2019 ERC Starting Grant Project '123STABLE' or 'Towards Nanostructured Electrocatalysts with Superior Stability



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My topic

- Hydrogen cycle at home:
- self sustained hydrogen home



Current Grand Challenges: to store energy & better catalytic processes



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ERC President visit to Slovenia, 28th November, Ljubljana

Proton exchange membrane fuel cell

No emissions – no $CO_2!$ Only $2H_2 + O_2 \rightarrow 2H_2O$ Higher efficiency!



PEM-FC electrocatalyst stil requires improvement of performance & stability & cost !

Most promising replacement of Pt/C are Pt-alloys, at least activity wise – therefore it is important to study their electrochemical behaveour – their stability!



Towards Nanostructured Electrocatalysts with Superior Stability



Dr. Nejc Hodnik, Assoc. Prof.

Electrocatalysis Group Leader (2 PhD students, 3 postdocs)



@ National Institute of Chemistry, Ljubljana, Slovenia

What happens to the nanoparticle on the atomic level?







What defines metal electrocatalyst activity?

e.g. PEM Fuel Cell (Pt) or Electrolyzer (Ir)

- -nature of the metal
- -surface area
- -support
- -morphology (surface facets)
- -structure
- -composition (presence of second metal) -presence of defects, steps, kinks, ad-atoms -size
- -alloying ligand and/or strain,
- -confinement, proximity, ensemble effect
- -surface patterning, nature of electrolyte -etc.

Practically everything we can think of!



Chorkendorff, Nørskov, Jaramillo*, et al., Science 2017, 355, 6321



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The reality of nanoparticles







The reality of nanoparticles

Structure-activity relationship on atomic level is a state-of-the-art in electrocatalysis



Structure-stability relationship at the atomic level is much less explored





Spot the difference at the atomic level

Find the four differences in the two electrocatalysts images before and after aging - and then mark in the second one.



4. redeposition

Hodnik* and Cherevko*, Curr. Opin. Electrochem., 2019, 15, 73

Because the history of the location's physical characteristics is known, reliable conclusions on very complex atomic scale events such as degradation mechanisms can be drawn.





Identical Location Transmission Electron Microscopy



0.1 M HClO₄, **200 cyc 0.05 – 1.2 V** vs. RHE, 300 mV/s, Ar

Ruiz-Zepeda & Hodnik*, et al. Nano Letters, 2019, 19, 8, 4919

Challenge is to track changes on the atomic level on the same nanoparticle!





Identical Location Transmission Electron Microscopy

My Research Objectives:





Ruiz-Zepeda & Hodnik*, et al. Nano Letters, 2019, 19, 8, 4919





Impact

- Introduce new methodological approach for the fields of (electro)catalysis, corrosion, sensors, batteries, etc.
- Establish Pt- and Ir-based nanoparticles structure-stability relationships
- Develop new Pt- and Ir-based electrocatalysts with prolonged performances

My TEAM

Thank you for your attention!

- 4 postdocs (2x2 + 2x3 years):
 - 1. synthesis
 - 2. TEM
 - 3. Online analytics (ICP-MS & OLEMS)
 - 4. computer simulation

- **3** PhD-students (2x4 + 1x3.5 years) :
 - 1. Pt-based system
 - 2. Ir-based system
 - 3. el. liquid TEM

- 4 part-time experts (no cost):
- 1. synthesis
- 2. *in-situ* TEM
- 3. synchrotron
- 4. computer simulation

+technician





Some advice: Physical and Analytical Chemical Sciences (PE4)

- Stage one:
 - Very good statistics: papers, citations etc., good postdoc, at least one high impact paper, invited lectures, ...
- Stage two:
 - Show that you are already relevant in the field
 - Propose something groundbreaking but still very doable and not completely out of this world – something only you can do due to your unique expertise
- There are very good instructions, local workshops and some good webinars (e.g. youtube) where ERC officer is telling what is needed...
- Problems when you get the grant:
 - "Negotiate" with host institution best possible conditions what is the correct ratio between what you deserve and what they are ready to offer, like laboratory, offices, lab space, vision, …





Thank you for your attention and thanks ERC!



"Besides improving the technology we should also try to adapt human habits."

