Engineering High-Entropy Materials (HEMs) on Various Substrates for High-Performance Electrocatalytic and Photo-electrocatalytic generation of Hydrogen

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The global energy demand towards sustainable energy seeks hydrogen's attention in the near future as a green, efficient, and versatile fuel. The promising ways to generate green hydrogen are through electrochemical (EC) and photoelectrochemical (PEC) splitting of water. The former technique relies only on the usage of electricity to split water, whereas the latter one harnesses the sunlight along with an external bias to split water into hydrogen and oxygen.

Recent advances in materials science are progressing in this field, particularly with the usage of various high-entropy materials (HEMs) along the effective substrate chosen to support it. The design and development of high-entropy alloys (HEAs) and high-entropy oxides (HEOs) containing transition metal elements with suitable composition results in enhanced catalytic performance comparable to conventional noble catalyst such as Pt group.

In EC studies, our research focuses on tailoring catalyst's composition, electronic structure and morphology to minimize the overpotential and charge transfer resistance.

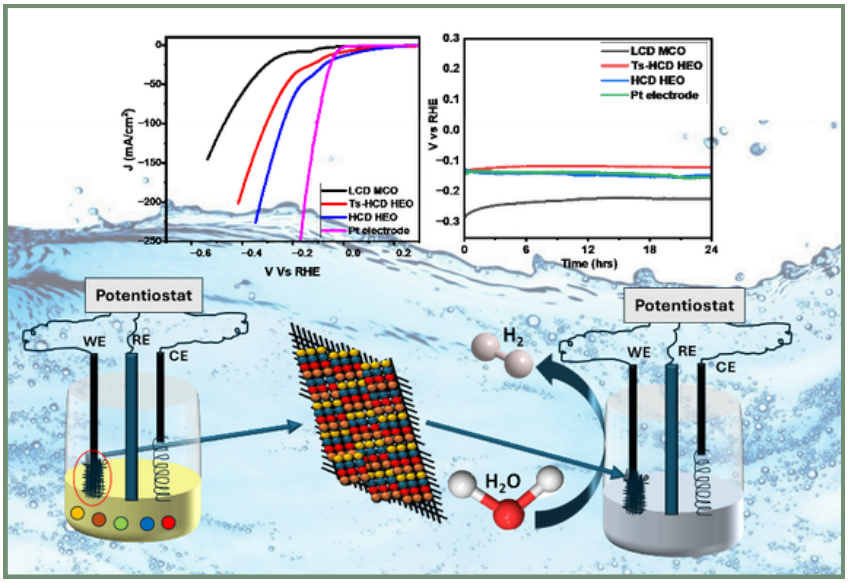

Figure 1. Graphical Representation of HEA electrocatalyst and its HER performance in alkaline media

Additionally, long-term stability is also carried out alkaline media for overall efficacy of electrocatalyst. In parallel, PEC work integrates these materials as co-catalysts with light-absorbing semiconductors such as silicon.

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These semiconductors are used to construct photoelectrodes capable of harnessing sunlight along with external bias to generate hydrogen at more positive onset potential w.r.t RHE. The design includes band alignment for efficient charge separation, surface passivation to suppress recombination and photo-corrosion prevention for long term stability.

In summary, the integrated EC–PEC framework leveraging high-entropy material catalysts on diverse substrates not only bridge fundamental insights with practical development. Rather, they also provide a clear path toward scalable hydrogen technologies that power a sustainable energy future.

As we move toward carbon-neutral energy solutions, advanced innovations towards EC and PEC catalyst plays a critical role in aligning with India's mission towards hydrogen economy. In our laboratory, we have successfully established a robust EC HER system utilizing high-entropy oxide electrocatalysts on diverse substrates, delivering performance comparable to state-of-the-art benchmarks for alkaline water electrolysis.

Additionally, we are working parallelly on developing Si supported HEA cocatalyst as photocathodic materials towards PEC generation of hydrogen.

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