Perovskite oxides using biomineralization for the production of H_2 carriers

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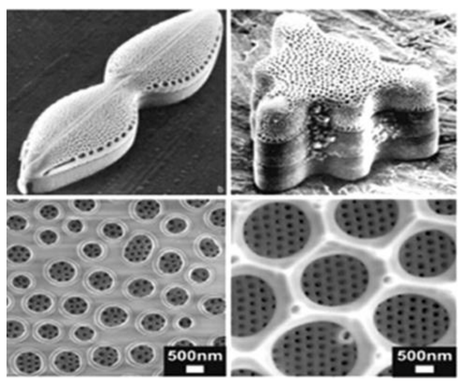
Background

The world is shifting towards developing a hydrogen (H_2) economy to reduce the use of fossil fuel and escalating CO_2 emissions. The growing study has highlighted the importance of H_2 carriers in H_2 delivery and storage. Biological system has provided us inspirations to design and engineering new catalyst for the production of H_2 carriers. Compared to conventional synthesis, biomineralization approach can offer the capacity to make material with disordered structure, particularly wherein access to disordered surface structure is beneficial. This material could exhibit better catalytic performance for a variety of functional applications, such as $Ti_aZr_bO_x$ for HMF production as a H_2 carrier, or $Sn_aZn_bO_y$ for H_2 carrier production. Controllable bimetallic ratio could be achieved to modulate the surface active sites and material structures for performance optimisation.

Biomineralization

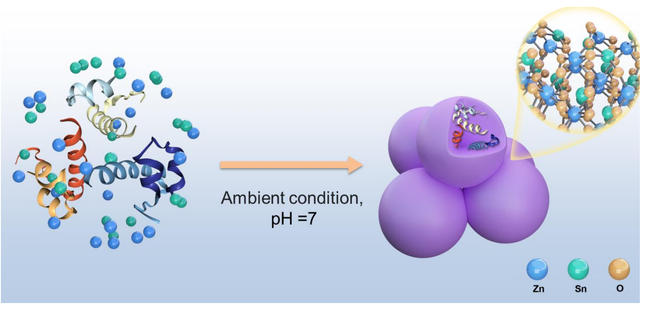


SEM images of structures of silica formed in natural diatoms (Naik, et al., 2008)

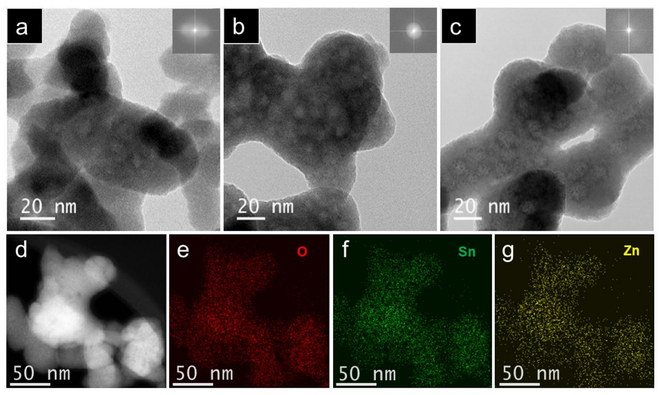
The utilization of biomolecules for synthesizing complex inorganic structure.

- Positively charged Amide induced polycondensation
- Neutral pH, Room temperature, Water solution
- One pot synthesis
- Green bio-enabled syntheses
- Translatable to various non-biogenic metal oxides: SnO_2, ZnO, TiO_2, ZrO_2

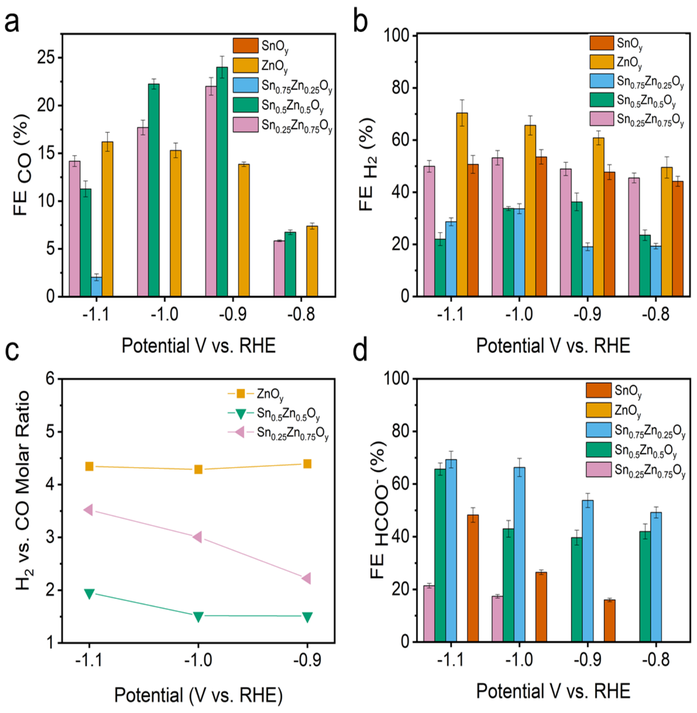
$Sn_aZn_bO_y$



Zn and Sn precursors were mixed with protamine in solution to form nanoparticles.



Syngas and formate as potential H_2 source/carriers

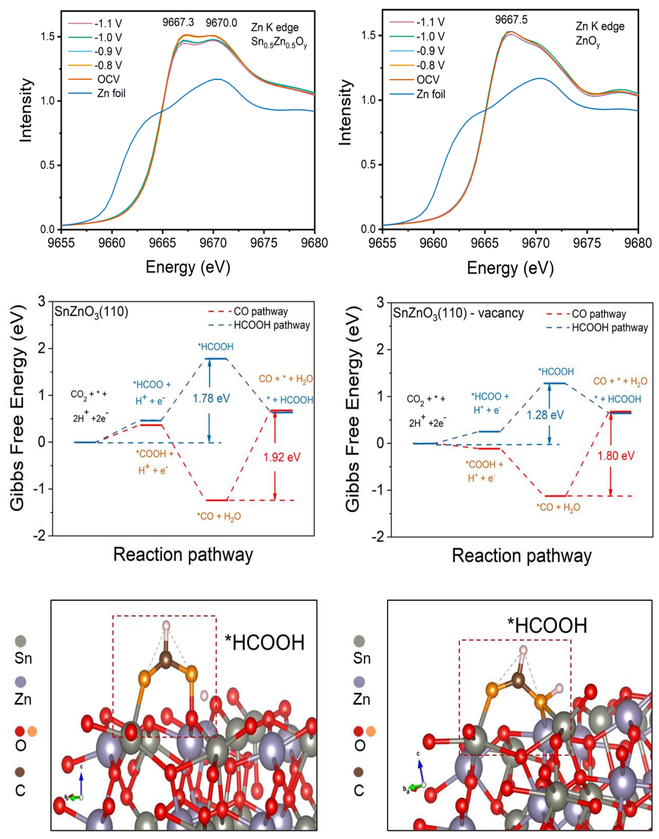


In-situ XANES

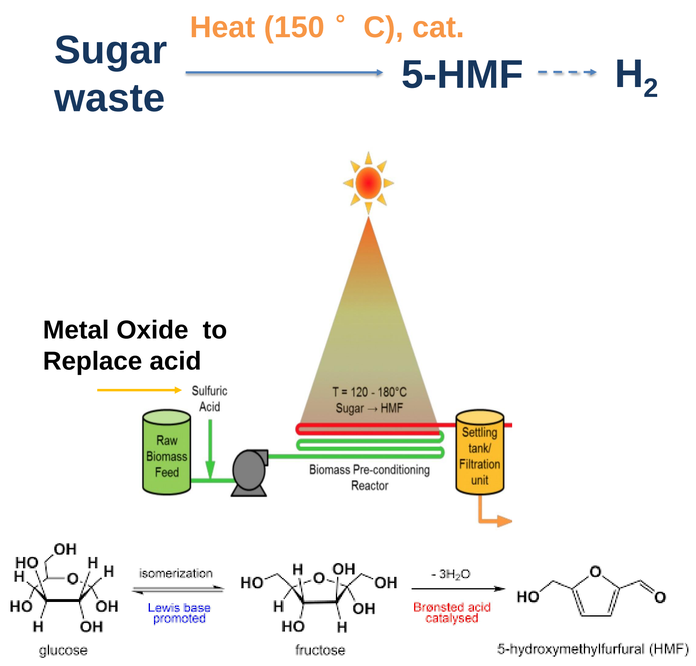
Zinc K edge shows the perovskite feature. The intensity decreases at the adsorption edge indicate the formation of oxygen vacancies.

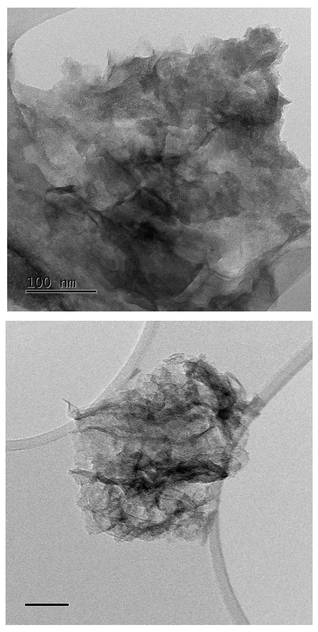
DFT

Sn and Zn under-coordinated metal centres exhibit superior capacity to absorb-activate the intermediates and modulate the selectivity.



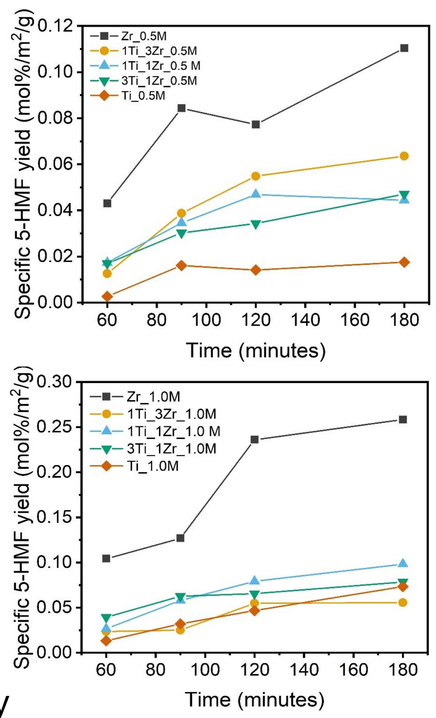
$Ti_aZr_bO_x$ Sugar to 5-HMF as a H_2 carrier





$Ti_aZr_bO_x$ forms unique 2D nanosheet-like morphology via biomineralization.

5-HMF yield (indoor test)



Solar thermal reactor (150 °C)

Solar thermal reactor built in UNSW lab.

Converting renewable solar to thermal energy for the reaction to achieve the production of 5-HMF as a carrier green H_2.

Conclusion

- The application of biomineralization to prepare distinct perovskite-type oxides as a straightforward synthesis strategy produces readily-defective catalyst for the production of H_2 carriers.
- The principle of the biomineralization process leads to the creation of nanomaterials with a highly disordered structure which contains a high volume of defects, and synchrotron characterisations reveals the geometric configuration and oxidation state of the perovskites which also possess oxygen vacancies.
- The potential of fabricating perovskite nanoparticles using biomineralization route is a desirable trait in many catalyst systems, with the findings highlighting the advantage of optimising reaction performance and selectivity for enabling such a trait.

Further work

- Further Investigation on $Ti_aZr_bO_x$ 2D morphology.
- Further experiment on Solar thermal conversion from sugar to 5-HMF.

Acknowledgement

I would like to express my sincere gratitude to Dr. Nicholas and Dr. Jason Scott for their support and guidance in this project. I would also like to thank Dr. Qiyuan Li for the solar thermal reactor construction.

Reference

Dickerson, M. B.; Sandhage, K. H.; Naik, R. R., Protein- and Peptide-Directed Syntheses of Inorganic Materials. Chemical Reviews 2008a, 108 (11), 4935-4978