

Electrocatalysis

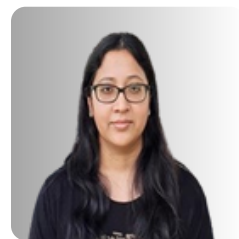
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The past energy economy was mainly based on fossil fuels like coal, oil, methane, etc. Exploring sustainable clean energy sources is a major societal and technological challenge in this century. In principle, solar and wind energy can meet a large portion of the global energy demand. However, they are intermittent and need efficient and economical storage solutions. Among various possibilities, hydrogen production and storage are attractive solutions. Gasification and steam reforming are established as cost-effective routes to hydrogen generation. However, their carbon content is significant. Thus, the evolution of the hydrogen economy is primarily dominated by the development of cost-effective and low-carbon footprint methods. Electrolysis of water is a promising direction for storing the electricity generated from renewable and carbon-free technologies as hydrogen fuel.

During water splitting, two half-cell reactions take place. The hydrogen evolution reaction (HER) occurs at the cathode and the oxygen evolution reaction (OER) occurs at the anode. Though both reactions are kinetically sluggish, the overpotential loss due to OER is much higher with respect to HER. Hence, OER is considered as the bottleneck of the entire water-splitting process. The technological need for the enhancement of OER kinetics has motivated intense research efforts throughout the world.

It has been shown that the electron transport through a chiral molecule induces a spin polarization without external magnetic fields which is known as the CISS effect. Hence, the spin-dependent electron transfer processes may take place at the liquid/solid interfaces during electrocatalytic OER using a chiral anode. Therefore, the CISS process affects the reaction pathway by controlling the spin-controlled charge transfer at the anode and paving a new pathway to improve the catalytic activity beyond the thermodynamic restrictions.

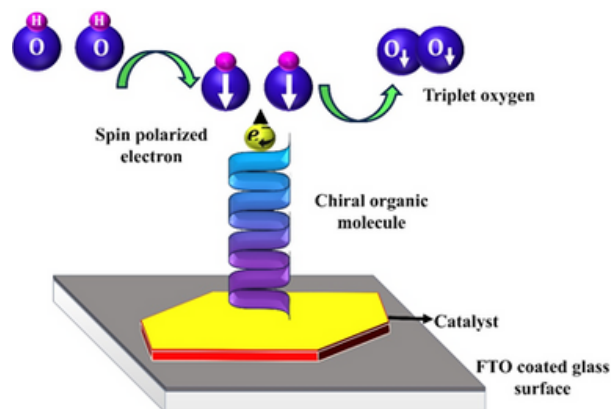
Recently, we have demonstrated the enhancement of OER activity of transition metal-based layered double hydroxides functionalized with chiral supramolecular assembly with respect to the only catalyst-coated electrode as well as achiral functionalized electrode. The spin-polarized charge transfer at the chiral anode also results in the selectivity of the product formation. The control experiments carried out in this study depict that the chiral organic molecule individually may not compete with the state-of-the-art OER catalyst. However, these groundbreaking approaches can be used in conjugation with the top-performing catalysts for the further improvement of their catalytic activity.



Therefore, the evolution of efficient, stable, and cost-effective OER catalysts to make water splitting a viable and scalable energy storage technology is a thirist area for researchers. First-row transition-metal oxides and layered double hydroxides are particularly interesting candidates for next-generation electrocatalysts because of their relatively low cost and easy fabrication process, but the progress is not up to the mark.

From a thermodynamic point of view, an ideal catalyst surface should bind to the reaction intermediates with optimal strength. Specifically, the activity of a catalyst is defined by the binding energies of the catalyst to the intermediate. Recently, some unconventional innovative approaches have been demonstrated to improve the electrocatalytic efficiency beyond the volcano limit by controlling the spin of the electron, and these methodologies are receiving growing concern.

My research is mainly focused on exploring this unconventional way of improving electrocatalysis by spin filtering the anodic or cathodic current using chiral molecule-modified catalyst systems. The justification behind the use of a chiral catalyst as the spin-filtering electrode is the chiral-induced spin selectivity (CISS) effect.



Proposed mechanism of OER at the chiral molecule modified anode

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