Future robots need no motors – HKU Engineering invents world's first nickel-hydroxide actuating material that can be triggered by both light and electricity

港大工程研創以光或電驅動「「氫氧化鎳」材料 - 機器人將可毋須倚賴摩打推動

Department of Mechanical Engineering,
University of Hong Kong

香港大學機械工程系

Funding Support: Research Grants Council, Hong Kong

研究經費：香港研究資助局

研發機器人的十大挑戰

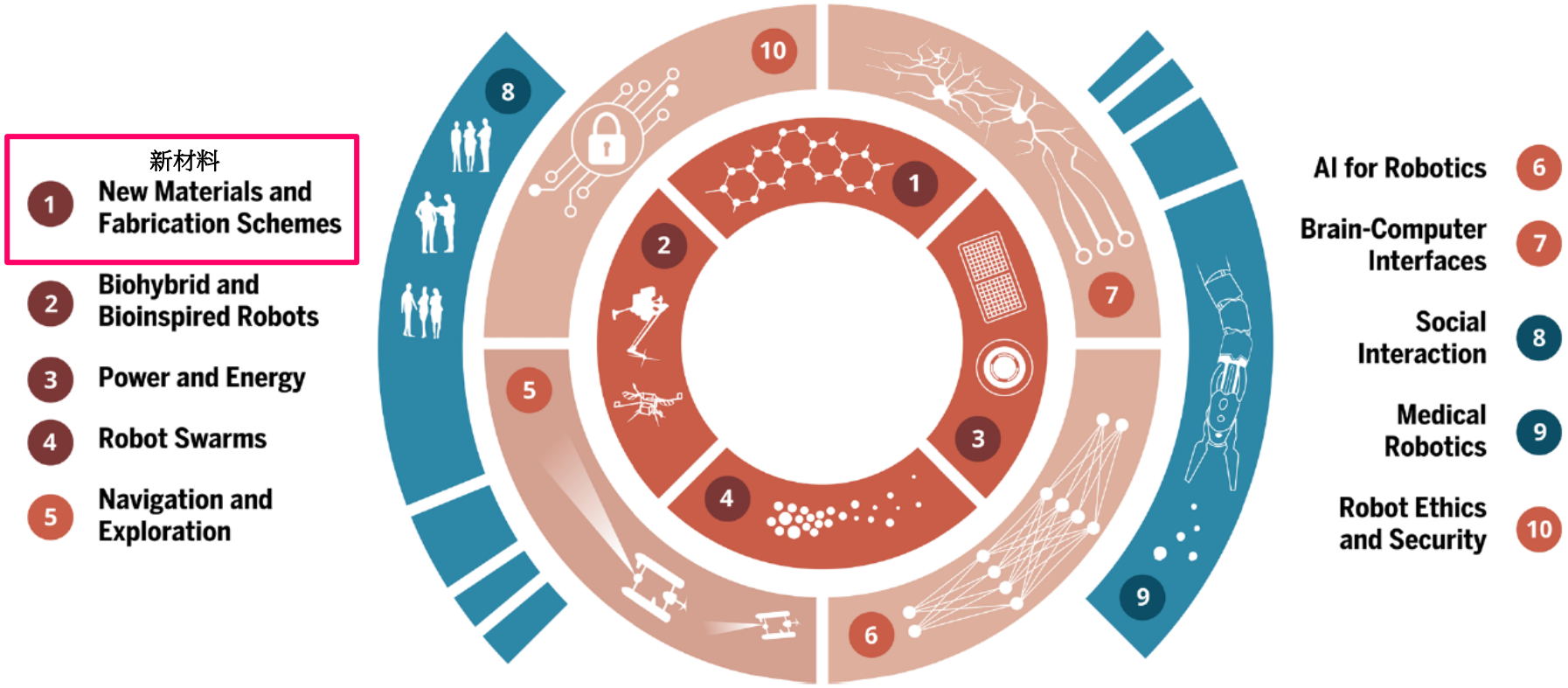


Fig. 1. Ten grand challenges of *Science Robotics*.

Yang et al. "The grand challenges of *Science Robotics*", *Science Robotics 3, eaar7650 (2018)*

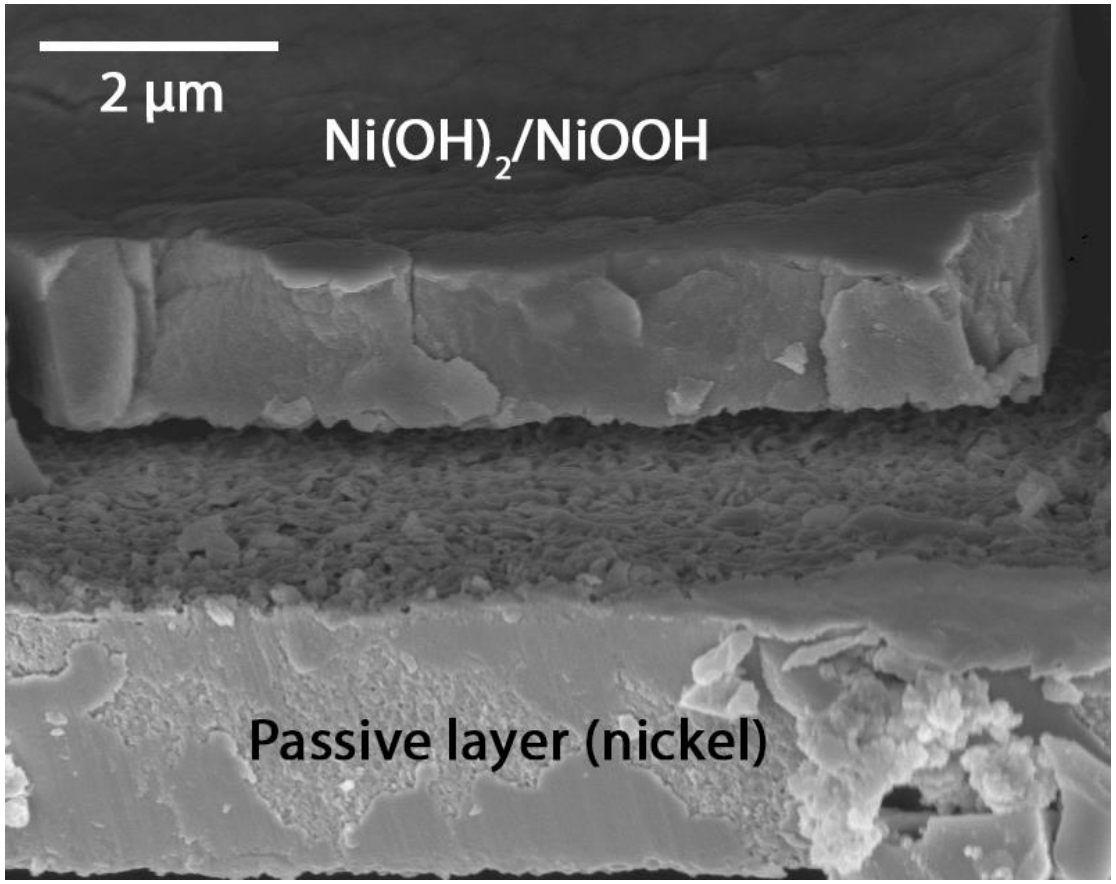
Future micro-robots need compact actuators that can be triggered by different means, such as electricity and light.

未來的微型機器人需要可以通過不同方式(如光和電)觸發的驅動材料

At HKU, we discovered a new actuating material, $Ni(OH)_2/NiOOH$

港大發現了一種新型的驅動材料氫氧化鎳($Ni(OH)_2/NiOOH$)

$Ni(OH)_2/NiOOH$ deposited on a passive layer (e.g. Ni) by anodic electrodeposition:
通過陽極電沉積法, 將$Ni(OH)_2/NiOOH$塗在被動層（例如鎳金屬）上：



電(< 1V)和光可以驅使氫氧化鎳移動

$Ni(OH)_2$/NiOOH can be made to move by

(i) electrochemical (electrical) voltages of < 1V

(ii) light

(I) Electrochemical actuation in $Ni(OH)_2/NiOOH$: 氫氧化鎳的電化學驅動機理

unit cell volume: **117.6 Å³**

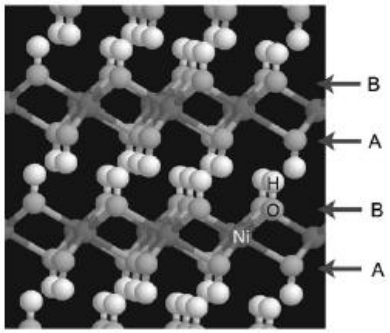
晶胞體積

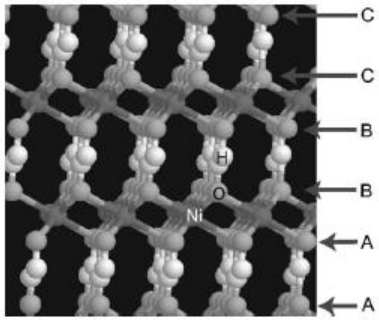
$\beta - Ni(OH)_2$ ⇌ $\beta - NiOOH$

氧化 oxidation

reduction 還原

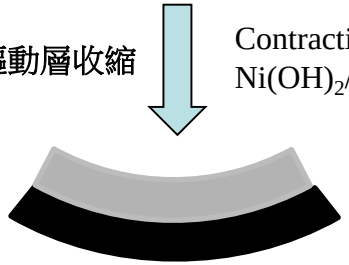
99.3 Å³



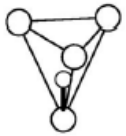


驅動層收縮

Contraction of $Ni(OH)_2/NiOOH$ layer

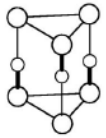


Off-center tetrahedral hydrogen



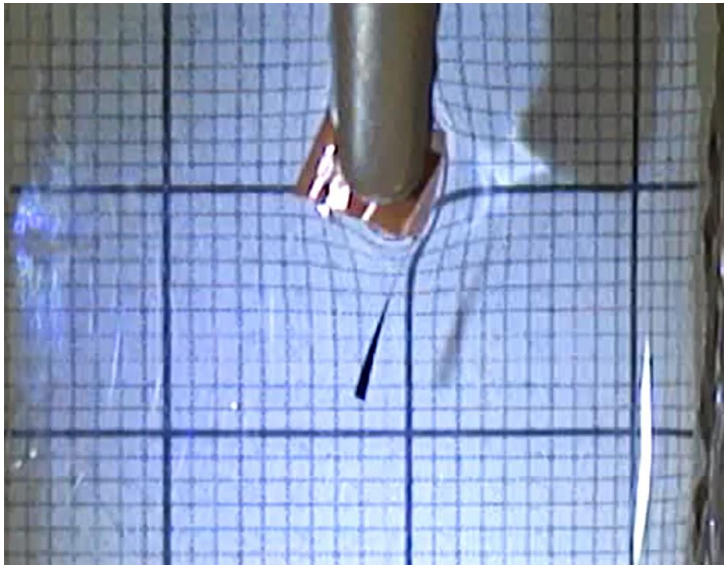
Van der Ven et al.
J. Electrochem. Soc. 153, A210

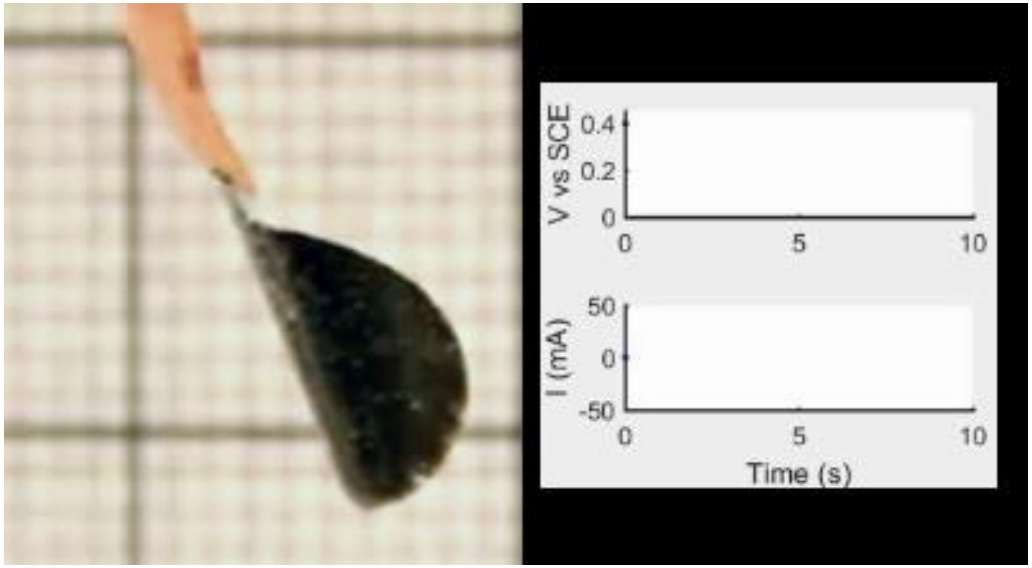
O-H-O bonds in trigonal prismatic sites

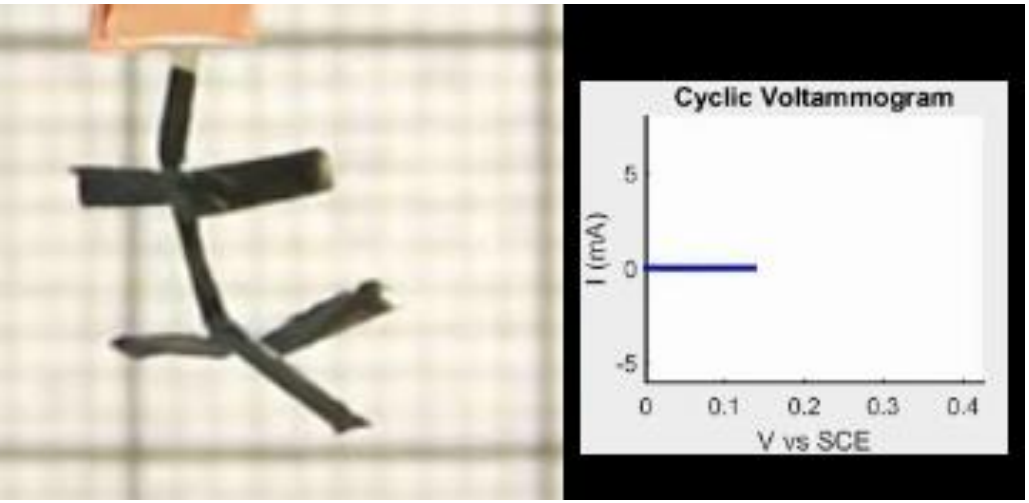


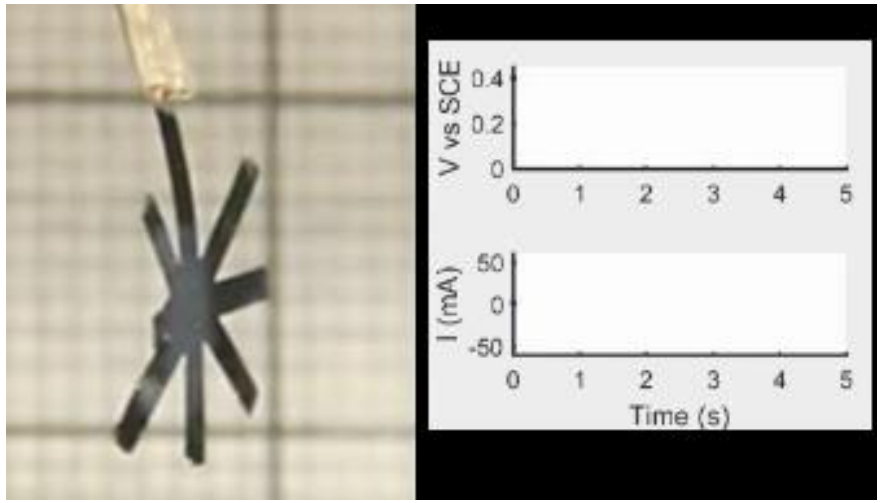
Some of the electrochemical actuators we produced:

我們研發電化學驅動器的例子









How to produce large device movements?

如何產生巨大的器件動作？

Contraction of

$Ni(OH)_2/NiOOH$ layer

器件曲度
Curvature κ

$$\text{Curvature } \kappa \propto \frac{t_a}{t_p^2 E_p}$$

器件曲度

stiffness of passive layer

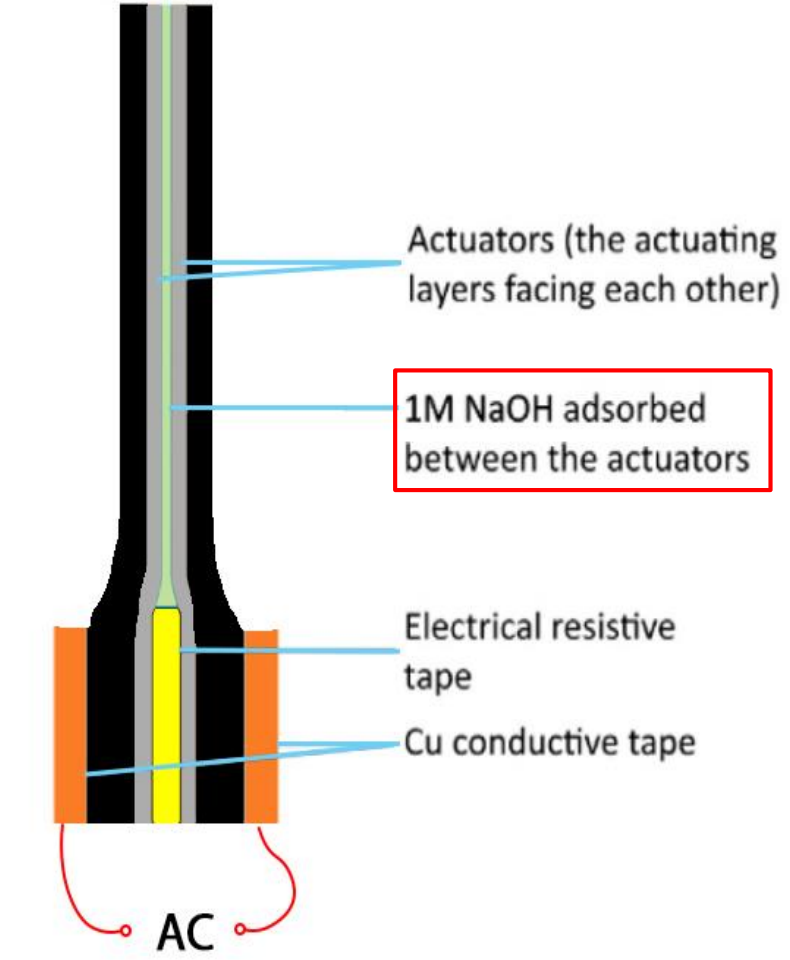
被動層的硬度

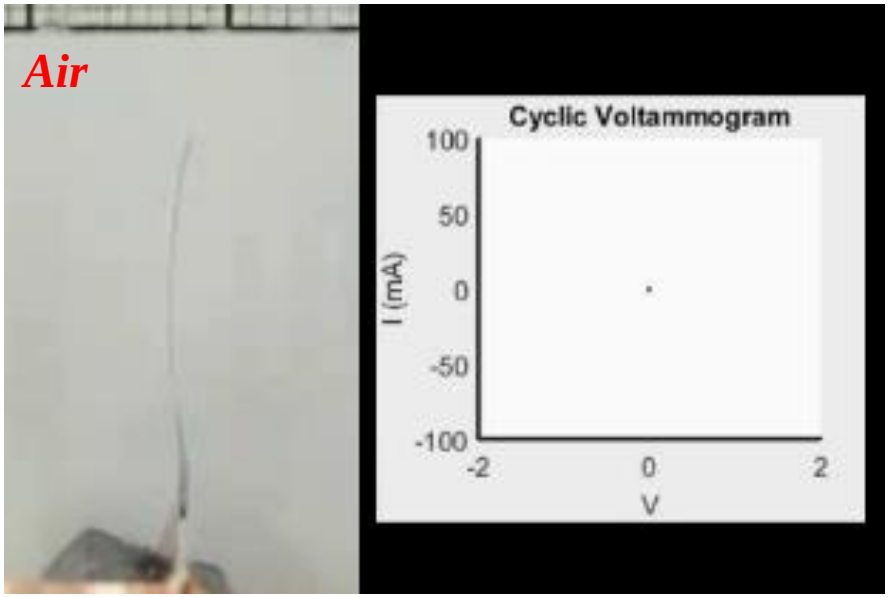
To increase κ => thicker active layer ($t_a \uparrow$),
thinner and softer passive layer ($t_p, E_p \downarrow$)

要增加器件曲度, 可加厚驅動層($t_a \uparrow$), 減薄和軟化被動層($t_p, E_p \downarrow$)

Getting rid of the electrolytic environment: 擺脫電解液的局限

- by packaging a thin layer of the required electrolyte into an assembly …
  將薄層的所需電解質包裝在組件中…

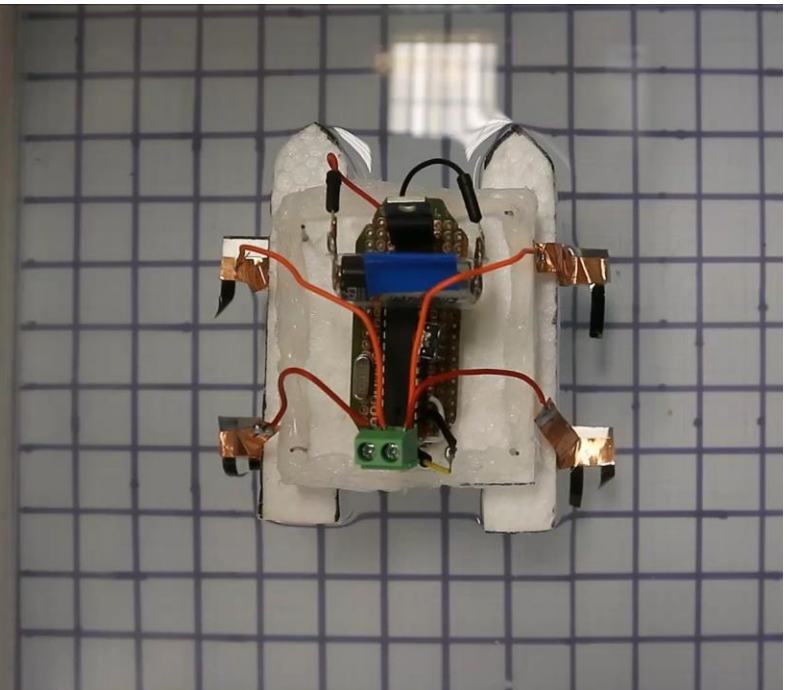


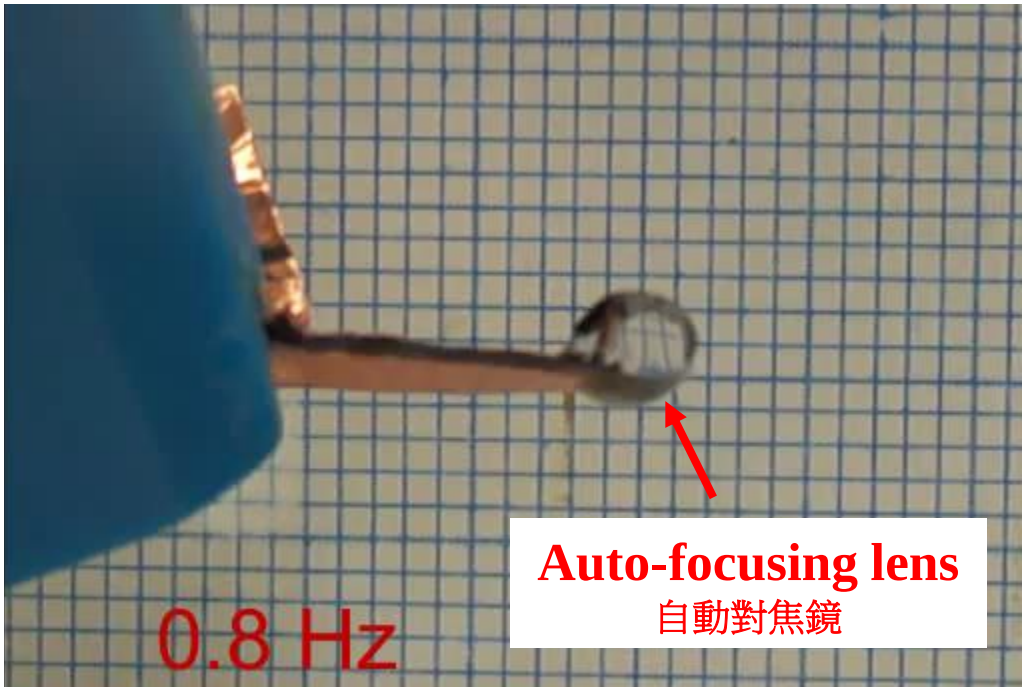


UG (本科生) Projects :

2016/17 Team

2017/18 Team





電(< 1V)和光可以驅使氫氧化鎳移動

$Ni(OH)_2$/NiOOH can be made to move by

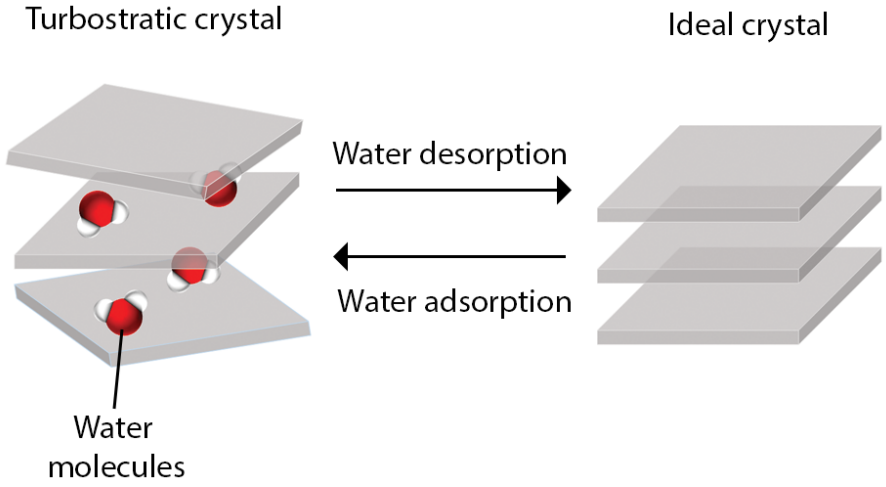
(i) electrochemical (electrical) voltages of < 1V

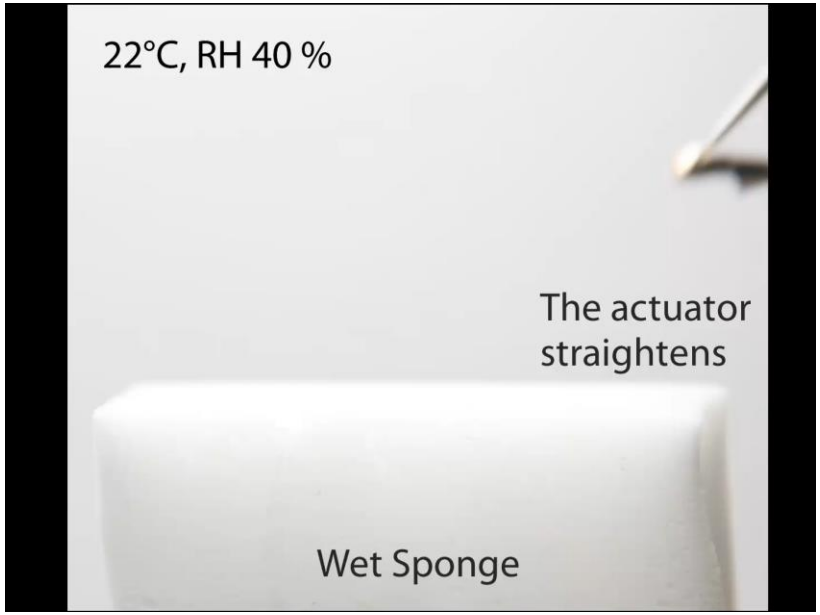
(ii) light

(II) Light driven actuation in $Ni(OH)_2$/NiOOH 光驅動的機理:

Volume changes as water molecules rapidly desorb into the environment:

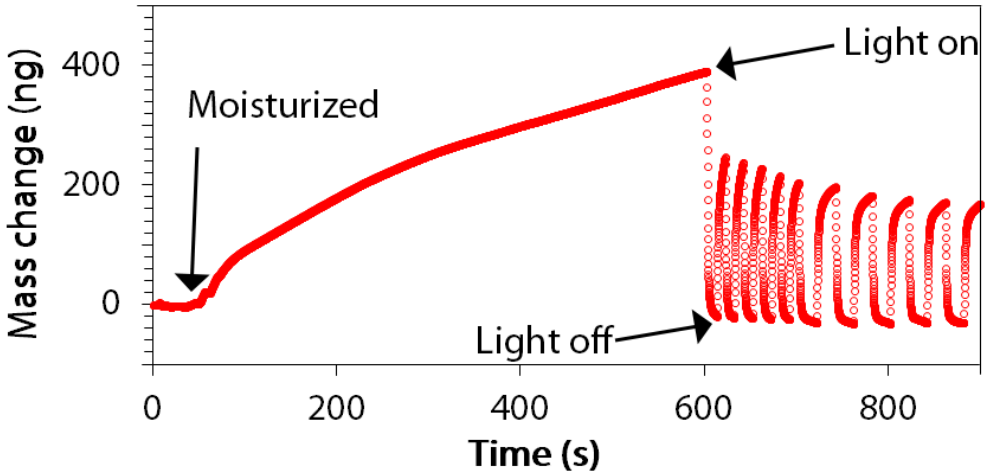
隨著水分子迅速解吸到環境中，體積發生變化：

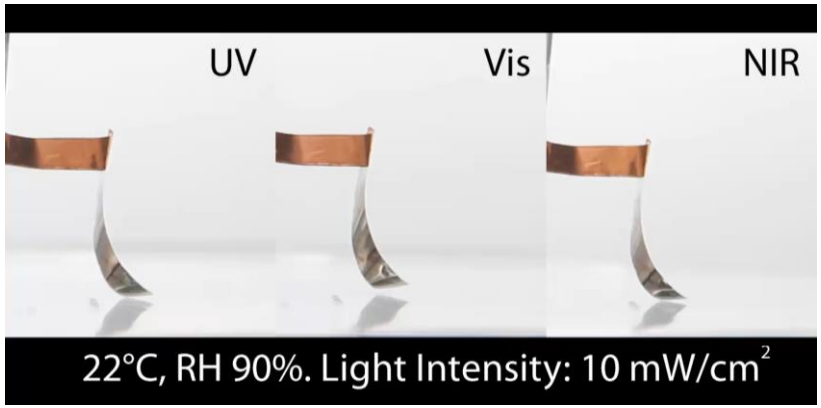




Water desorption (hence volume change) can be triggered by light:

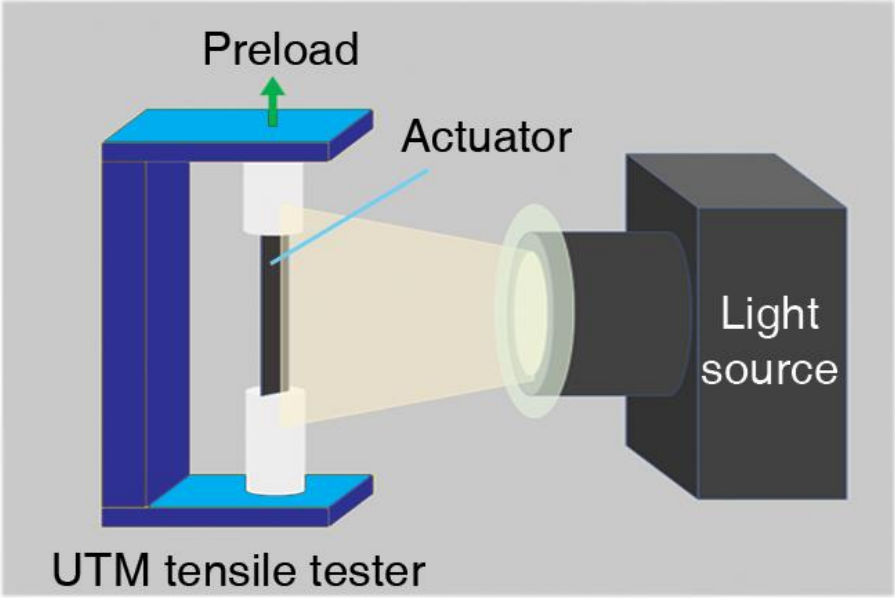
水解吸（和體積變化）可以由光引發：

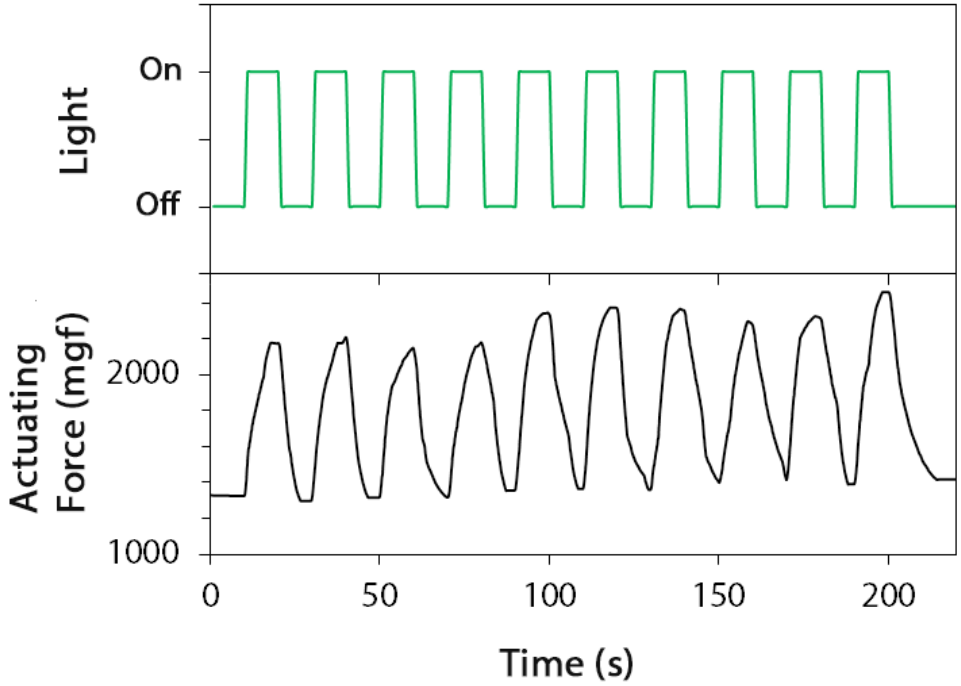




$Ni(OH)_2$/NiOOH can produce gram-forces when triggered by light, equivalent to 1500-3000 times of its own weight:

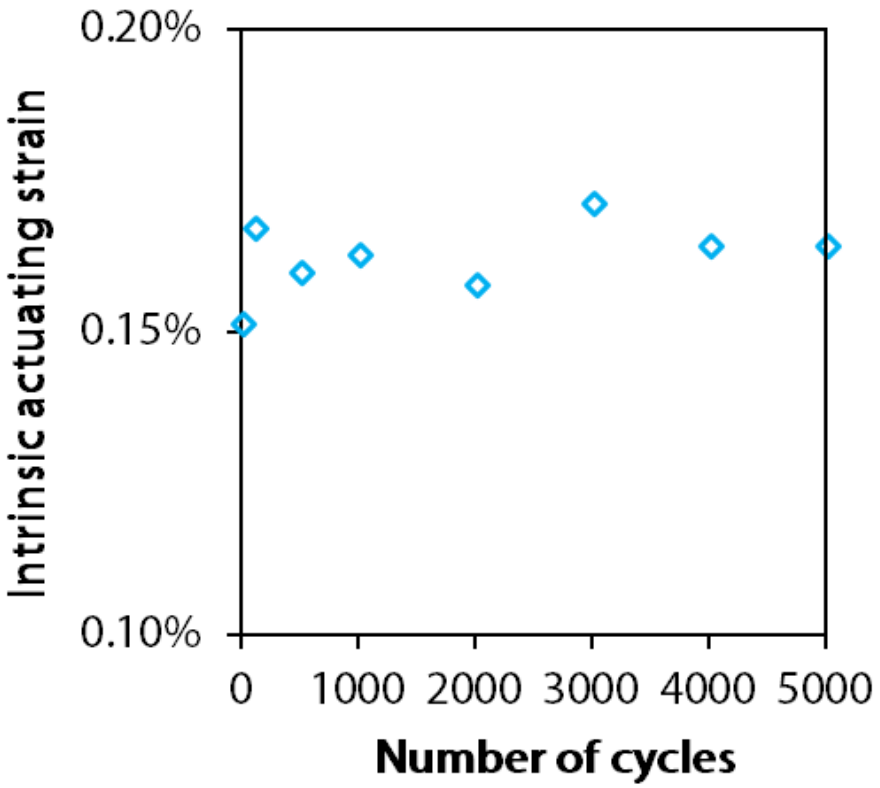
光觸發時會產生克(gram)量級的力, 相當於驅動材料的自身重量的1500-3000倍 ：





Performance highly repeatable over thousands of cycles:

數千週期的高度重複性：

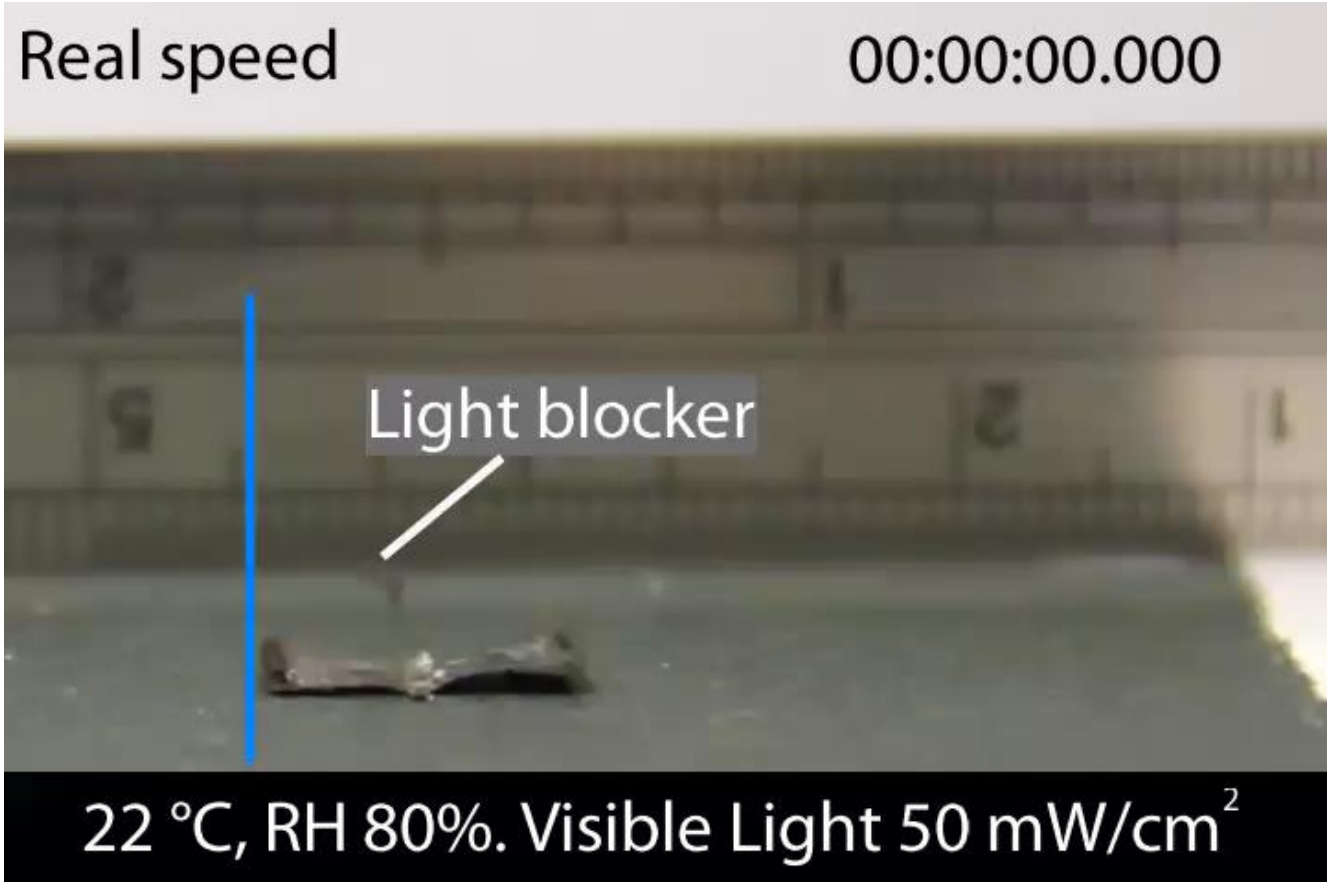


Micro-Hercules 微型大力士:

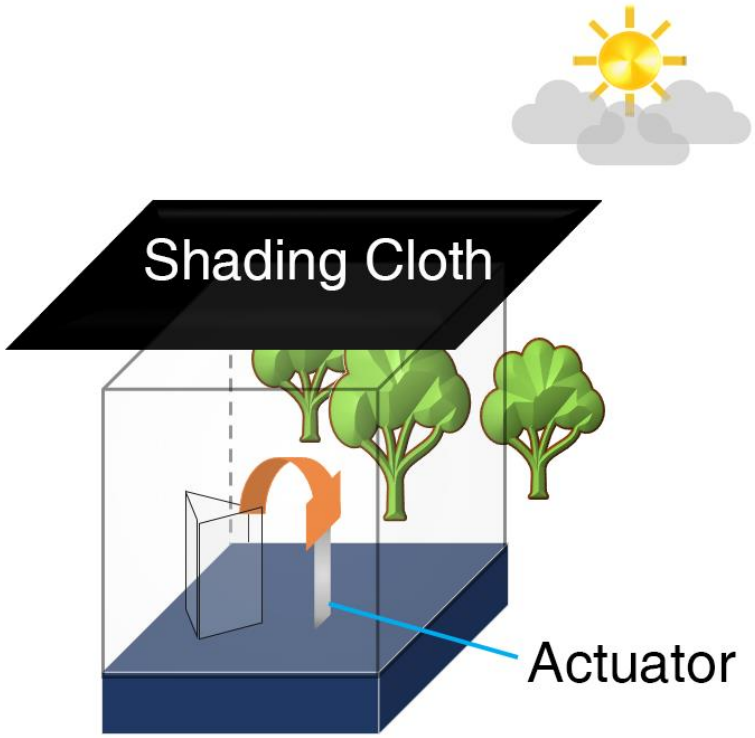
Lifting 50 times (or more) of the weight of the actuating material
舉起比驅動材料重50倍或更多的重量

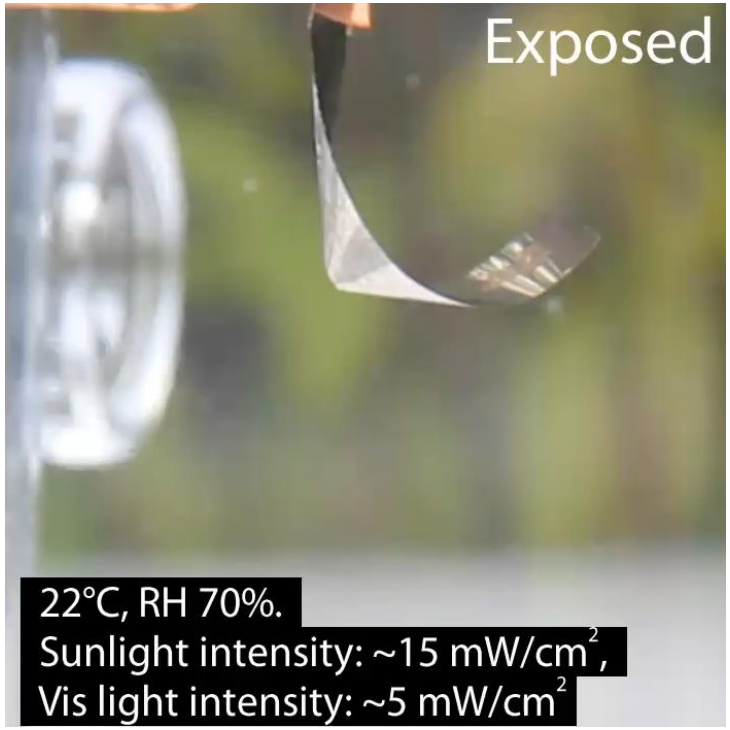
Robotic insect? We are getting there …

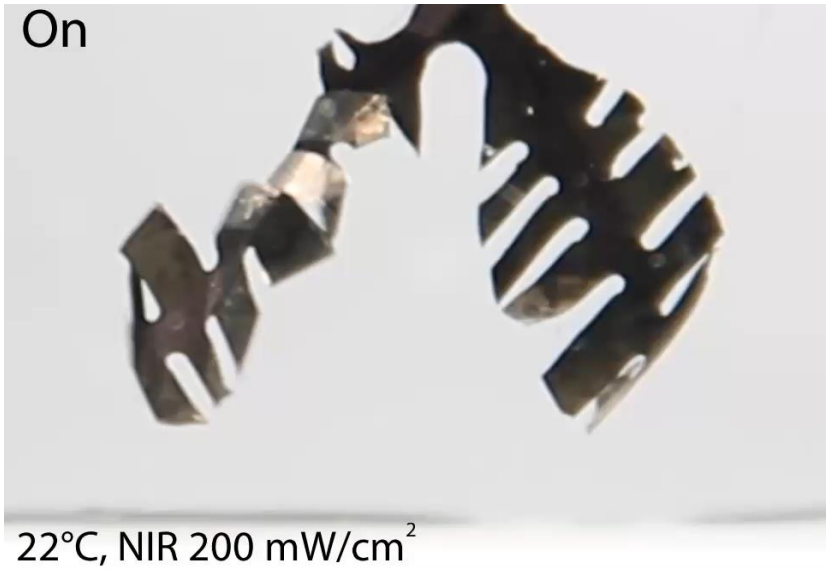
機器昆蟲？快可實現了 …

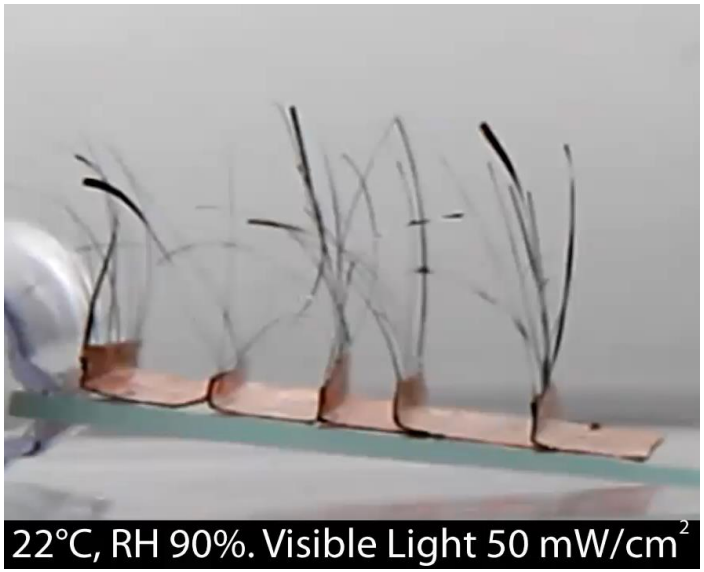


Bio-mimicking 仿生應用 …









Summary:

A new electricity and light driven actuating material reported in:

(i) Science Robotics, in press

(ii) Sensors and Actuators B248, 657 (2017)

Novelty:

(i) The first smart actuating material that can be triggered by both electrochemical and light signals

(ii) Compared with other known electrically driven actuators, our material requires much lower voltages (of < 1 V).

(iii) Our material can produce large actuation forces of 1500-3000 times its own weight.

(iv) Our materials are very convenient and inexpensive to make.

Inventors are an all-ME@HKU team:

Dr. Kenneth K.W. Kwan (BEng, PhD, Postdoctoral Fellow)

Miss Runni Wu (PhD student)

Prof. Alfonso H.W. Ngan (Chair Professor, Principal Investigator)

Dr. Tony Feng (Associate Professor, collaborator on electrodeposition)

Dr. W.D. Li (Assistant Professor, collaborator on light measurement)

概要：

我們的 “氫氧化鎳”光電驅動材料已在以下期刊發表：

(i) Science Robotics

(ii) Sensors and Actuators B248, 657 (2017)

創新之處：

(i) 首種可由電化學和光信號兩者觸發的智能驅動材料

(ii) 相比現有的電動驅動材料，氫氧化鎳只需非常低的電壓（**<1 V)**

(iii) 這材料可產生相當於自身重量**1500-3000**倍的動力

(iv) 氫氧化鎳的生產非常方便和便宜

這項發明由香港大學機械工程系一力承擔：

Dr. Kenneth K.W. Kwan (機械工程系本科**,**博士畢業**,** 博士後研究員**)**

Miss Runni Wu (博士生**)**

Prof. Alfonso H.W. Ngan (機械工程系講座教授，首席研究員**)**

Dr. Tony Feng (機械工程系副教授**,** 電沉積方面的合作者**)**

Dr. W.D. Li (機械工程系助理教授**,** 光測量方面的合作者**)**

~ End ~