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TANDEM NTF

FNSNF

TANDEM - Two Absorber Nanostructured DEvice Module for direct solar water splitting

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EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

LPI Laboratory for Photonics and Interfaces

EMPA Materials Science & Technology

INTRODUCTION

The sun offers the potential for harvesting enormous amounts of energy, although its present-day contribution to the energy mix is a miniscule 1-2% [1]. The amount of solar power striking the earth's surface at any one instant is equivalent to 130 million 500 MW power plants [2], nearly 10^4 times greater than our present day power needs. The ability to capture even a small percentage of this hugely abundant resource would render unnecessary the current reliance on CO_2 emitting fuel sources.

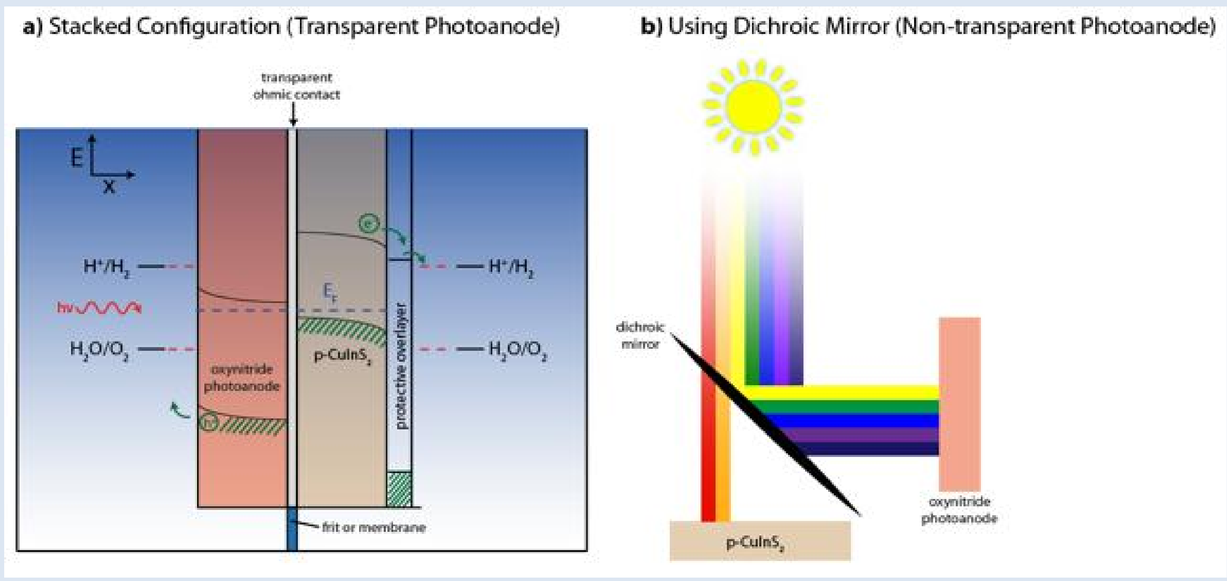
Photocatalytic or electrochemical water splitting, referred to very often as artificial photosynthesis, is a middle-to-long-term solution with tremendous promise. In analogy with nature's design, water is used as a feedstock of protons and electrons that are used to generate hydrogen fuel, a process which is driven by the energy contained in the solar photons. The energy-rich gaseous fuel product can participate directly in a hydrogen economy, or can be used to generate syn-gas, methane or ammonia, which is possible with present-day industrial scale technology. The strategy of generating a fuel, and not electricity, from sunlight alleviates the problems associated with electricity storage.

This project is designed to address major challenges that have thus far hindered the industrialization of artificial photosynthesis. It aims to find and improve cheap and efficient photocathode and photoanode materials for photoelectrochemical applications and to ensure long term operation with the implementation of corrosion resistant protective coatings.

Goal: Unassisted solar water splitting by Tandem cells

The photoanode and the photocathode will be combined, together achieving the required photovoltage to enable unbiased overall water splitting. This new device will enable unassisted solar water splitting.

Possible device architectures for Tandem cells



Results after 18 months : Photoanode (in plan): Uniform $LaTiO_2N$ electrodes by electrophoretic deposition with control of particle morphology, cocatalyst and protective layer deposition. Photocathode: Solution synthesis of $CuInS_2$ and surface passivation of $CuIn_xGa_{1-x}Se_2$ towards efficient water reduction.

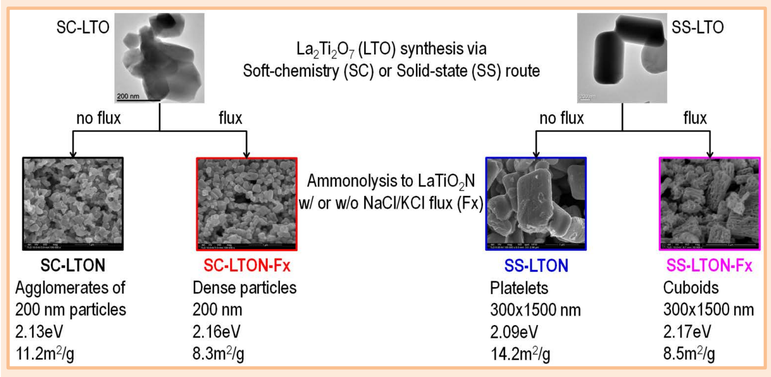
Progress – 18 months

Photoanode

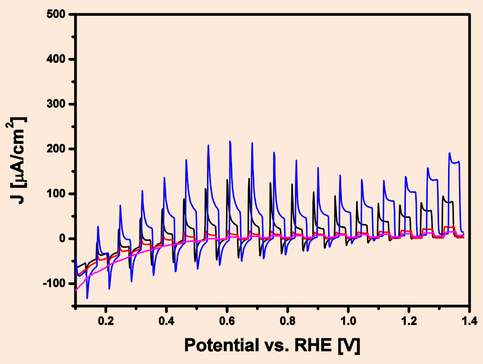
Synthesis and Morphology tuning of $LaTiO_2N$ [3,4,5]

Soft chemistry and anionic substitution via thermal ammonolysis: A solid – gas reaction with NH_3 at T = 950 ° C which allows morphology tuning.

$La_2Ti_2O_7 + 2\ NH_3 \rightarrow 2\ LaTiO_2N + 3\ H_2O$



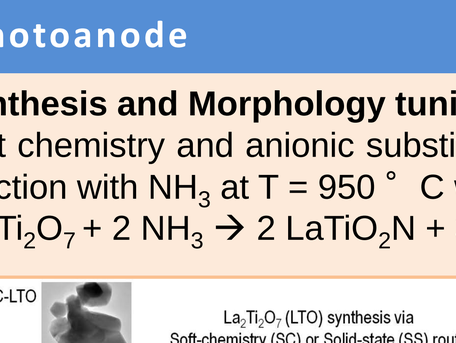
Synthesis routes of LTON semiconductor powders and their shape, size, band gap, and BET surface area



Photocurrents of necked $LaTiO_2N$ obtained in a 0.1 M aq. Na_2SO_4 (pH= 13.40 by adding NaOH) and at 10 mV/s scan rate under intermittent light illumination (100mW cm^{-2}, λ≥420nm).

Performance enhancement by adding co-catalysts and protective layers

CoO_x nanoparticles as co-catalysts



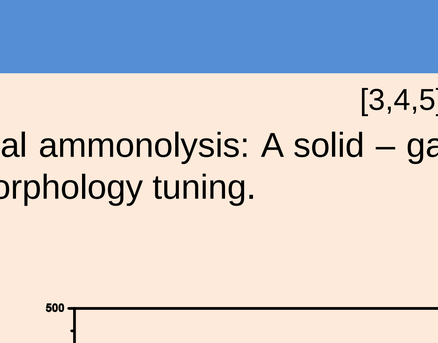
HAADF-STEM image of CoO_x nanoarticle (10 nm) on SCLTON

SEM image of a SS-LTON particle loaded with 40nm sized CoO_x nanoarticles.

TEM image of CoO_x nanoarticle (40 nm) on SCLTON-Flux

TEM image of CoO_x nanoarticle (10 nm) on SSLTON-Flux

Adding protective layers



Reproducible Photocurrent:

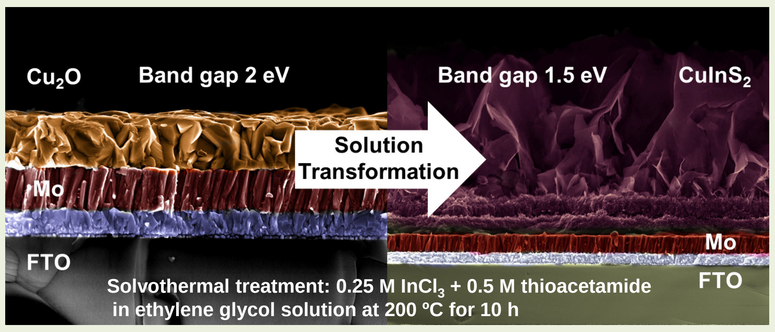
J at $1.23V_{RHE}$= 1.80 mA/cm^2

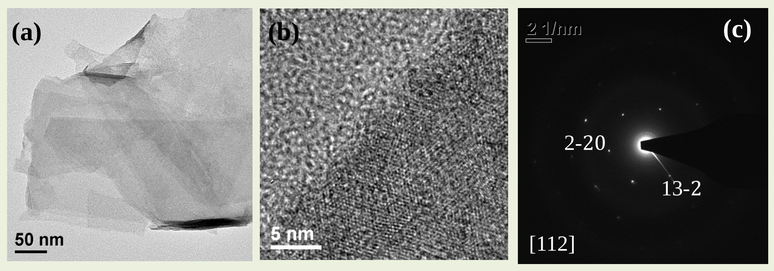
J at $1.23V_{RHE}$= 1.78 mA/cm^2

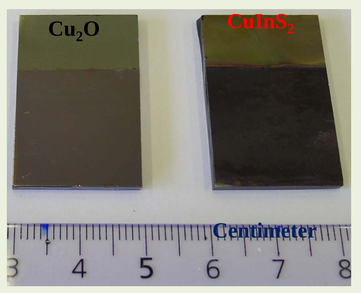
Photocurrents of necked $LaTiO_2N$ obtained in a 0.1 M aq. Na_2SO_4 (pH= 13.40 by adding NaOH) and at 10mV/s scan rate under intermittent light illumination (100mW cm^{-2}, λ≥420nm).

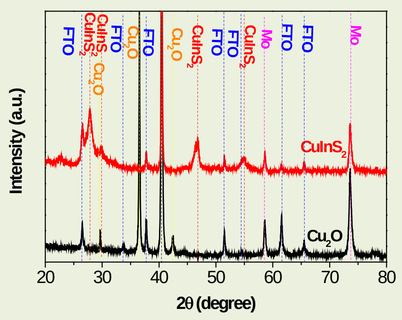
Photocathode

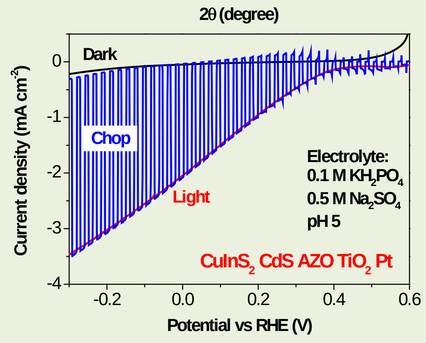
Solution transformation of Cu_2O into $CuInS_2$ [6]



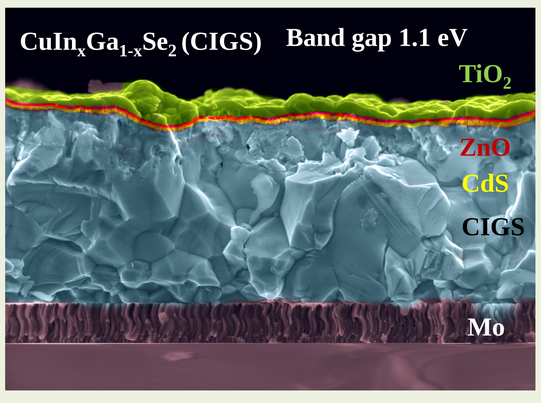


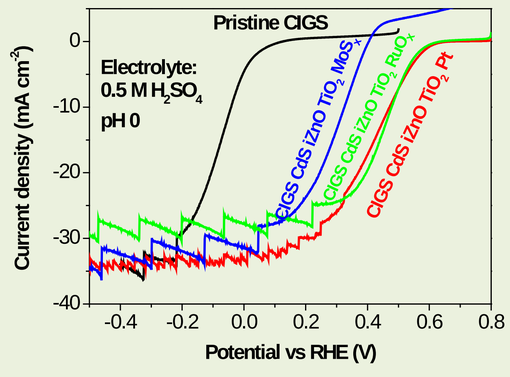






Passivating $CuIn_xGa_{1-x}Se_2$ towards efficient and durable water reduction





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