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ABSTRACT:

Designing Materials for the Hydrogen Age: the Need for Nanoscale Insights

Aparna Saksena[1]
[1] Max-Planck-Institute for Sustainable Materials, Max-Planck-Strasse 1,
Dusseldorf 40237, Germany

Decarbonation of society is necessitated by growing concerns about climate change, and motivates the search for clean and sustainable industrial processes and fuels. Hydrogen is a strong candidate to be a carbon-neutral energy vector for the future. Yet, from a materials standpoint, hydrogen is synonymous with challenges: first for material durability and sustainability in hydrogen-rich environments, and second for the green production of hydrogen. For both aspects there is a need for developing new materials, and to guide their design requires insights, on the finest scale, into how hydrogen distributes within the material or how the electrochemical reactions used for generating clean hydrogen modify the microstructure. Quantitative imaging of hydrogen at the nanoscale is not yet routinely achievable.

My research focuses first on developing the methodologies to probe hydrogen at the ultimate scale, based on the latest developments of cryogenic atom probe tomography in correlation with electron microscopy. I then apply these frontier techniques to model materials relevant to the hydrogen economy in the broader context. I aim to unveil mechanisms that limit their performance or operational lifetime to establish the feedback loop necessary to design new materials. In this overview presentation, I will draw examples from both high-strength steels, in which even trace amounts of hydrogen can cause severe and catastrophic degradation of the mechanical properties, and catalytically-active thin films to advance the understanding of the influence of microstructural defects and how to exploit them to boost the catalysts' performance and optimize their design.

By combining nanoscale characterization with microstructural control, my work provides insights into designing more efficient catalysts and hydrogen-resistant materials, contributing to the development of a sustainable hydrogen economy.