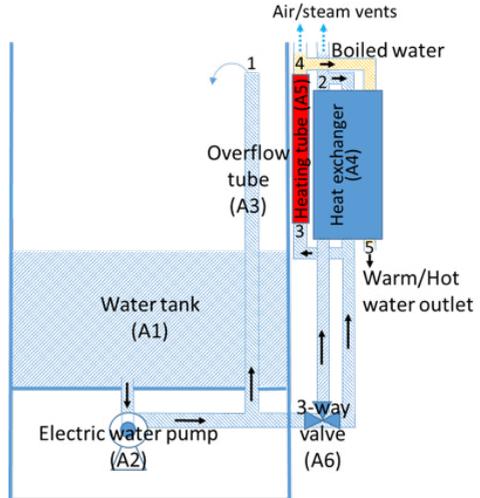
Inventor

Professor Chi Wai HUI
Department of Chemical and Biological Engineering



Intellectual Properties

CN Patent No.: ZL202020166175.0



Ultrathin Vapor Chamber for Electronics Heat Dissipation

Technology

HKUST developed a type of wettability patterned evaporator adopting nanostructured mesh for ultrathin vapor chamber which can be functioned as heat dissipator for electronics. The invention is ultrathin (as low as $190\mu\text{m}$), with excellent temperature uniformity (>30 times kCU) and flexibility to work under a bended condition, hence ideally for use in thermal management for high-efficiency electronics with space constraint, such as personal mobile devices.

Inventors

Professor Huihe QIU and Dr. Yinchuang YANG
 Department of Mechanical and Aerospace Engineering

Intellectual Properties

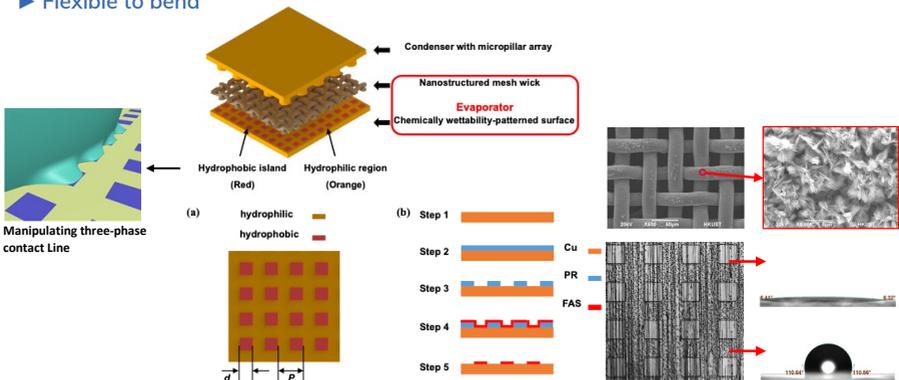
US Patent No.: US 9,685,393 B2
 CN Patent Application No.: 201910912018.1
 HK Patent Application No.: 42021032640.1

Potential Applications

- ▶ Smartphone and tablet devices
- ▶ High efficiency electronics
- ▶ Flexible electronics devices
- ▶ Power battery thermal management

Advantages

- ▶ Extra thin ($<200\mu\text{m}$)
- ▶ Effective horizontal thermal conductivity $> 11,500 \text{ W/(m}\cdot\text{K)}$ (10 times of graphene)
- ▶ High heat dissipation capacity
- ▶ Flexible to bend



Green-House-Gas-Free Elastocaloric Cooling/ Heating Technology - Materials and Devices



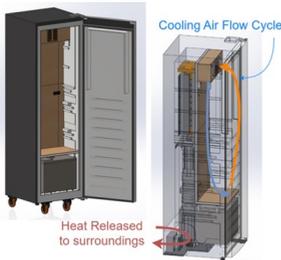
Technology

By harvesting the unique phase transformation latent heat of shape memory alloys, the elastocaloric effect is utilized and developed into cooling/heating modules like fridges and air conditioners. This green technology revolutionizes the conventional refrigeration technology that has been using harmful refrigerants for decades.

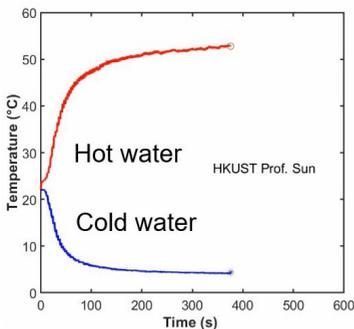


Potential Applications

- ▶ Fridges
- ▶ Air conditioners
- ▶ Homes, office rooms, shopping malls, industries. Anywhere in need of cooling



Heat exchange performance of the prototype



Advantages

Compared with the conventional vapor-compression cooling, our elastocaloric cooling technology has the following advantages:

- ▶ Completely avoid the usage of greenhouse gas refrigerants. Use solid shape memory alloys instead
- ▶ Save electricity consumption and reduce carbon emission by at least 10%
- ▶ The cooling core material (shape memory alloy) is a typical smart material that is 100% recyclable



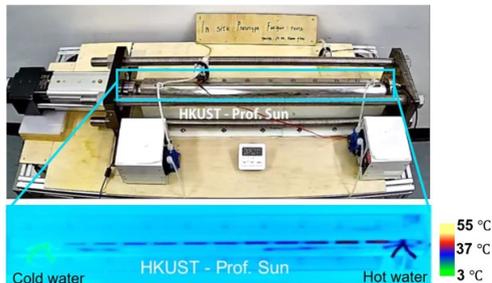
Inventor

Professor Qingping SUN
Department of Mechanical and
Aerospace Engineering



Intellectual Properties

CN Patent Application No.:
202110913517.X ; 202110167797.4 ;
202111402483.4 ; 202110231470.9 ;
202010800831.2



Thermal image of the heat exchange fluid (water) in prototype

Nano-enabled Circular Technologies for Sustainable and Negative Carbon Lifestyle

Technology

Two breakthroughs circular, net-zero technologies, **NanoDew** and **h-NanoSurface**, are designed to increase air conditioners' cooling efficiency through rapid moisture condensation and air dehumidification to attain 20-25% electricity savings. Its applications can extend to various cooling appliances & systems as well as enhancing energy conservation and sustainability through applications in water harvesting and reversing desertification.

Potential Applications

- ▶ Air conditioners, dehumidifiers, refrigerations
- ▶ Water harvesting and reversing desertification
- ▶ Food production & storage
- ▶ .. and various industrial applications!

Advantages

- ▶ 25% Improved cooling efficiency
- ▶ 10% Decrease in greenhouse gas emission per household
- ▶ 15% Reduction in electricity bill
- ▶ Durable, self-cleaning & antibiofouling
- ▶ Highly scalable for mass fabrication/ manufacturing

Why? and Hows?

Safe & Green
Inexpensive
Manufactured

No Energy Smart
Off Grid
Zero Carbon Clean



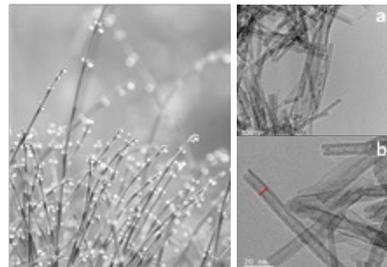
Inventor

Professor King Lun YEUNG
Department of Chemical and Biological Engineering

Intellectual Properties

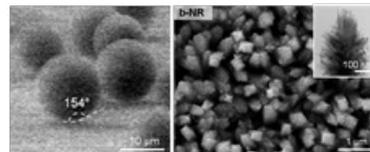
US Patent No. 10486102
CN Patent No. ZL201580055648.1
HK Patent No. HK1238198
CN Patent Application No. 202310420865.2

NanoDew



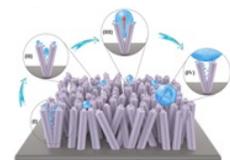
Rapid moisture condensation

h-NanoSurface



Floating water droplets

Efficient surface cooling



h-NanoSurface

A Sustainable Evaporative Cooling Coating within a Broad Range of Relative Humidity



Technology

HKUST has developed a novel coating material composed of MOF and hygroscopic salt. The coating can achieve cooling in the surface via the adsorption-evaporation process of atmospheric water.

This is an excellent agent of green cooling strategy. The material possesses high cooling power (up to 300W/m²) in a wide range of relative humidity ambient environments (28%-70%) and large maximum cooling temperatures (up to 15°C).



Potential Applications

- ▶ Building materials
- ▶ Data centers
- ▶ Solar panels
- ▶ Battery cooling systems



Advantages

- ▶ Zero energy consumption
- ▶ Work effectively in a wide range of relative humidity
- ▶ Good cooling gradient



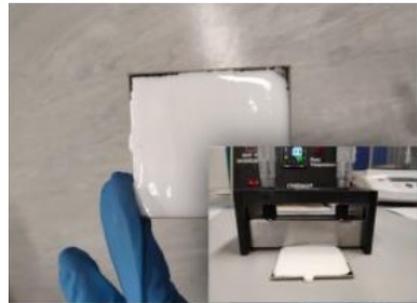
Inventor

Professor Yanguang ZHOU
Department of Mechanical and
Aerospace Engineering

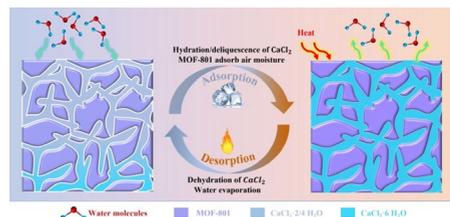
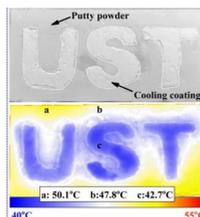
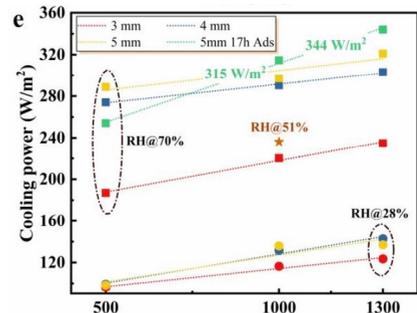


Intellectual Properties

US Patent Application No.: 18/322242
CN Application No.: 202310508660.X
HK patent application in-progress



The calculated cooling power of HKUST CaCl₂@MOF-801 based coatings with various thicknesses under different solar irradiations





Energy Harvesting

Solution-Processed Selective Solar Absorbers.....	P.34
Highly Efficient Organic Solar Cell.....	P.35
An Anti-Static, Anti-Reflection and Self-Cleaning Nano-Coating for PV Panel Efficiency Enhancement.....	P.36

Solution-Processed Selective Solar Absorbers

Technology

HKUST invents a solution-processed ceramic solar absorber by scalable fabrication method at low-cost with commercially abundance materials. The design can achieve great solar absorptance, low thermal emittances with great spectral selectivity and long-term thermal stability.

The invention consists of an infrared reflector, a ceramic absorptive coating, a SiO₂ anti-reflection coating. The absorption bandwidth can be adjusted by controlling the thickness of the coating.

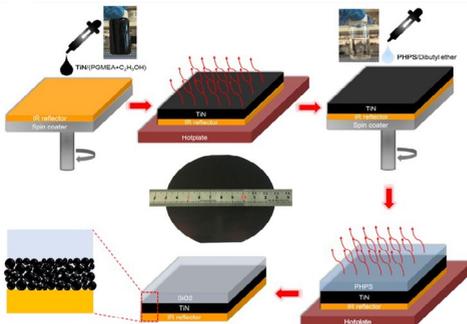
Potential Applications

- ▶ Solar steam generation
- ▶ Solar heating
- ▶ Seawater desalination

Advantages

- ▶ Low cost (<\$1-2/m²)
- ▶ Compatible with various substrates
- ▶ Excellent long-term thermal stability up to 1000K

Simplified process of the fabrication of the solar absorber



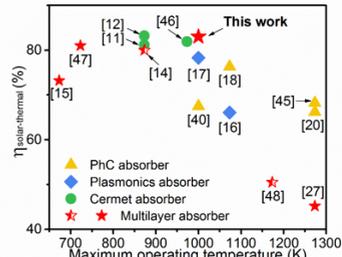
Inventor

Professor Baoling HUANG
Department of Mechanical and
Aerospace Engineering

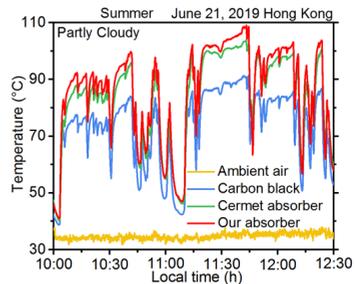
Intellectual Properties

CN Patent No.: ZL202010775417.0
HK Patent No.: HK40037864
US Patent Application No.:16/947516

Efficiency of solar-thermal energy conversion - Comparison of HKUST invention and other multilayer absorber



Comparison of the thermal absorption performance by an experiment (HKUST absorber showed the best thermal absorption consistently)



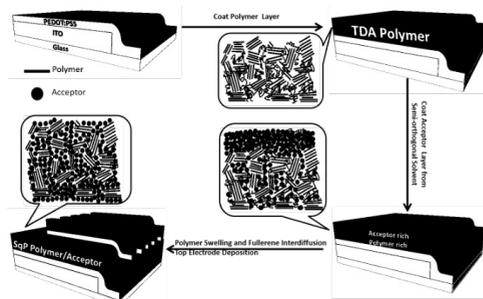
Highly Efficient Organic Solar Cell

Technology

HKUST is devoted to driving sustainable energy harvesting. Through a series of inventions on advanced materials and fabrication methodologies related to organic solar cells, HKUST presents a significant series of technologies with demonstrated great efficiency.

The series of key inventions include:

- ▶ A vertical **benzodithiophene (vBDT) building block** which can be paired with acceptor to achieve an efficient organic solar cells
- ▶ A series of **acceptor-donor-acceptor (A-D-A) acceptors** based on fused thiophene system named IXT for organic solar cells demonstrating remarkable power conversion efficiency
- ▶ A **helogenation strategy** to improve thiophene-based electron acceptors performance
- ▶ A series of polymer donors based on **Chlorinated benzodithiophene unit** for OPV devices
- ▶ Methodology to **sequentially process Organic Solar Cells' active layer** in large application area with excellent reproducibility



Potential Applications

- ▶ Organic Solar Cell

Advantages

- ▶ High power conversion efficiency (PCE) up to 12.7%
- ▶ High reproducibility

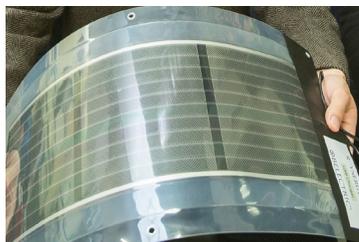
Inventor

Professor He YAN
Department of Chemistry

Intellectual Properties

CN Patent No.: ZL201880017468.8 ;
ZL201980006127.5 ; ZL201880024183.7
US Patent No.: 11205753
CN Patent Application No.:
201980005239.9 ; 202010369781.7
HK Patent Application No.:
42021027930.3

The invented high efficiency organic solar cell



An Anti-Static, Anti-Reflection and Self-Cleaning Nano-Coating for PV Panel Efficiency Enhancement



Technology

HKUST develops a nanocoating, concurrently possessing multiple functions including super-hydrophilic, anti-static, anti-reflection, weather resistant features, significantly enhances the power generating efficiency of PV panels.

The product can also be extended to specific fields (such as building envelope systems/automobile glass windows) by integrating self-cleaning, anti-fogging and de-frosting properties, thereby reducing maintenance, manufacturing and decarbonization costs.



Potential Applications

- ▶ Bathroom mirror
- ▶ Curtain wall window
- ▶ Automobile windscreens
- ▶ PV panels



Advantages

- ▶ Super-hydrophilic
- ▶ Excellent antistatic, anti-reflection, weather resistance, and water scouring resistant
- ▶ Improves PV panels efficiency by ~20%
- ▶ Saves 50% on cleaning labor cost



Inventor

Professor Jinglei YANG
Department of Mechanical and
Aerospace Engineering



Intellectual Properties

CN Patent No.: ZL202011014257.4



Fill up our online inquiry form if you want to further explore the technologies in this booklet :



https://ust.az1.qualtrics.com/jfe/form/SV_aUUMKEGewJAzCd0



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