Designing Nanocatalysts for Renewable Energy Applications

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Renewable Energy

https://youtu.be/RCU4CQ0_hCQ

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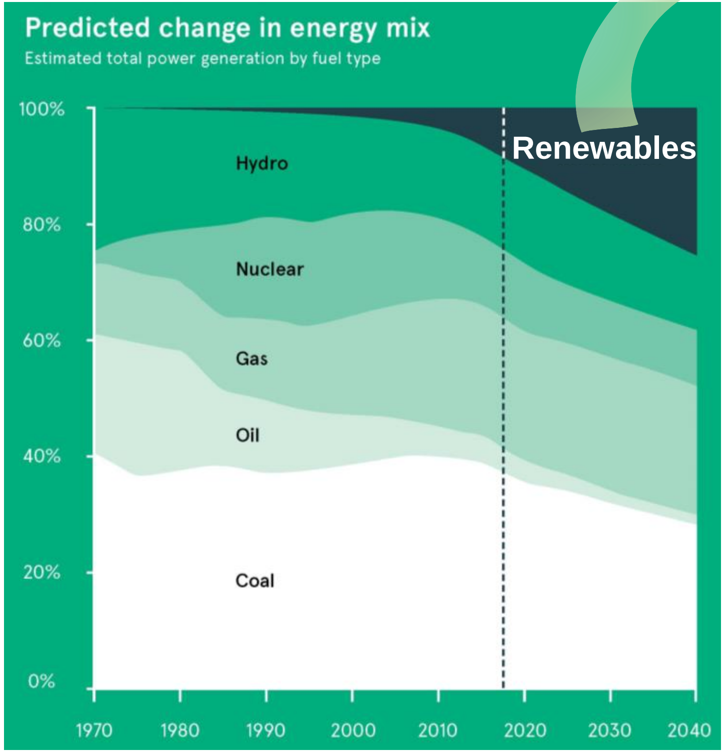
Introduction



BP, 2018

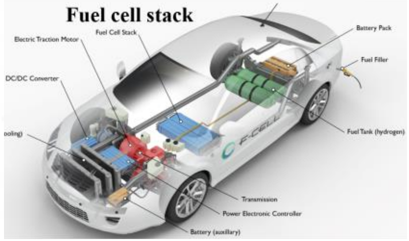
Time to go green – Renewable energy

Forecasts show an increasing reliance on renewable energy in the decades to come.

A fundamental shift in the energy mix to renewable energy relies on improved processes for it to be competitive against fossil fuels and thus allow a sustainable solution for alternative carbon resources.

In this poster:

Fuel cell



Biomass

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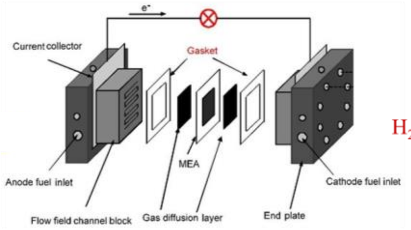
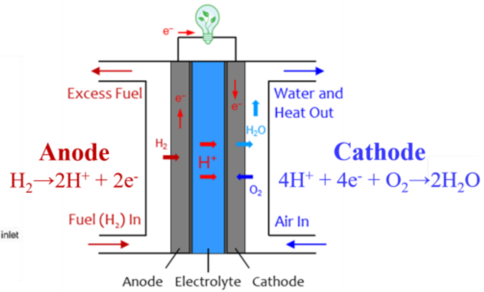
Objective

Designing catalytic materials for renewable energy applications:

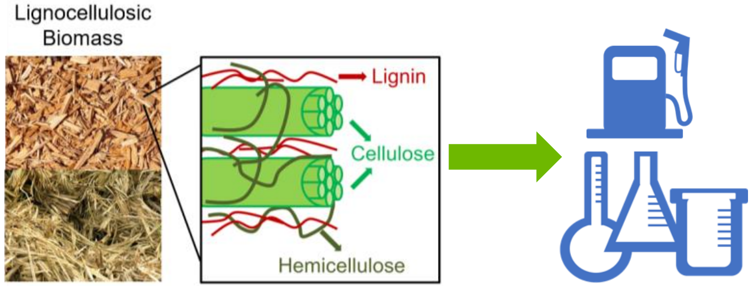
Electrocatalysis in proton exchange membrane fuel cell (PEMFC):





Oxygen reduction reaction (ORR)

Thermal catalysis in biomass conversion:

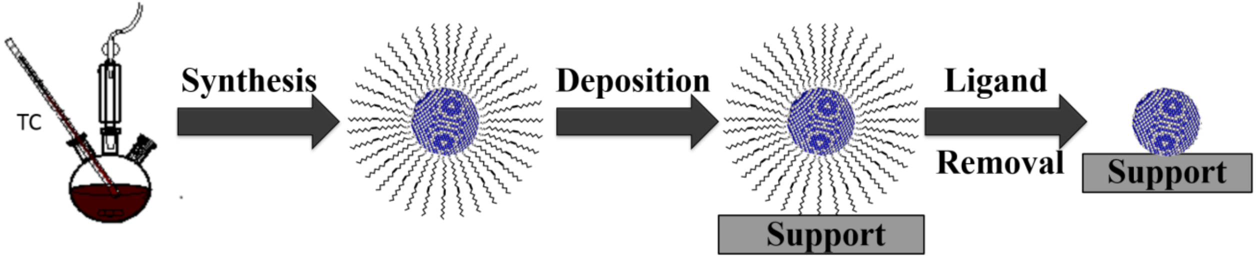


Hydrodeoxygenation reaction (HDO)

- The development of a suitable catalyst for renewable energy applications is necessary to push these technologies toward widespread adoption.
- Nanoparticles with well-controlled size, shape, and composition can be used to guide the fundamental understanding of structure-activity relationships of ORR and HDO reactions.

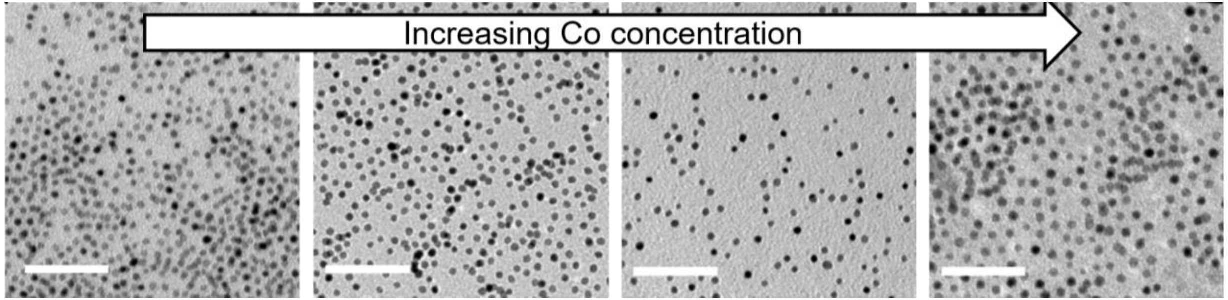
Methods

- Preparation of nanoparticle catalysts:



- Tunability in size, shape, and composition:

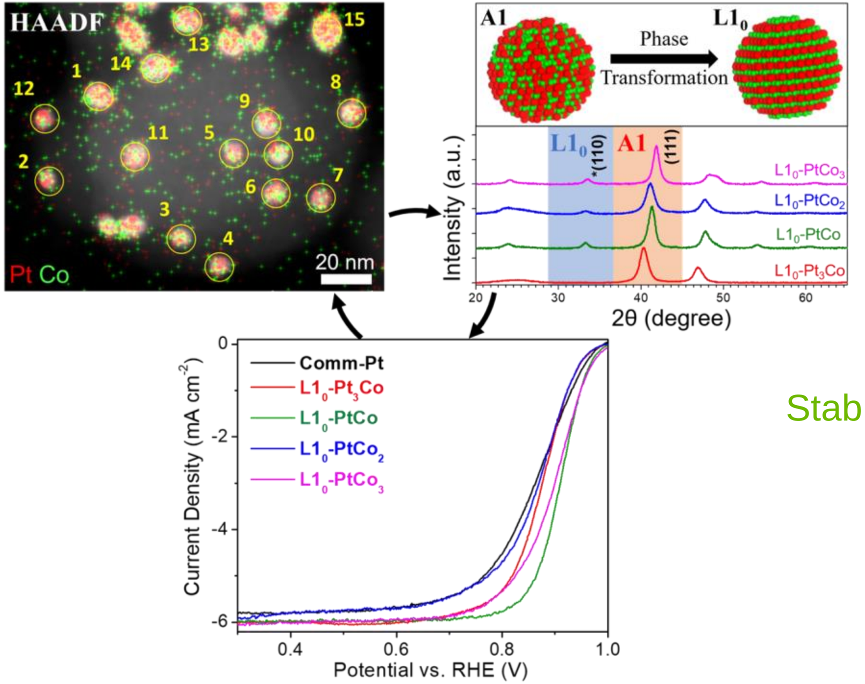
Platinum-cobalt metal alloy nanoparticles



High-temperature solution-phase synthesis has been used to prepare highly uniform, crystalline bimetallic NCs with controlled size, shape and composition at the atomic level as homogeneous building blocks for catalysis studies.

Results

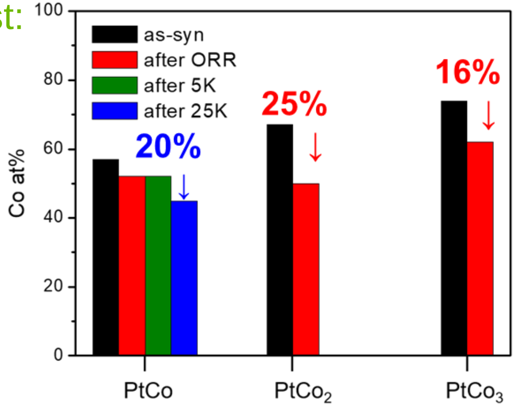
- ORR reaction for fuel cell applications:



Monodisperse Pt-Co nanocatalysts were synthesized with atomic-scale homogeneity in size (4-5 nm) and a wide rage of cobalt composition (25-75 at%).

The composition-dependent structural ordering further correlates with the ORR activities and thermal-treated PtCo/C showed the best performance in terms of ORR activity and stability in an acidic environment.

Stability test:



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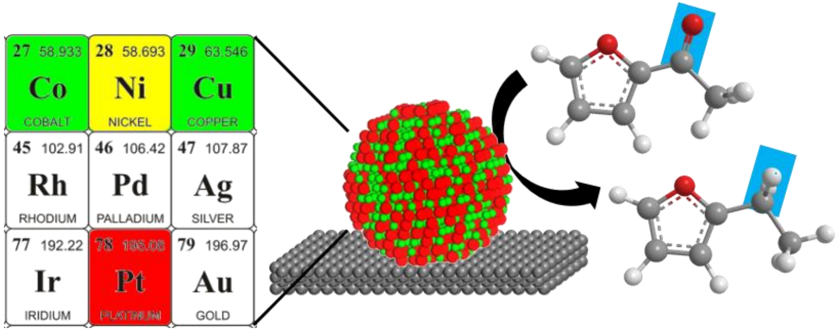
Lee, J.D. et al. *ACS Appl. Mater. Interfaces* **2019**, *11*, 26789–26797.

Results

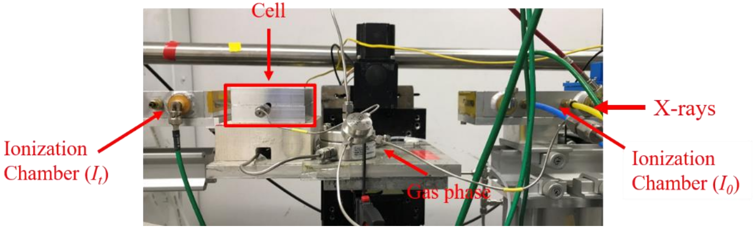
- HDO reaction in biomass conversion:

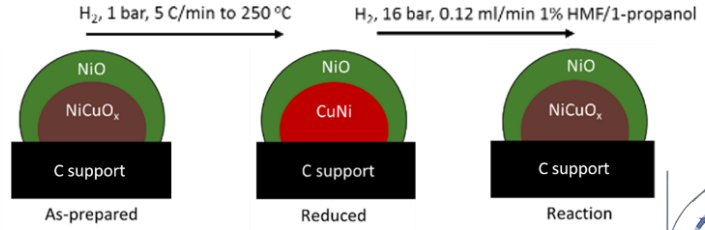


The selectivity for HDO of biomass-derived molecules is strongly affected by the choice of bimetallic components for Pt-based and Ni-based nanocatalysts with the optimum composition needed to reach maximum selectivity identified.

The highly active Ni-Cu HDO catalyst was characterized under reaction conditions with X-ray techniques to unravel the active structure.

Synchrotron-based X-ray techniques:





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Lee, J.D. et al. *Appl. Catal. A* **2020**, *606*, 117808.
Goulas, K.A, and Lee, J.D. et al. *Catal. Sci. Technol.* **2018,** *8*, 6100–6108.

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Conclusions

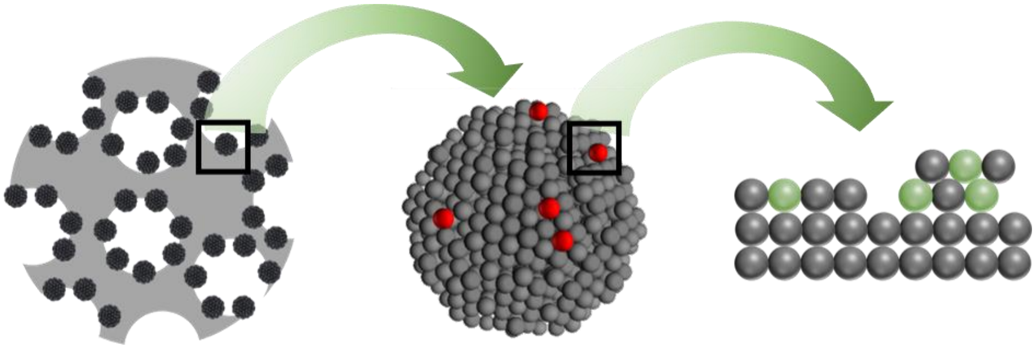
This poster introduces the synthesis, characterization, and application of monodisperse metal nanocatalysts with an emphasis on tailoring different aspects targeting fuel cell and biomass applications.

Systematic studies revealed the high-performance Pt-Co and Ni-Cu nanocatalysts for applications in electrocatalytic ORR and thermal catalytic HDO reactions, which contributes to the community by reducing the material cost, improving the catalyst performance and process efficiency.

This work provides fundamental insights into the intrinsic correlation between the relevant catalytic performance and the chemical composition of metal alloys, and thus aids research efforts toward developing the best possible catalytic materials for renewable energy applications.

Future work

Moving from binary systems to dilute alloys and complex materials.



- A multifaceted approach that spans a range of pressure, temperature and materials complexity will be used as the basis of establishing design principles of complex materials with targeted structure and properties to improve and develop efficient catalytic processes.

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IMASC

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Thermal catalysis for biomass conversion:

1. Lee, J.D. et al. Engineering the Composition of Bimetallic Nanocrystals to Improve Hydrodeoxygenation Selectivity for 2-Acetylfuran. *Applied Catalysis A: General* **2020**, *606*, 117808.
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IMASC Integrated Mesoscale Architectures for Sustainable Catalysis

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