Artificial leaf for carbon dioxide conversion using sunlight

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1 Research Objectives

1. Understand the fundamental science to enable future advancements in the field.
2. Develop a multicomponent system to enhance the efficiency of the process.
3. Trial different materials and optimise their synthesis.

2 Targeted UN Sustainable development goals

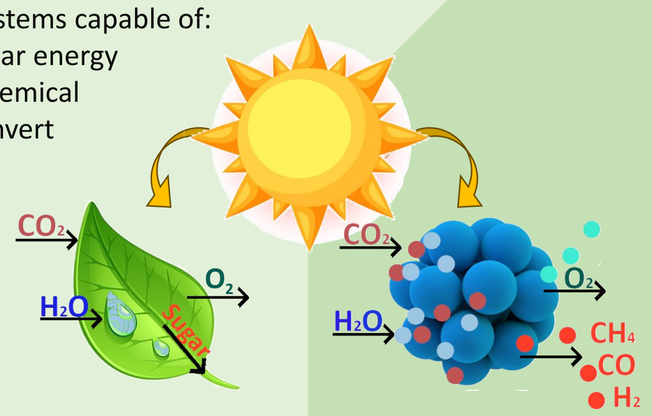
GOAL 7 — Affordable and clean energy

GOAL 13 — Climate action

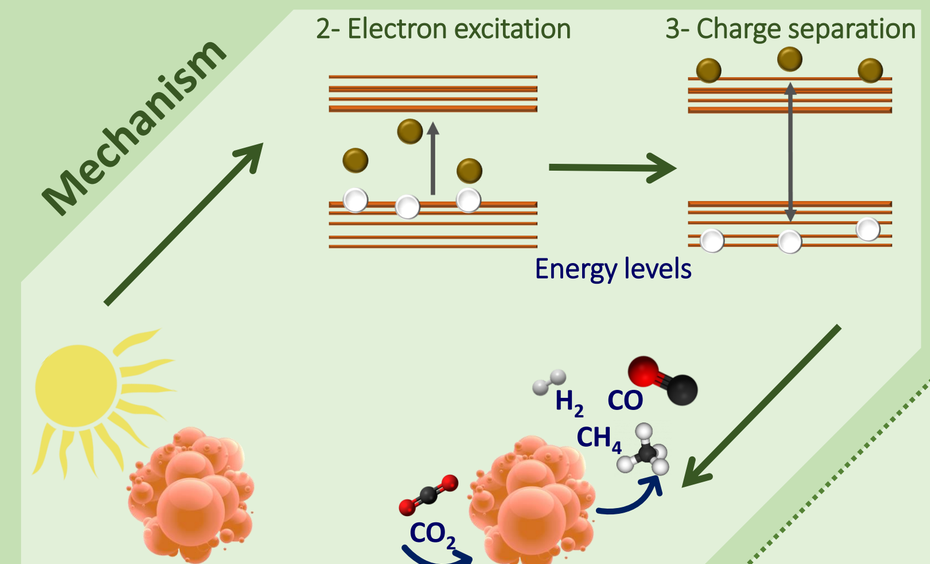
3 Concept of Artificial Photosynthesis

Artificial photosynthesis is a technology inspired by the natural process in plants, where sunlight is used to convert water (H_2O) and CO_2 into clean fuels.

Artificial photosynthesis involves the design of molecular systems capable of:
1- Capturing solar energy
2- Catalysing chemical reactions to convert CO_2.



Mechanism



4 Stages of the Technology Development

01 — Understanding the fundamentals of semiconductor physics

02 — Applying chemistry principles to optimise material quality

03 — Use engineering skills to build precise testing instruments

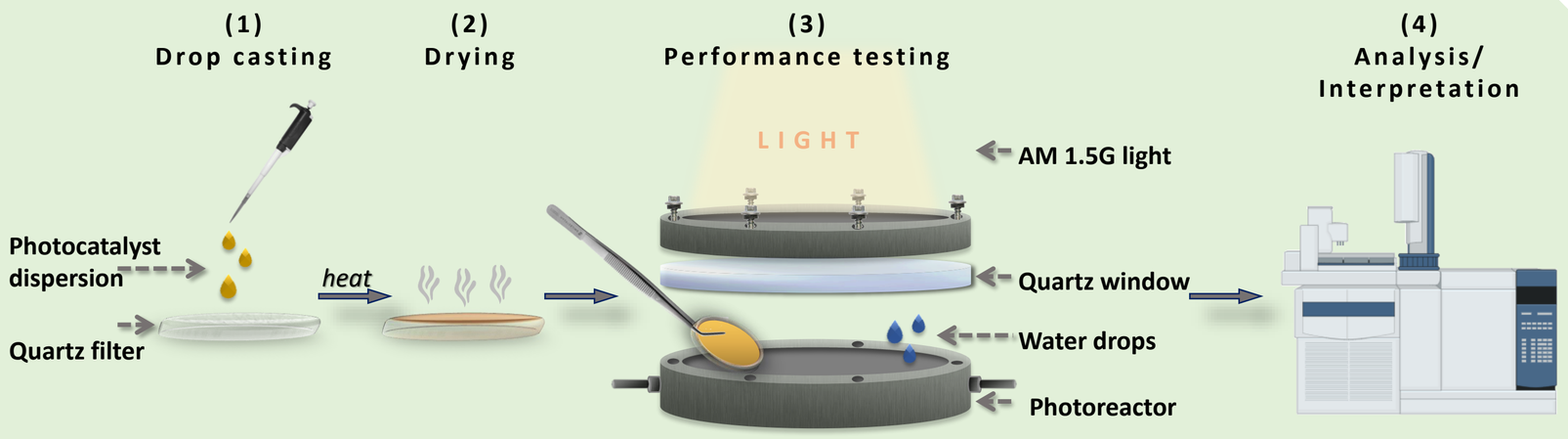
04 — Scale-up synthesis and artificial leaf manufacturing

05 — Propose regulatory measures for the implementation of the technology

5 Testing Set-up Design and Optimisation

Once a photocatalyst is designed and synthesised:
(1) The powder is dispersed on a filter.
(2) The filter is dried out to remove any solvents.
(3) The filter is placed in a stainless steel photoreactor with drops of water and filled with carbon dioxide gas.

After being illuminated with simulated sunlight for some time,
(4) The gas inside the chamber is tested using gas chromatography to detect any traces of hydrogen (H_2), carbon monoxide (CO), or methane (CH_4).

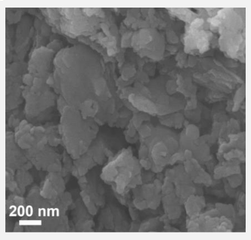


6 Catalytic System Design

Potential semiconductor candidates were chosen and synthesised

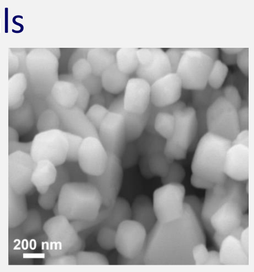
Carbon nitride sheets
$g\text{-}C_3N_4$

S1



Perovskite nanocrystals
$Cs_3Bi_2Br_9$

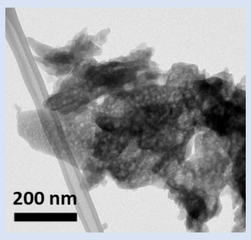
S2



The materials were optimised to further improve the activity

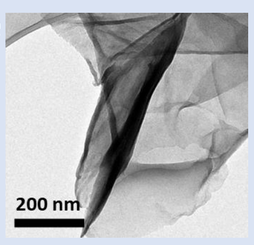
Exfoliated $g\text{-}C_3N_4$

S3

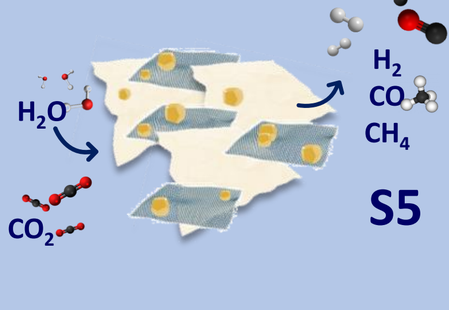


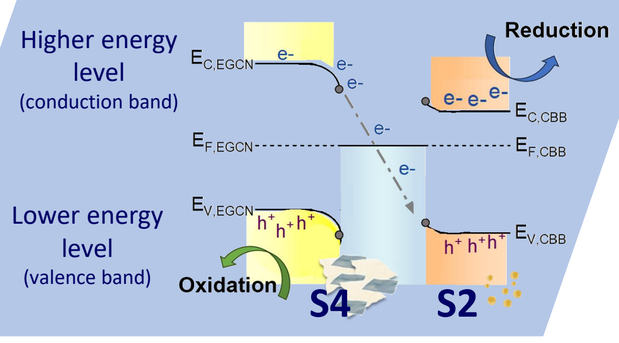
Addition of reduced graphene oxide

S4

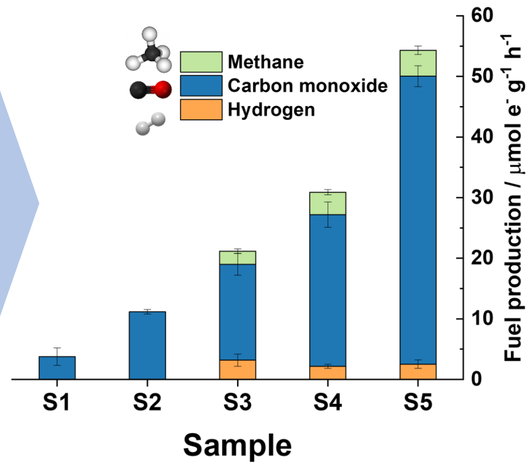


A system was built encompassing the different components





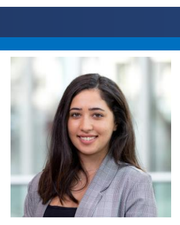
Solar fuel production



7 Conclusions

- A novel heterojunction of semiconductors was developed for carbon capture and conversion to clean fuels.
- The material was optimised to produce 11 times more fuels with an increased production of CH_4 and H_2.
- The developed system was optimised to operate under ambient conditions with simulated sunlight.

References:
[1] Y. Baghdadi *et al.*, "$Cs_3Bi_2Br_9/g\text{-}C_3N_4$ Direct Z-Scheme Heterojunction for Enhanced Photocatalytic Reduction of CO_2 to CO," *Chemistry of Materials,* vol. 35, no. 20, pp. 8607-8620
[2] Y. Baghdadi *et al.*, $g\text{-}C_3N_4/rGO/Cs_3Bi_2Br_9$ mediated Z-scheme heterojunction for enhanced photocatalytic CO_2 reduction (to be submitted)



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