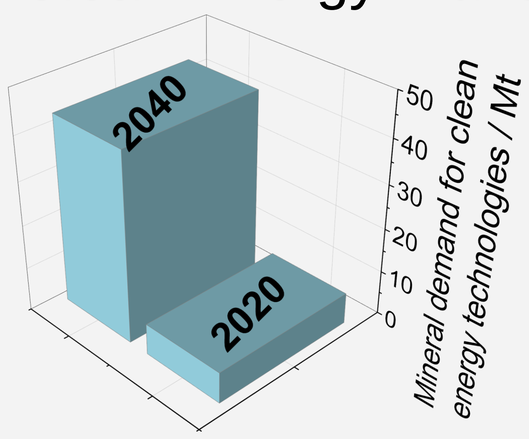
Reducing the Amount of Critical Minerals on Graphene-Supported Electrocatalysts for Hydrogen Production

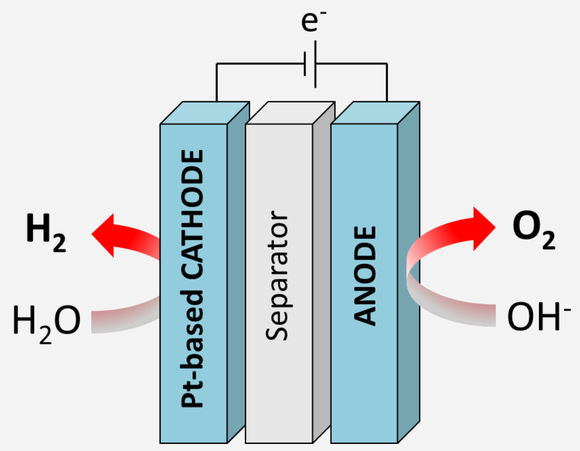
Constantine Tsounis, School of Chemical Engineering, UNSW
Project Supervised by Prof. Rose Amal, Dr. Zhaojun Han, Prof. Liming Dai

Critical Minerals in the Clean Energy Transition

Critical minerals such as Co, Ni, Pt, and so on, are required in large quantities in a range of clean energy technologies, such as solar panels, batteries, and electrolyzers which produce green hydrogen.[1]



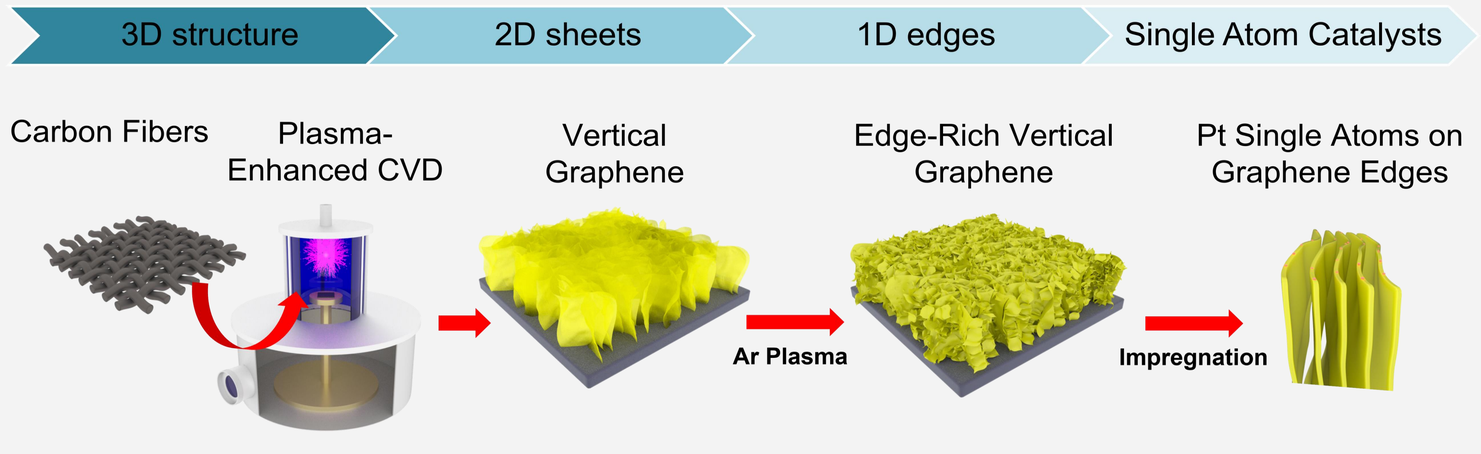
For the production of hydrogen using an electrolyzer, the state-of-the-art catalysts can contain up to 2 mg/cm^2 platinum. There is a need to reduce the amount of platinum required to decrease supply chain risks and electrolyzer cost.[2]



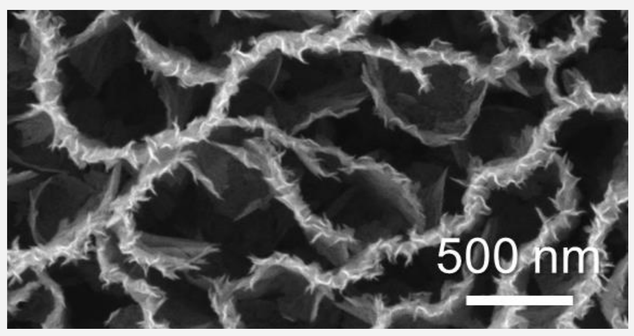
Research Solution

To address this challenge, we a used carbon-based catalytic support, namely, edge rich vertically aligned graphene, which is cheap, scalable, and stable.[3, 4]

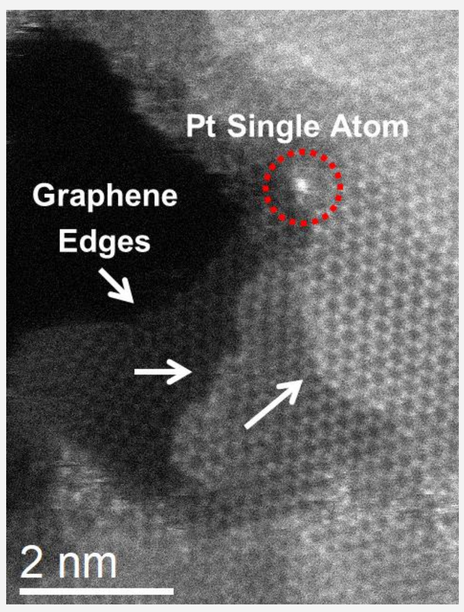
We then deposited ultra-low concentrations of platinum onto the edge rich graphene, which are the active catalysts for electrochemical hydrogen production.[4]



Material Properties

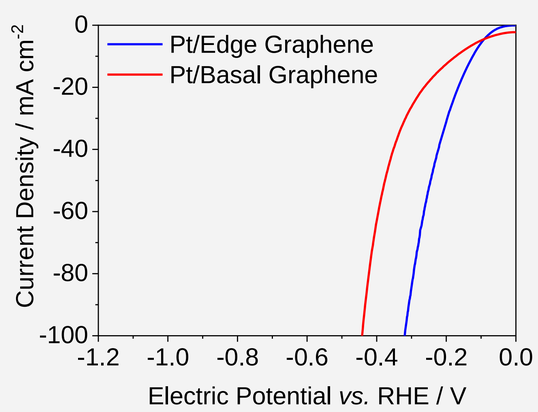


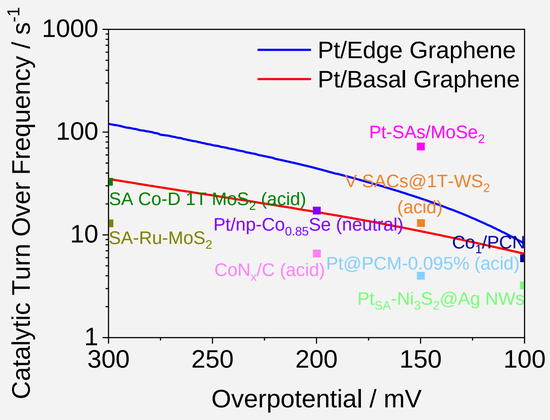
Catalyst	Amount of Pt
Commercial (PEM)	2 mg/cm^2
Pt/Edge Graphene	0.00071 mg/cm^2



Electron microscopy revealed that the platinum deposited was in single atom form, decorating the graphene edges. These single atoms are the sites where hydrogen is produced.[4]

Catalytic Properties





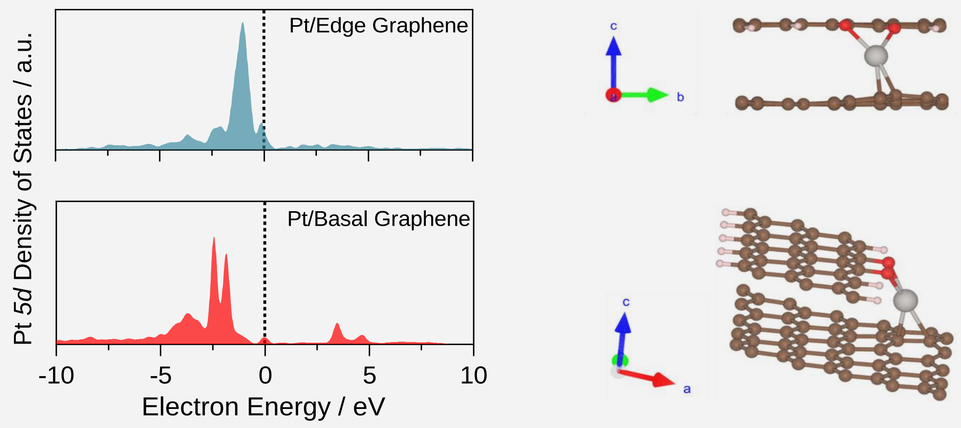
Amongst our materials, we found that platinum deposited on the graphene edge had significantly improved catalytic performance compared to platinum on the base of the graphene sheet.[4]

Compared to other state-of-the-art electrocatalysts, our material exhibited one of the highest intrinsic activities in hydrogen production.[4]

The Underlying Science

Using a combination of X-ray absorption spectroscopy and density functional theory calculations, we showed that platinum bound to the graphene edges exhibited a higher electron density near the Fermi level, which promoted efficient hydrogen production compared to platinum deposited on the basal plane of graphene.[4]

This research paves a pathway toward the design of high performing platinum catalysts, which can decrease the amount of platinum required in electrolyzers.



ARC Industrial Transformation Training Centre for the Global Hydrogen Economy

References

[1]IEA (2021), *The Role of Critical Minerals in Clean Energy Transitions*, International Energy Agency, Paris.
[2]IRENA (2020), *Green Hydrogen Cost Reduction: Scaling Up Electrolysers to Meet the 1.5ºC Climate Goal*, International Renewable Energy Agency, Abu Dhabi.
[3]Han, Z.; Tsounis, C.; Amal, R. US Patent App. 17/434,896, 2022
[4]Tsounis, C.; Subhash, B.; Kumar, P. V.; Bedford, N. M.; Zhao, Y.; Shenoy, J.; Ma, Z.; Zhang, D.; Toe, C. Y.; Cheong, S.; Tilley, R. D.; Lu, X.; Dai, L.; Han, Z.; Amal, R. Pt Single Atom Electrocatalysts at Graphene Edges for Efficient Alkaline Hydrogen Evolution. *Adv. Funct. Mater.*, **2022**, *32*, 2203067.