

Nanofluidics : **fluid properties at the molecular scale and application to water treatment** **and energy conversion**

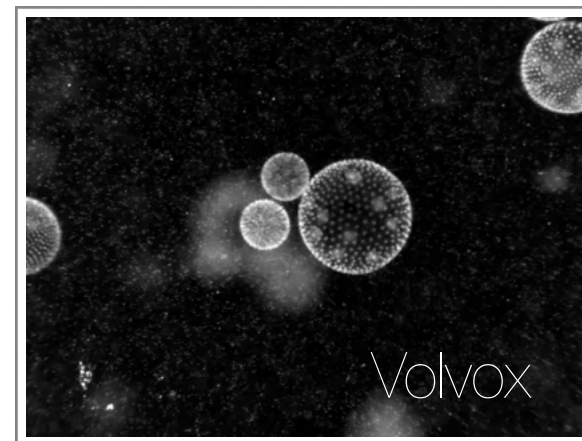
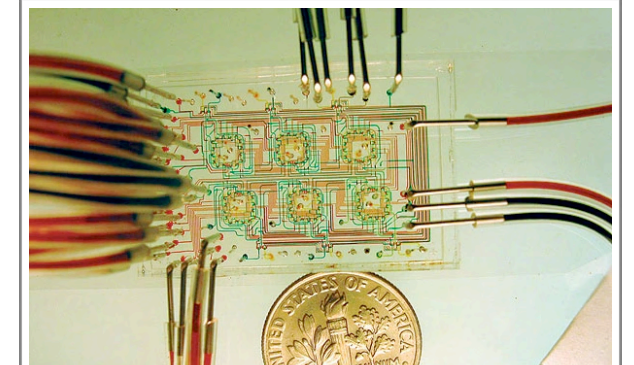
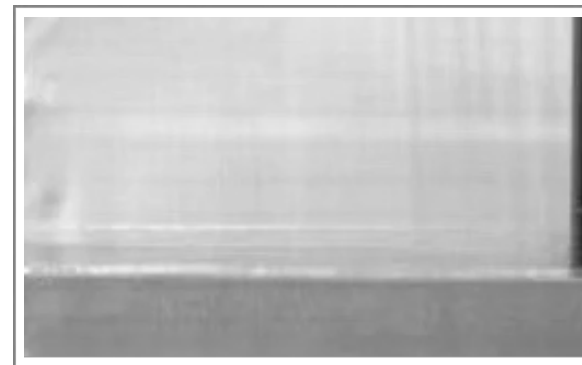
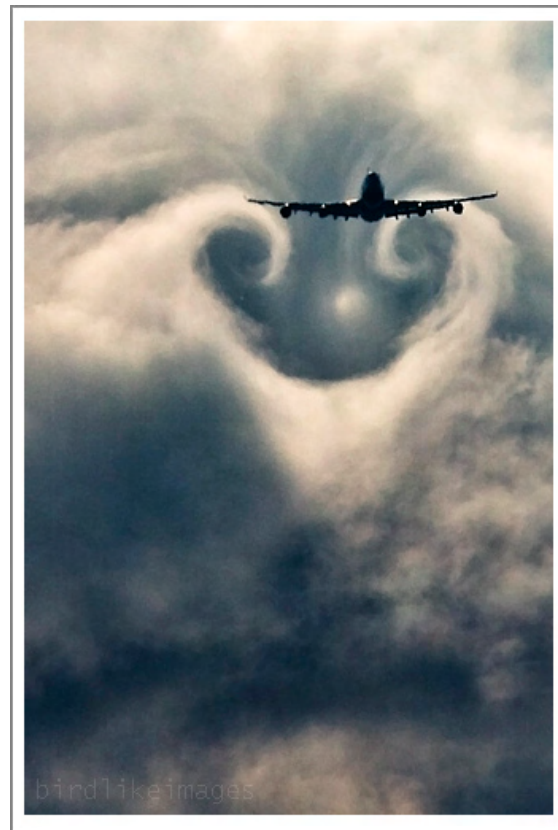
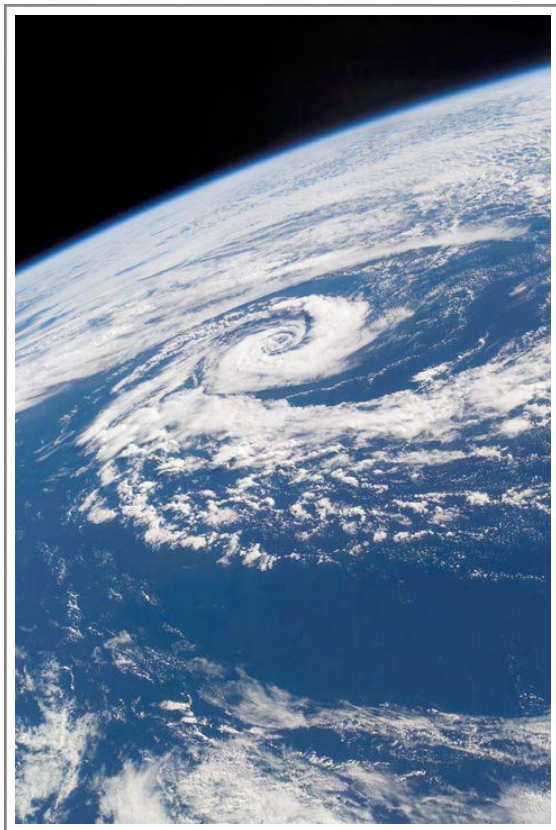
Laboratoire de Physique, Ecole Normale Supérieure Paris & CNRS

Alessandro Siria, Marie-Laure Bocquet, Lydéric Bocquet



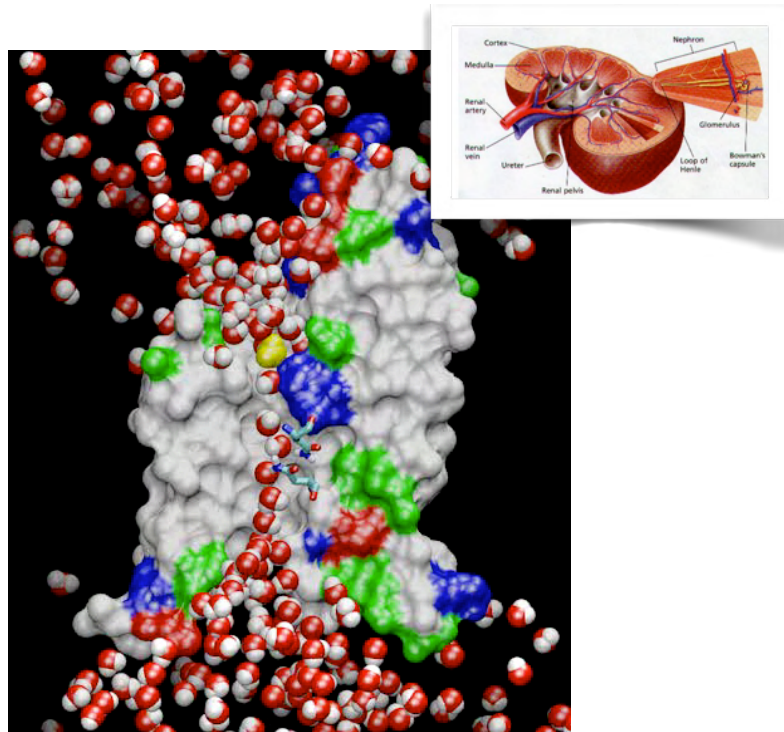
HYDRODYNAMICS : FIELD OF SCIENCE STUDYING BEHAVIOUR OF FLUIDS

$$\rho \left(\frac{\partial \vec{v}}{\partial t} + \vec{v} \cdot \nabla \vec{v} \right) = - \nabla P + \eta \Delta \vec{v}$$



The amazing, *universal*, Navier-Stokes

GETTING INSPIRED BY NATURE



Nature developed fluidic channels at the molecular scale with enhanced performances!

new properties at nanoscales ? new assets to play ?



National Graphene Institute, UK

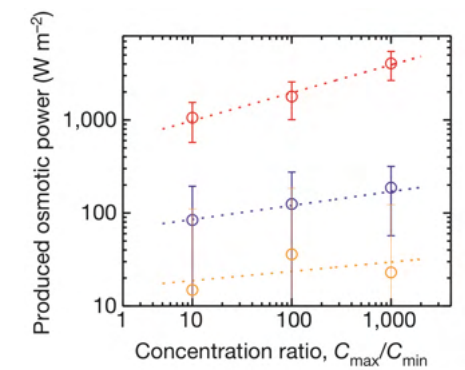
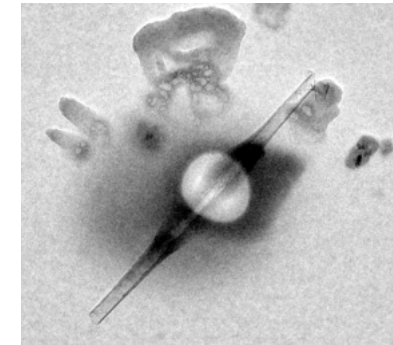


MIT water initiative, USA

FUNDAMENTAL BREAKTHROUGHS

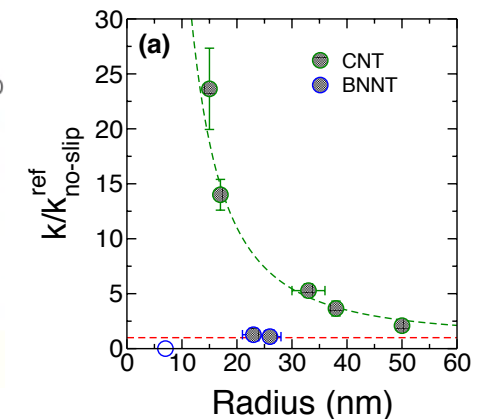
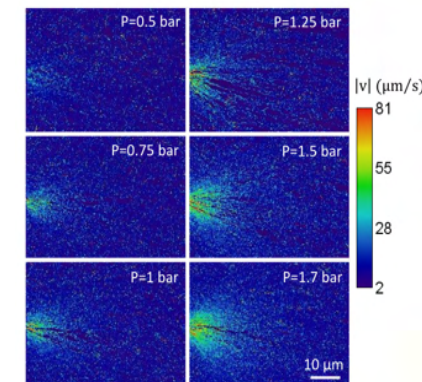
- Osmotic energy conversion in BN nanotubes

Siria et al. Nature (2012), Nature Rev. Chemistry (2017)



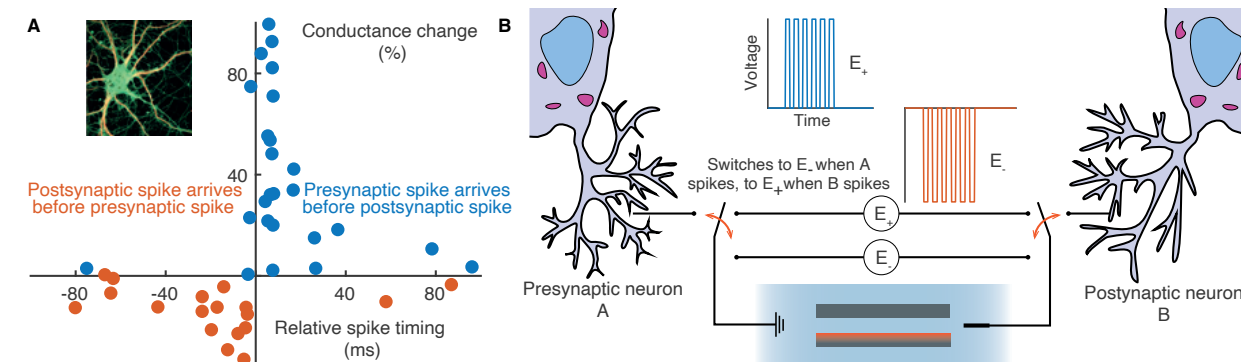
- Quantum enhanced fluidic transport in Carbon nanochannels

Secchi et al. Nature (2016),
Kavokine et al. Nature (2022)



- Graphene based Iontronics

Robin et al. Science (2021)



SHORT PATH TO INNOVATION

Blue energy: a fully renewable source of energy



Efficient water and liquid treatment



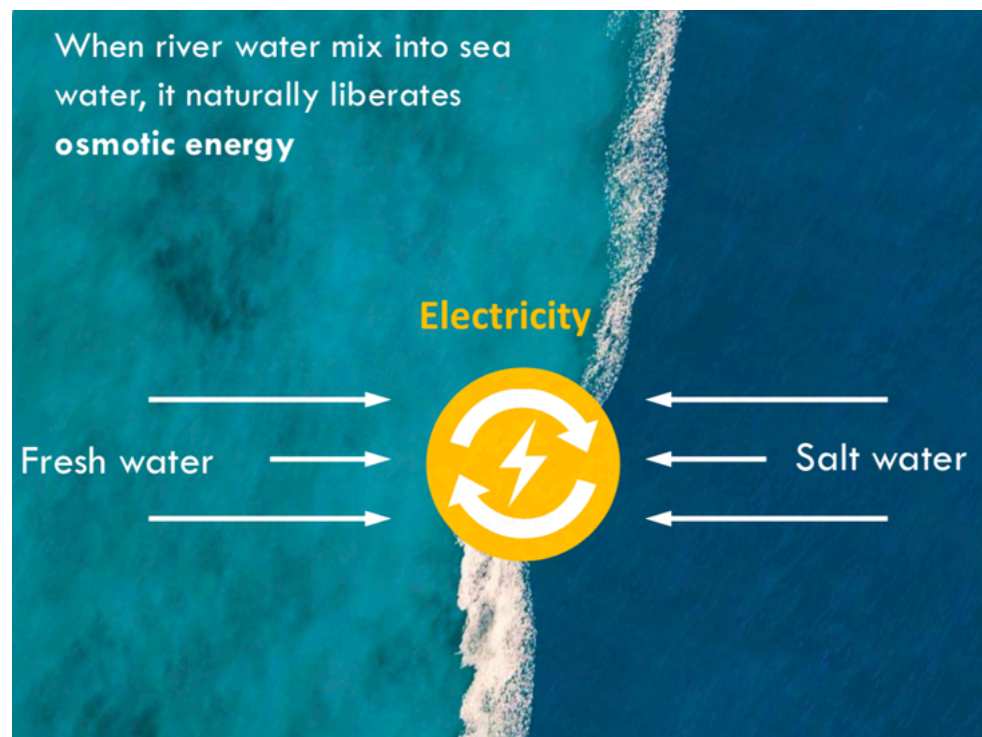
Additive nanoscale printing



Novel class of nanoscale instruments



WHAT IS OSMOTIC ENERGY?



Mixing is a spontaneous phenomenon : we can then extract and convert this “hidden” energy.

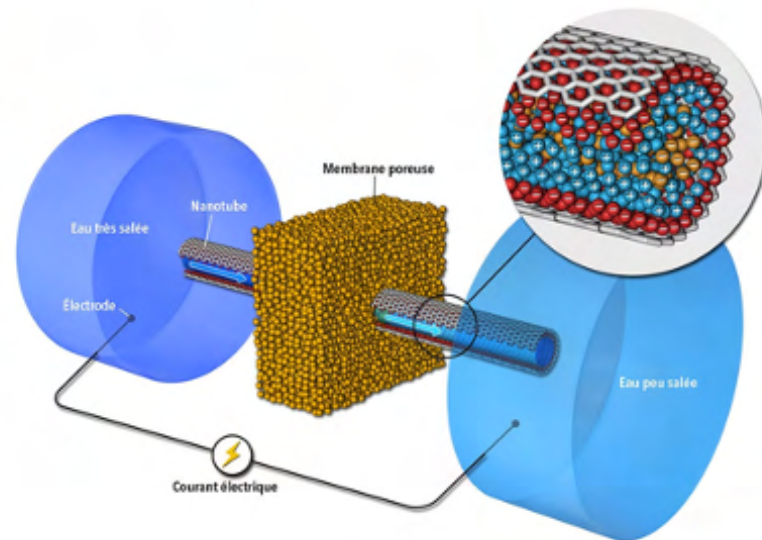
This energy comes from the disorder : we can translate Entropy in Energy and Electricity

What is the maximum energy available?

$$\Delta G_{\text{mix}} \approx -T \Delta S_{\text{mix}} \approx 1 \frac{\text{kWh}}{\text{m}^3} \quad \Rightarrow \quad \textbf{>20000 TWh/year}$$

2000 Nuclear reactors

THE MIRACLE OF NANOMATERIALS



Novel nanomaterials exhibiting enhanced surface reactivity to water can boost energy conversion

LETTER

doi:10.1038/nature11876

Giant osmotic energy conversion measured in a single transmembrane boron nitride nanotube

Alessandro Siria¹, Philippe Poncharal¹, Anne-Laure Biance¹, Rémy Fulcrand¹, Xavier Blase², Stephen T. Purcell¹ & Lydéric Bocquet¹

LETTER

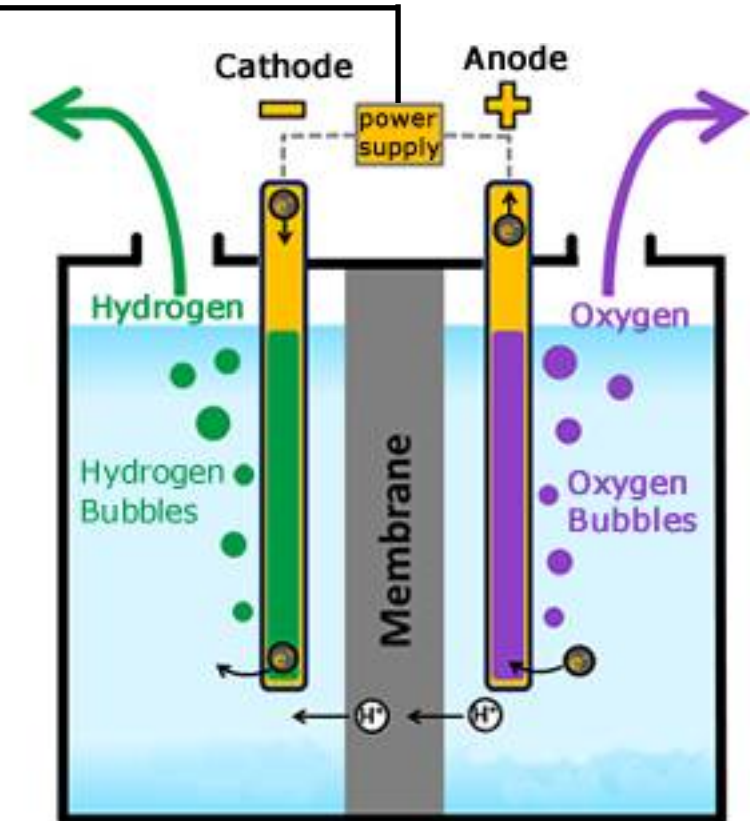
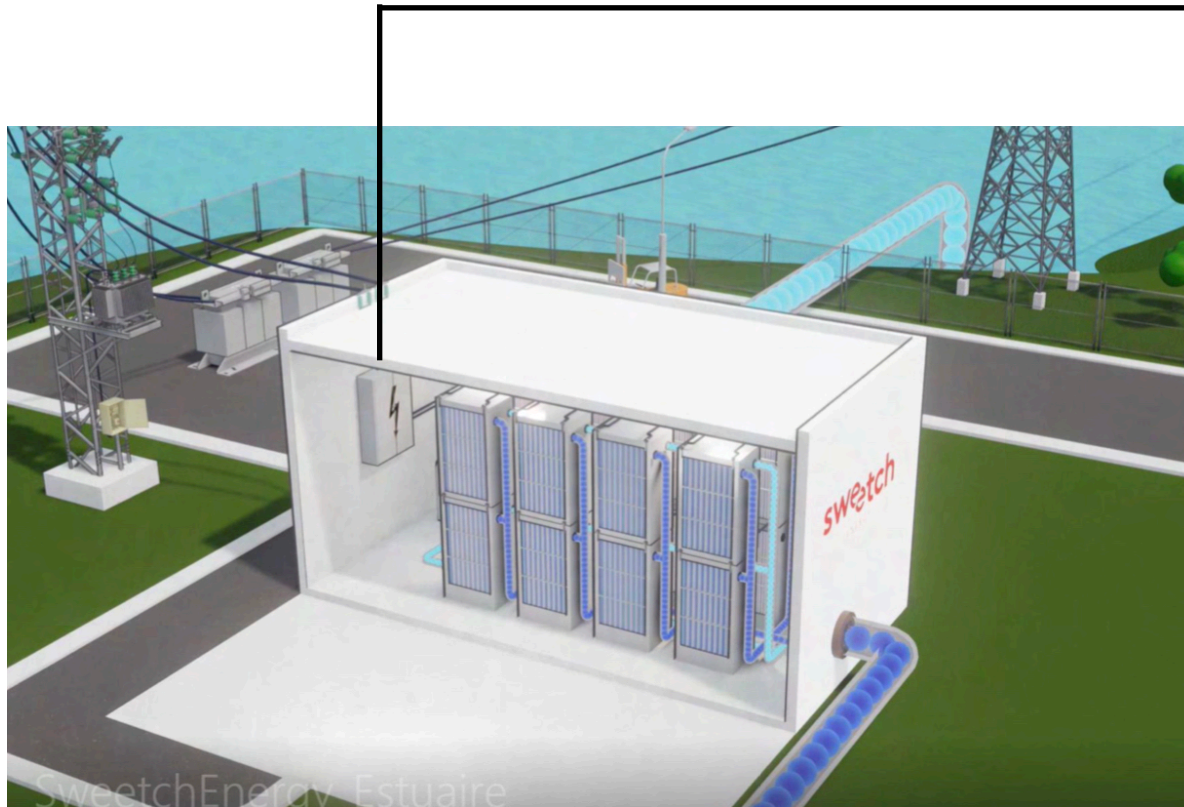
doi:10.1038/nature18593

Single-layer MoS₂ nanopores as nanopower generators

Jiandong Feng¹, Michael Graf¹, Ke Liu¹, Dmitry Ovchinnikov², Dumitru Dumcenco², Mohammad Heiranian³, Vishal Nandigana³, Narayana R. Aluru³, Andras Kis² & Aleksandra Radenovic¹

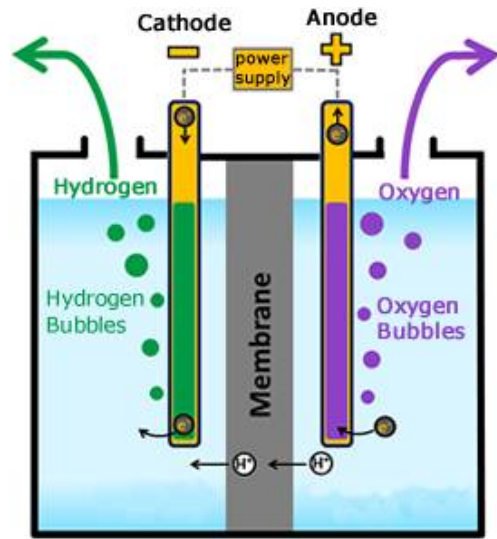
FROM LAB TO INDUSTRY : NEED TO SCALE UP

NEW CHANCES FOR GREEN HYDROGEN

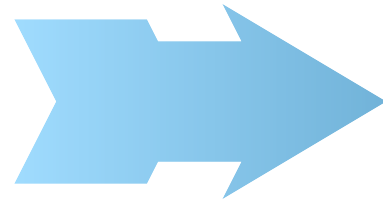


Delocalized and democratic source of energy to power electrolysis set-up

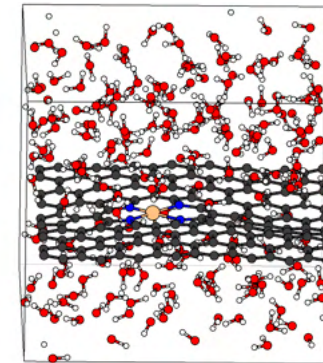
UNLEASHING THE POWER OF INOD FOR GREEN HYDROGEN



Standard electrolysis setup



INOD membrane stack

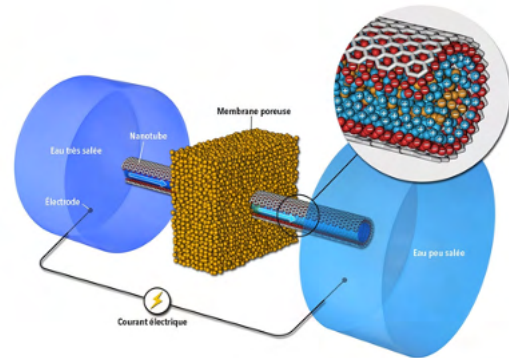


**Quantum simulation
for single atom
catalysis**

Tailored membrane made by Sweetch together with advanced Catalysis technologies

MANY GAMES TO PLAY

Blue energy: a fully renewable source of energy



sweetch
ENERGY



Advanced nanofluidic functionalities can boost green hydrogen production

