

Strain-engineering of amorphous metals electrodes

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CONTEXT

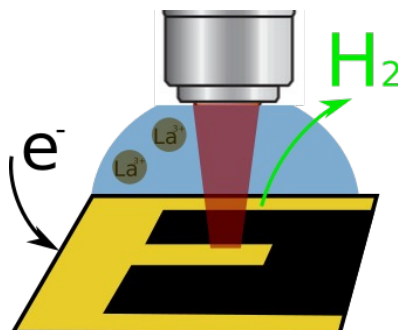
Hydrogen is today mainly obtained by hydrocarbon steam reforming, which produces large CO₂ quantities. Because of the rising concern about greenhouse gas emissions, the widespread use of hydrogen as an energy carrier requires the development of a carbon-free production chain. In case it makes use of renewable electricity sources, hydrogen production by electrolysis may be the key to trigger the expansion of this promising sector. However, only a few percent of the total hydrogen production comes today from water electrolysis, mainly because of its cost, which is about four times higher than the cost of hydrogen obtained by steam reforming. Electrolysis requires an electrocatalyst, typically platinum, which is rare and expensive.

Electrolytic production of H₂ is thus handicapped by its dependence on platinum and by the adverse role played by the hydrogen bubbles produced at the electrode surface in the hydrogen production itself. It is therefore crucial, in order to minimize the cost and energy losses, to avoid materials like platinum as much as possible, and to limit the adverse effects of bubbles production.

It has already been demonstrated that elastic strains can modulate the electrocatalytic activity of metals [1-3], so that more abundant materials could be strained in order to compare with platinum in terms of electrocatalytic activity. The question of the mechanical quantity driving the electrocatalytic activity is however open, and we propose an experimental approach based on an imaging technique to address this issue.

IMAGING TECHNIQUE

The various objects in this study have been imaged using the same reflection microscope. The sample is illuminated using a stabilized white lamp and interference filters to select a monochromatic illumination in the visible range.



As illustrated in the schematic view above, this reflection microscope is used to observe the electrode's surface during hydrogen production. By adding a small amount of a Lewis acid metallic cation, here lanthanum, which is able to precipitate when the pH turns alkaline to the solution, the obtained images reveal the footprint of the hydrogen production rate.

APPLICATION TO DEFORMABLE ELECTRODES

This imaging technique is applied to monitor in-situ, in-operando the early stages of the hydrogen production at the surface of deformable micro-cantilevers made of an amorphous metal. This first reveals that the hydrogen production is very non-uniform along the cantilever. An initial deformation could also be imposed to the micro-cantilevers, so that the imaging technique has been applied to amorphous metal cantilevers with varied external mechanical loadings. This reveals that the hydrogen production is significantly altered on the surface under tension of the bent cantilever. Contrarily, the hydrogen production is enhanced when the surface is under compression. The strain however does not seem to be the driving mechanical quantity. Moving towards more quantitative results requires to solve the associated 3D diffusion-reaction problem, which will be discussed.

REFERENCES

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