Supported Ir and IrRu nanoparticles as highly active oxygen evolution catalysts for PEM water electrolysers

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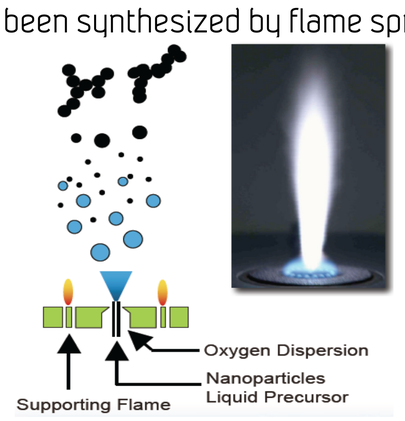
NOVEL

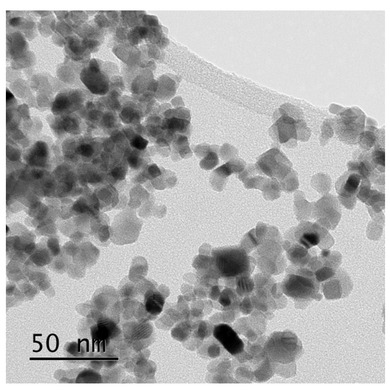
Background

- The catalyst of choice for the anode in PEM electrolysers have since the first journal publication by Russell [1] et al. in 1973 been Ir black or IrO_2
- The anode catalyst loading in PEM electrolysers has not changed significantly during the last decades due to the relatively low surface area and low catalyst utilization [2].
- Significant efforts have been made to increase the electrocatalytic activity of the Ir catalysts
  - Alloying with more active materials (Ru) or ternary (inactive) materials for improved stability and activity

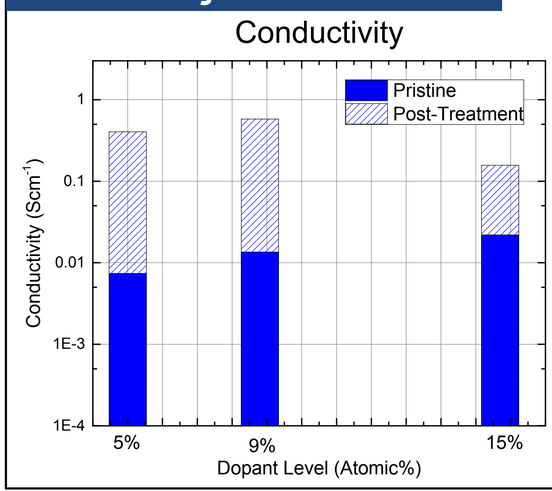
Support synthesis

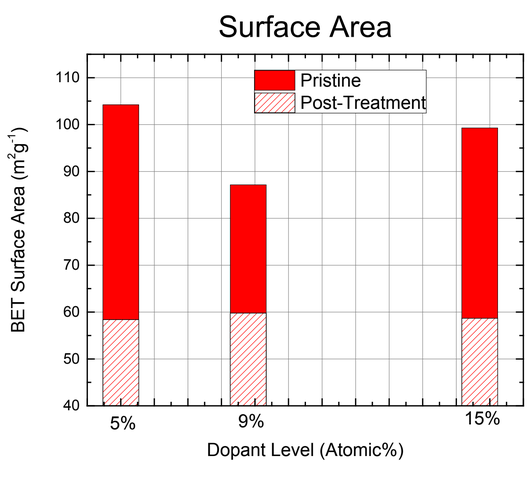
Undoped and Sb/Nb-doped titanium and tin based oxide powders have been synthesized by flame spray pyrolysis





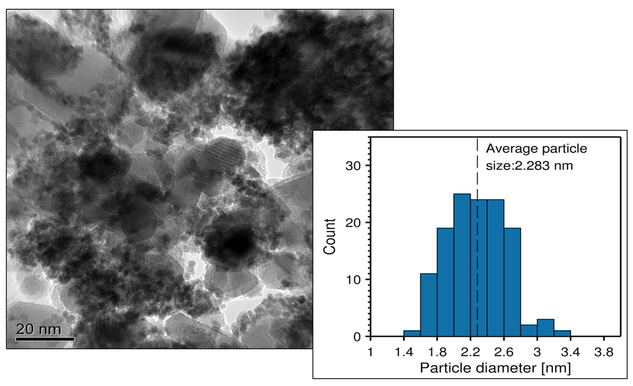
Conductivity and surface area





Catalyst synthesis

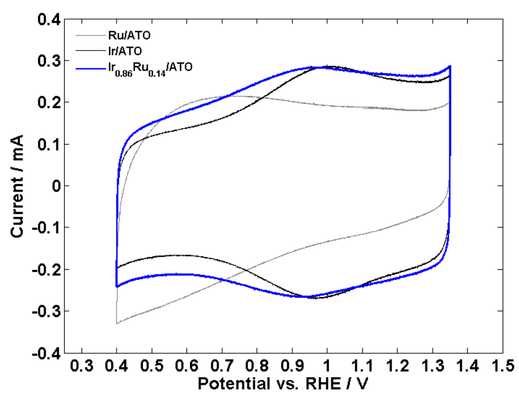
- Microwave polyol synthesis in continuous flow reactor.
- Ir, Ru and Ir-Ru alloy nanoparticles of 2-3 nm average size
- Fast and scalable synthesis (15g catalyst in 10 minutes)

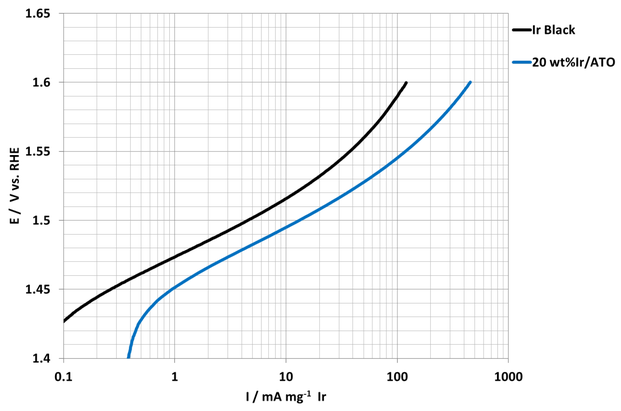


Rotating disk experiments

The catalysts show high reversible pseudo capacitances and is similar to thermally formed oxides. The original metal nanoparticles are irreversibly converted to their (hydr)oxide form.

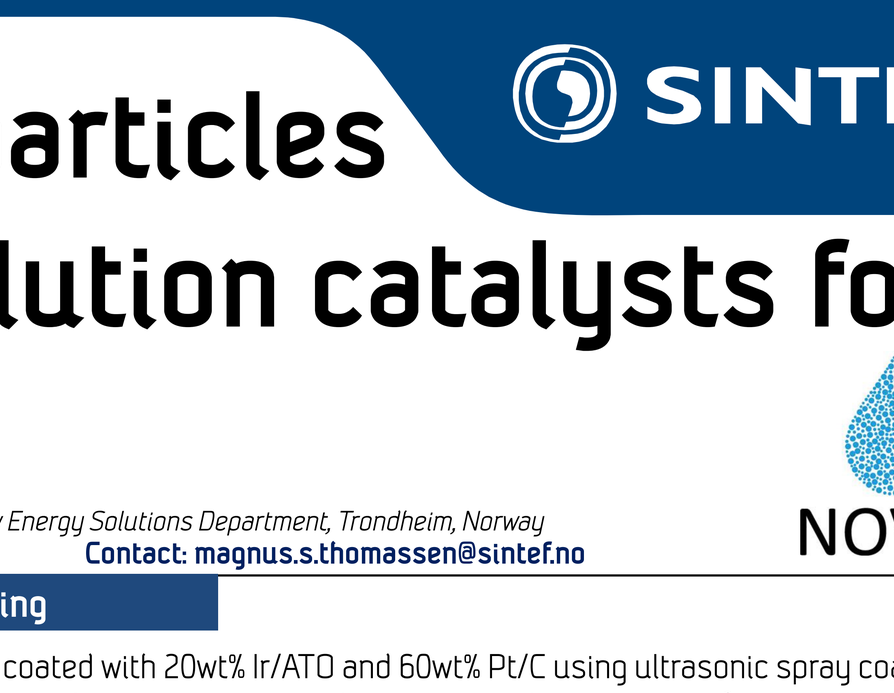
The mass activity of the supported Ir nanoparticles are about 300% of unsupported Ir. The main cause of the increased activity is the increase in active Ir surface area





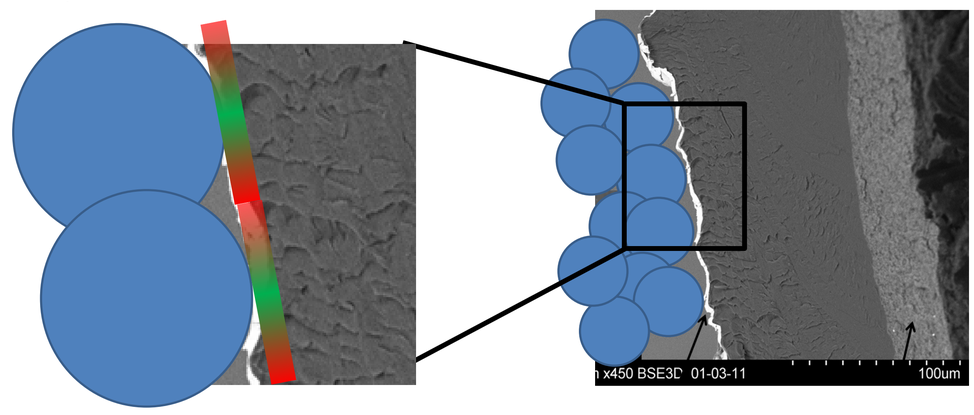
MEA testing

- N117 coated with 20wt% Ir/ATO and 60wt% Pt/C using ultrasonic spray coater
- Similar performance as IrO2 with 4x lower loading, 0.9 mgcm^{-2} total PGM loading.

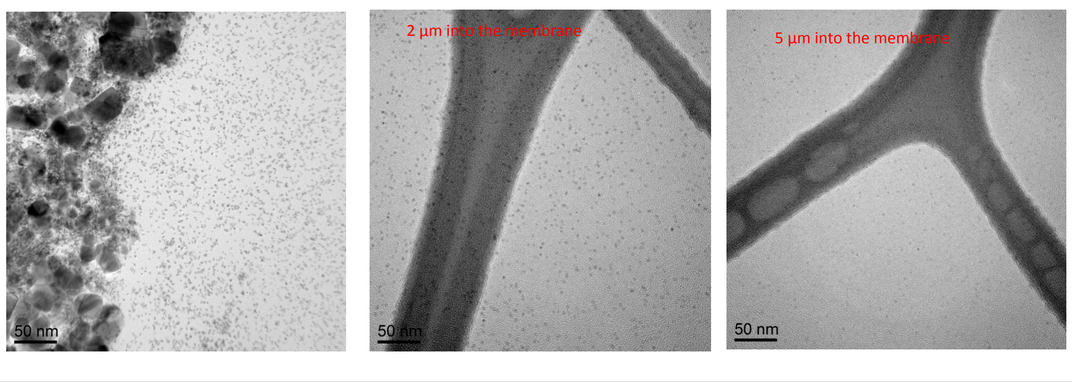


Remaining challenges

- Low in-plane conductivity of catalyst layer
  - Low conductivity of catalyst and/or
  - Thin catalyst layer
- No microporous layer between Ti-sinter and catalyst layer
- Can cause significant potential drop in-plane between catalyst/titanium contact points
- Can lead to areas of inactive catalysts and areas with high local heat production



- Long term stability of small Ir nanoparticles
- Indications of dissolution of Ir and re-precipitation in membrane after 100h current cycling test



Conclusions

- TiO_2 and SnO_2 doped with Sb and Nb produced via flame spray pyrolysis can be produced with suitable particle and pore size distribution.
- Nanoparticles of Ir and Ru and alloys of these exhibit high catalytic activity due to a significant increase in surface area
- Challenges in using these types of catalysts in PEM electrolysers due to lower conductivity remain
- Further *in situ* stability testing and interface contact improvements are still necessary

Acknowledgments & References

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant agreement n° [303484] (Novel).
The Research Council of Norway has co-funded this research through the ENERGIX –programme

1. Russell, J., L. Nuttall, and A. Fickett. Hydrogen generation by solid polymer electrolyte water electrolysis. in Am. Chem. Soc. Div. Fuel Chem. Meeting, Chicago (August .1973). 1973.
2. Carmo, M., et al.,. International Journal of Hydrogen Energy, 2013. 38(12): p. 4901-4934