Sonochemical Hydrogen Production from Seawater: A Sustainable and Cost-effective Approach

Cherie CY Wong [a], James Kwan [a]

[a] Department of Engineering Science, Parks Road, Oxford, OX1 3PJ, UK.

Priority Topic Area: **Clean Energy and Climate Action**

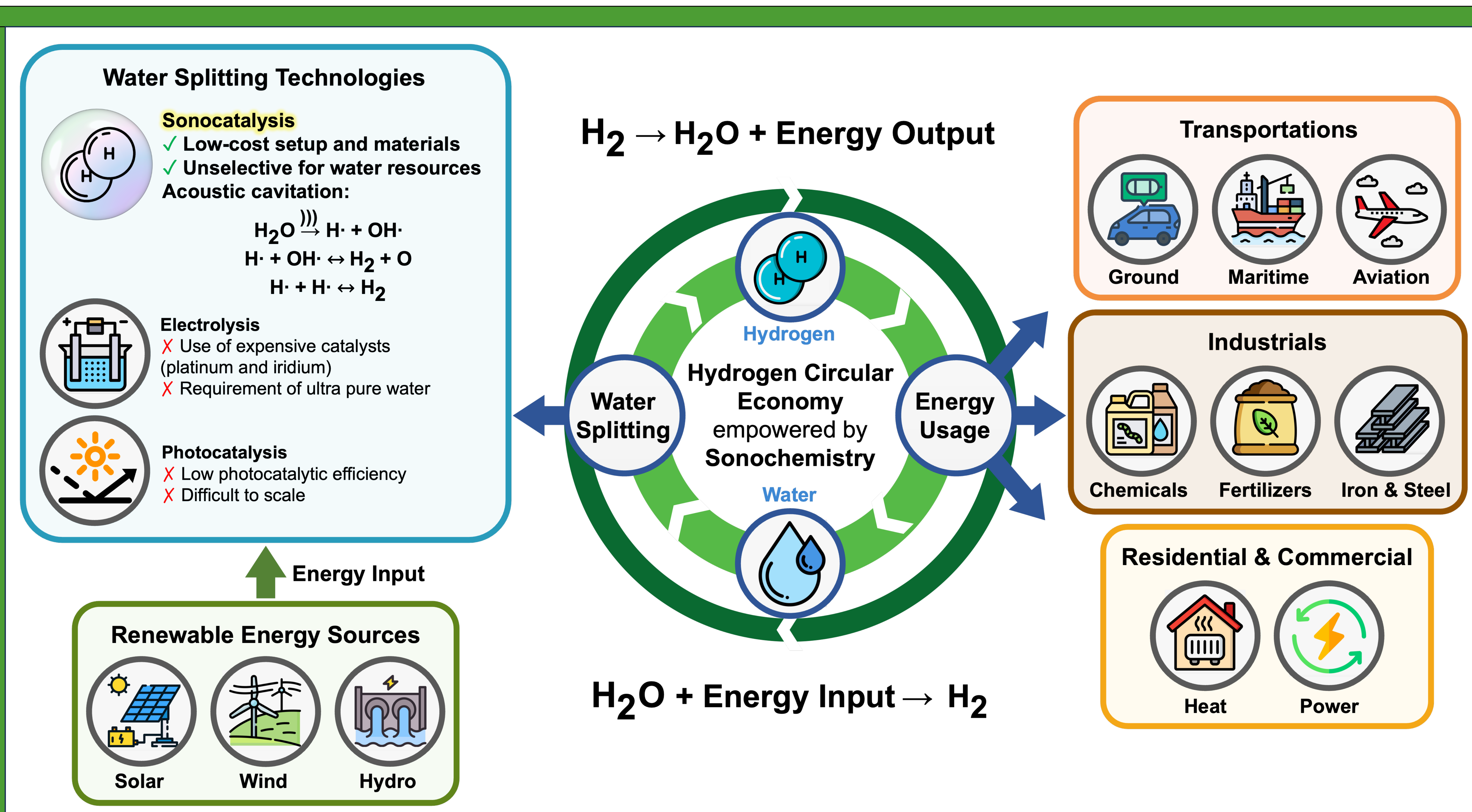
1 – Objectives

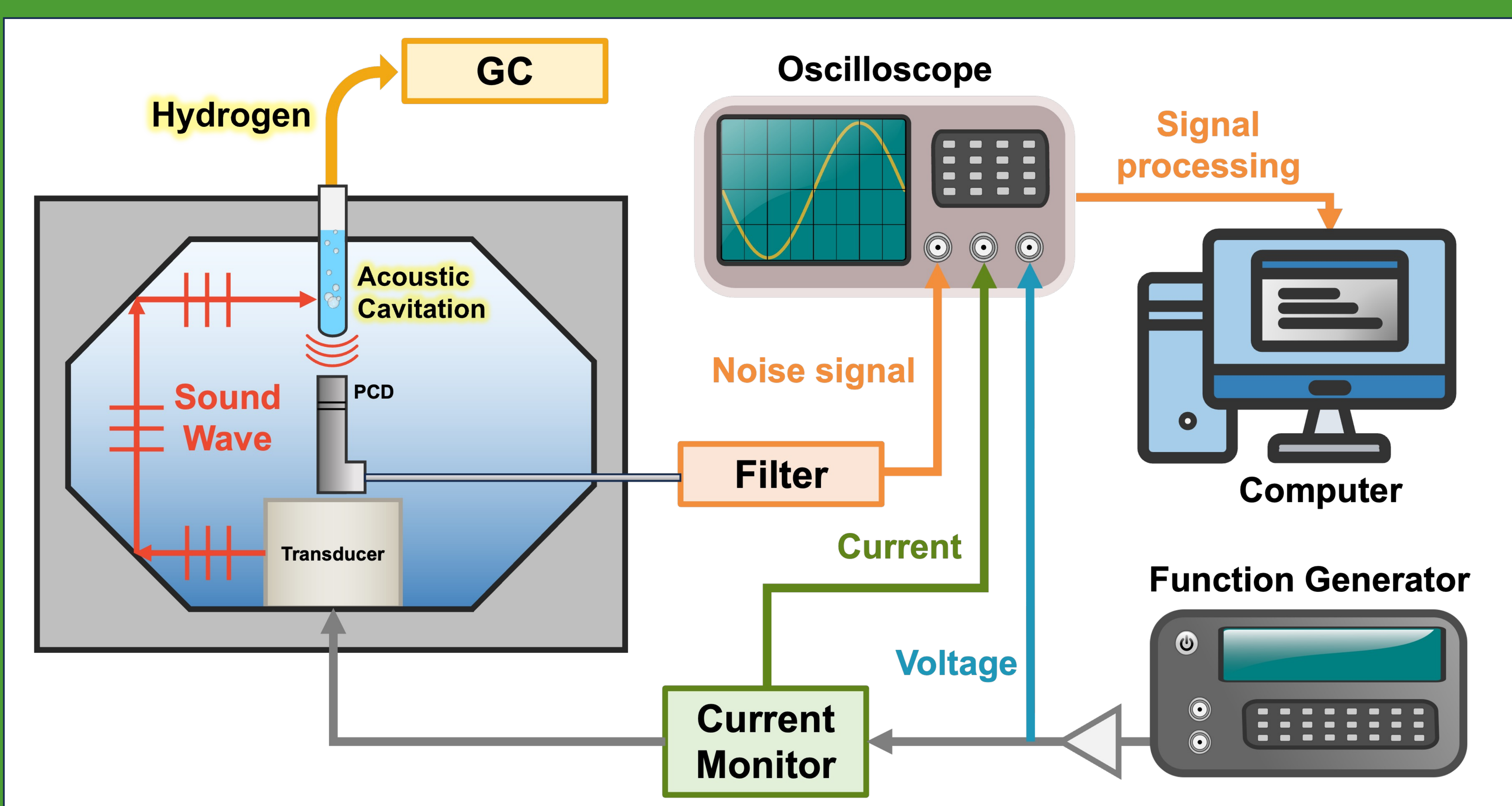
Green hydrogen offers the potential to achieve net zero by the hydrogen circular economy. However, **current green water splitting** technology suffers from **a range of challenges, including**

1) The use of ultra-pure water and scarce noble-metals
2) Low efficiency

Sonocatalytic water splitting has the potential:

1) **Achieve low-cost setup and operating cost;**
2) **The use of unprocessed seawater**





2 – Methodology

A **highly efficient sonochemical reactor**, that cylindrically converges ultrasound waves, is used to create an intense localised region of high acoustic pressure amplitudes. The region is **capable of spontaneously nucleate cavitation and generate hydrogen**.

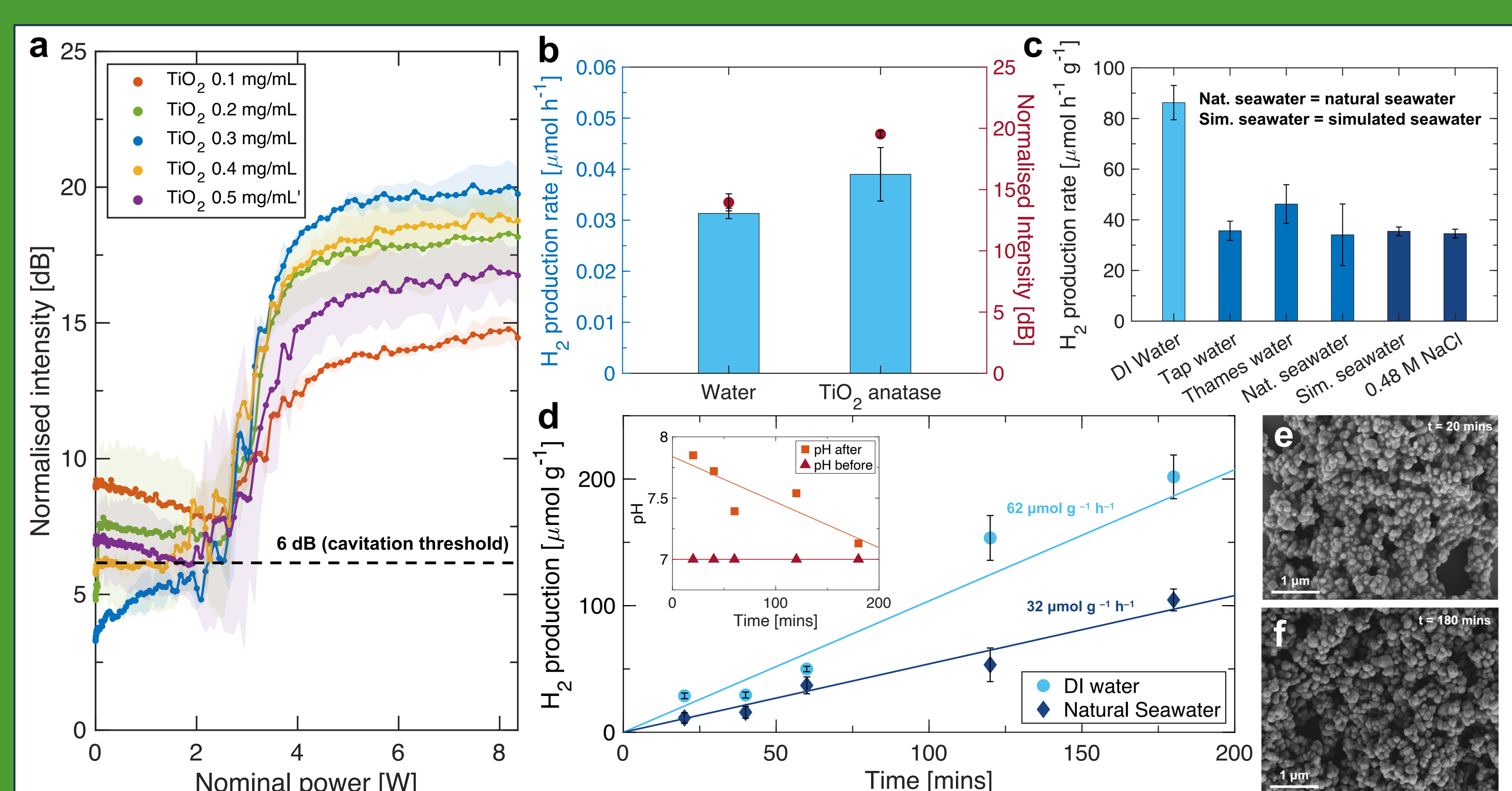
To measure the operating power of the reactor, the voltage and current were monitored. For cavitation noise detection to monitor the cavitation activities, a passive cavitation detector (PCD) was positioned underneath the reaction vial. The noise data was recorded for subsequent data processing.

Cheap, off-the-shelf TiO_2 was used as sonocatalyst to reduce the energy barrier of the reaction, further increasing the sonochemical hydrogen production rate.

3 – Results

a) **Optimisation of the reactor power and the concentration of TiO_2 catalyst.** The threshold for acoustic cavitation was 2.5 W. 0.3 mg/mL TiO_2 had the highest cavitation activity, and hence the sonochemical activity,
b) **The presence of TiO_2 catalyst was shown to have a higher H_2 production rate.** This is due to the introduction of more bubble nucleating sites on the phase boundaries.
c) The H_2 production rate of different water resources. **Natural seawater produced H_2 effectively by sonochemistry.**
d) **DI water has ~2x H_2 production compared to seawater**, due to the presence of salt decreased the gas solubility.

e-f) SEM images of TiO_2 catalyst at 20 mins and 180 mins, they **emphasised the recyclability of the catalysts.**



4 – Benefit to society

The versatility of hydrogen fuel could replace fossil fuels in multiple carbon-intensive sectors of our economy. It is vital that we search for the best hydrogen production approach for the imminent green transition. **Sonochemistry offers a cheap and sustainable method for direct green hydrogen generation from seawater**, that is previously limited by water electrolysis, the standard green hydrogen production technology. We hope the work will **foster development in future industrial-scale green hydrogen production research** and contribute to the world net-zero transition.

5 – Next steps

A **techno-economic model (TEA) and life cycle assessment (LCA)** would be carried out to **compare the economic and environmental impacts of sonochemical hydrogen production** with other existing green water splitting approaches, including electrolysis, photolysis, and thermolysis.

IChemE YOUNG ENGINEERS AWARDS for Innovation and Sustainability

References/Acknowledgements

Wong, Cherie CY, et al. "Enhancement of sonochemical production of hydroxyl radicals from pulsed cylindrically converging ultrasound waves." Ultrasonics Sonochemistry 99 (2023): 106559.
Dresp, Sören, et al. "Direct electrolytic splitting of seawater: opportunities and challenges." ACS Energy Letters 4.4 (2019): 933-942.
Gao, Fei-Yue, Peng-Cheng Yu, and Min-Rui Gao. "Seawater electrolysis technologies for green hydrogen production: challenges and opportunities." Current Opinion in Chemical Engineering 36 (2022): 100827.

C. C. Y. W. thanks the Department of Engineering Science (University of Oxford) and Balliol College (University of Oxford) for their support through the EPSRC DTP Scholarship and the Dervouguilla Scholarship, respectively.

IChemE