UNIVERSITY OF BIRMINGHAM | COLLEGE OF ENGINEERING AND PHYSICAL SCIENCES

The development of aligned PtNi NW electrodes for PEMFCs

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CDT Fuel Cells and their Fuels
University of Birmingham

EPSRC
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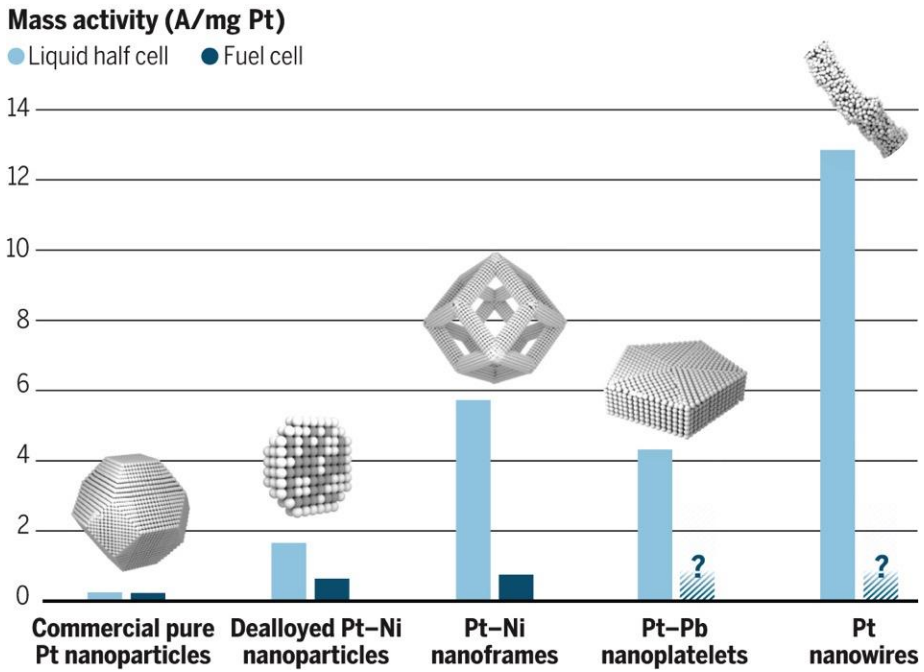
Current challenges of PEMFC catalysts



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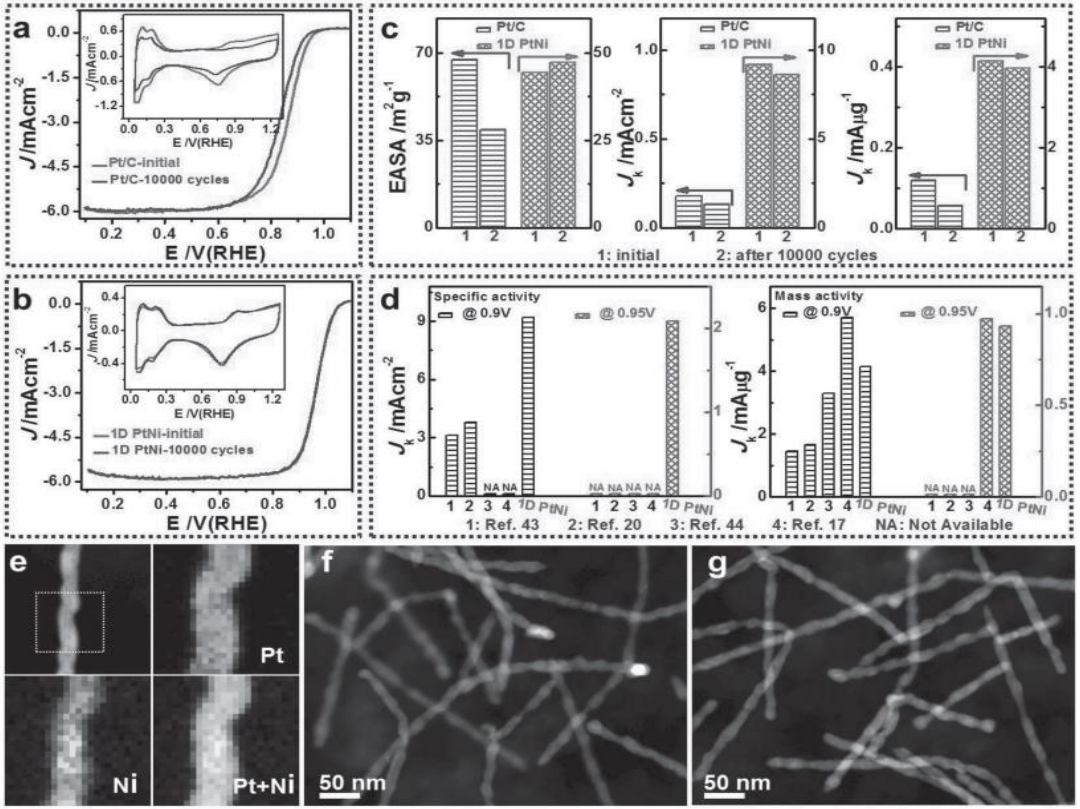
A great catalyst - PtNi nanowires



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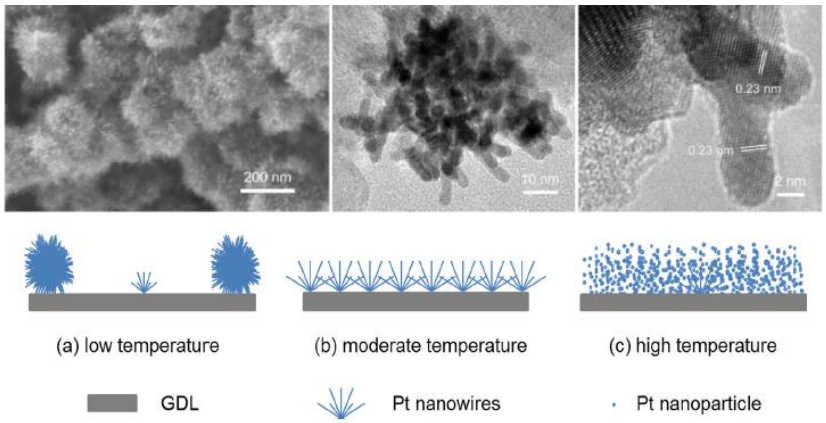
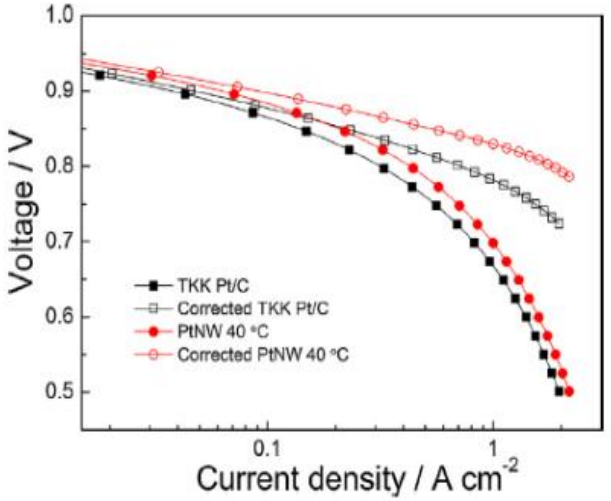
A good electrode – Aligned Pt nanowire arrays





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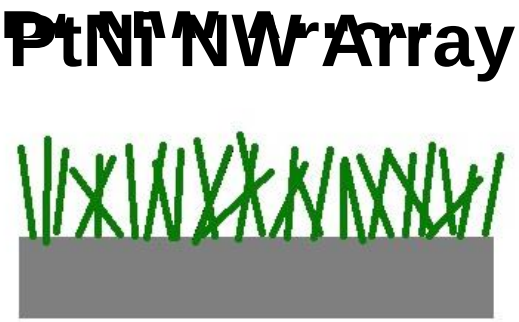
- High catalytic activity from the single crystal nanowires.
- Aligned nanowire arrays show increased fuel cell performance, notably at high current densities.

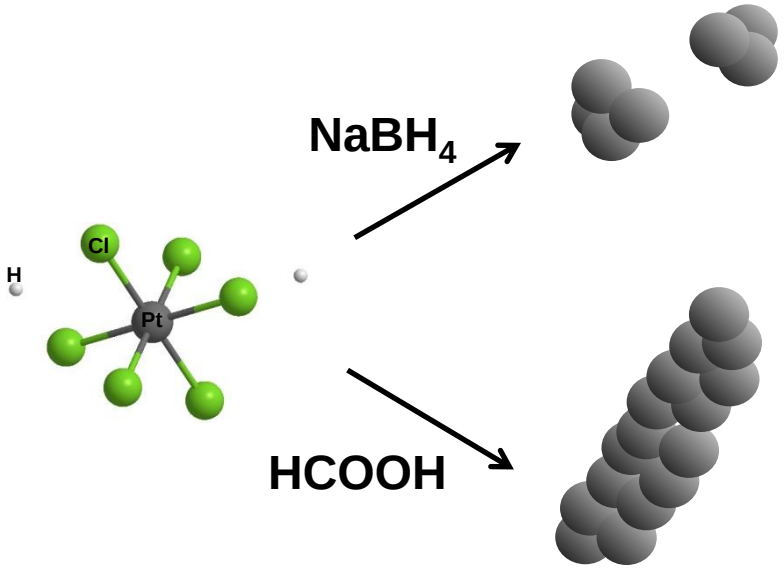
The goal – Aligned PtNi nanowire array electrodes



- If similar nanowire array electrode can be made with PtNi rather than pure Pt, further performance enhancements can be expected:

→ A simple idea but not so easy to achieve.

Pt nanowires by formic acid reduction

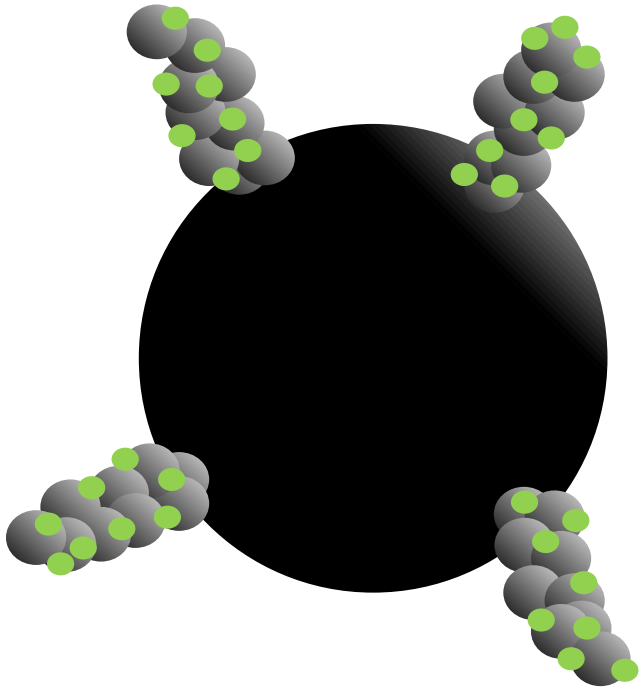


Ni impregnation

- Synthesis method

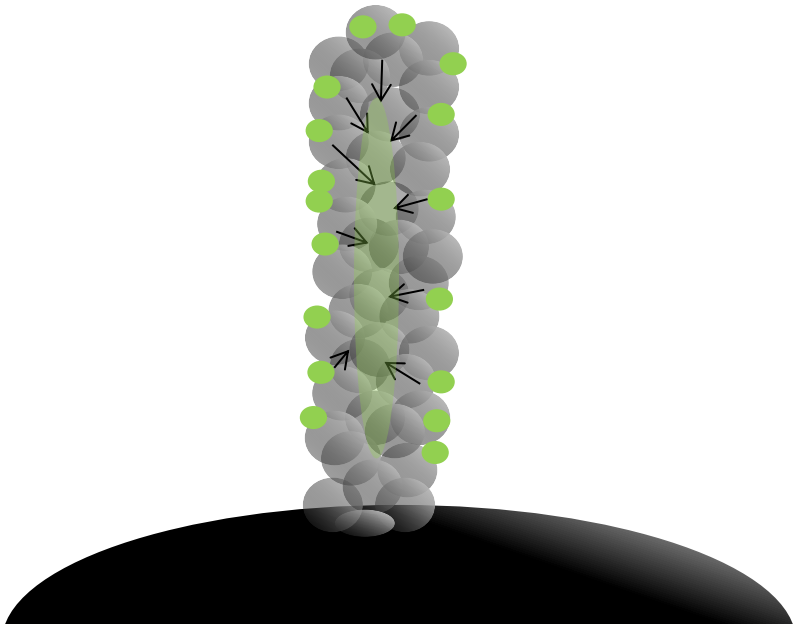
1. Growth of Pt NWs on carbon using HCOOH.

2. Impregnation of Ni on the Pt NWs using $NaBH_4$.

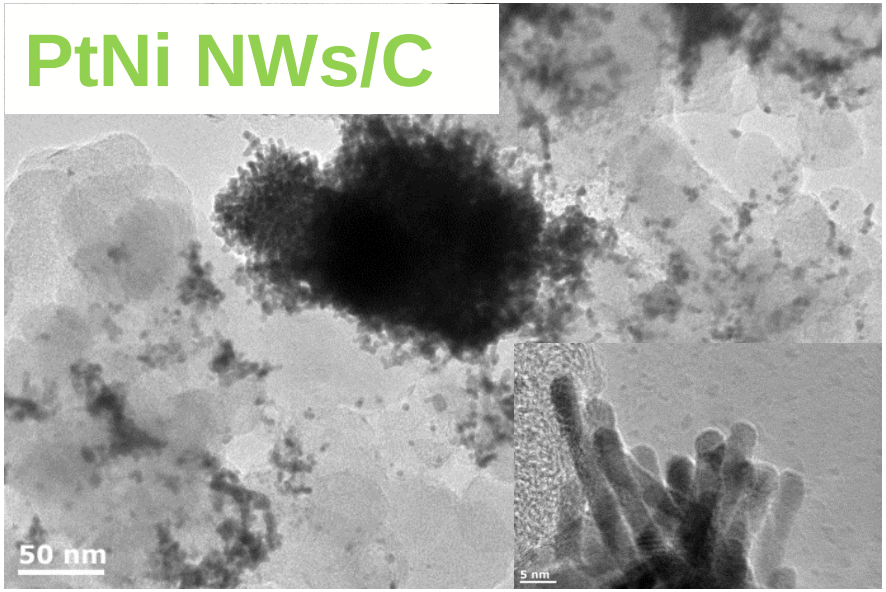


Thermal annealing of PtNi

3. Thermal annealing under a flow of H_2/Ar for 24 hrs.



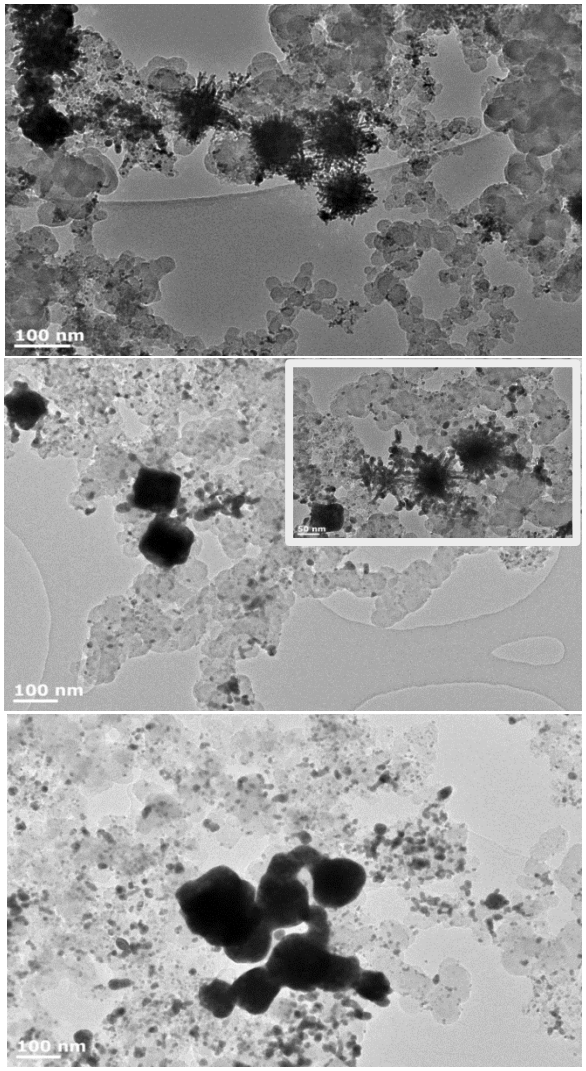
Effect of annealing temperature on morphology



150 °C

250 °C

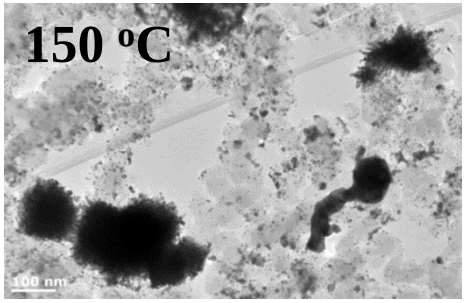
350 °C

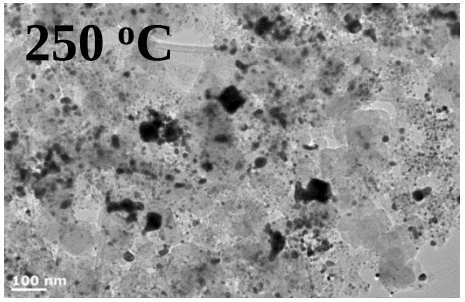


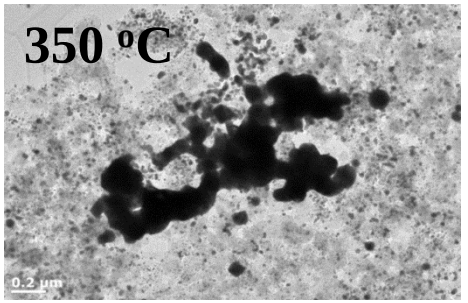
- Conventional annealing temperatures of up to 900 °C cannot be used if NW morphology is to be retained.

Effect of composition on coarsening

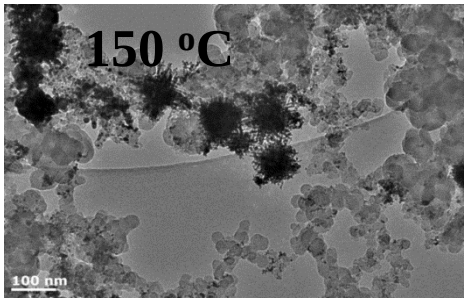
Pt NWs/C

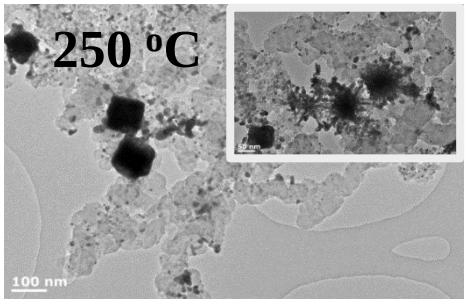


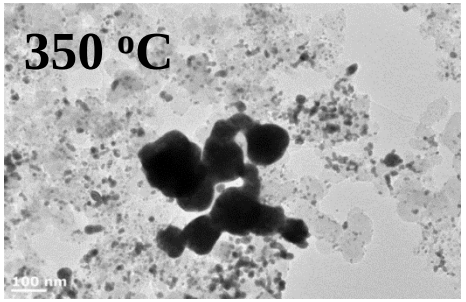




PtNi NWs/C



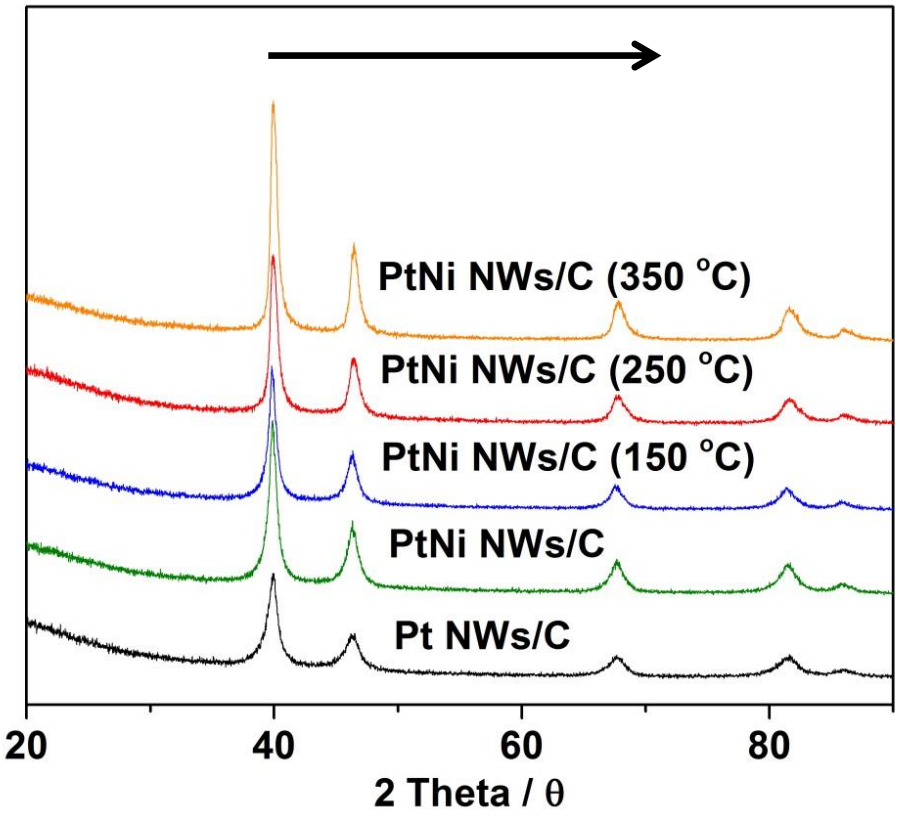




- Samples impregnated with Ni are more resistant to coarsening than the samples of pure Pt.

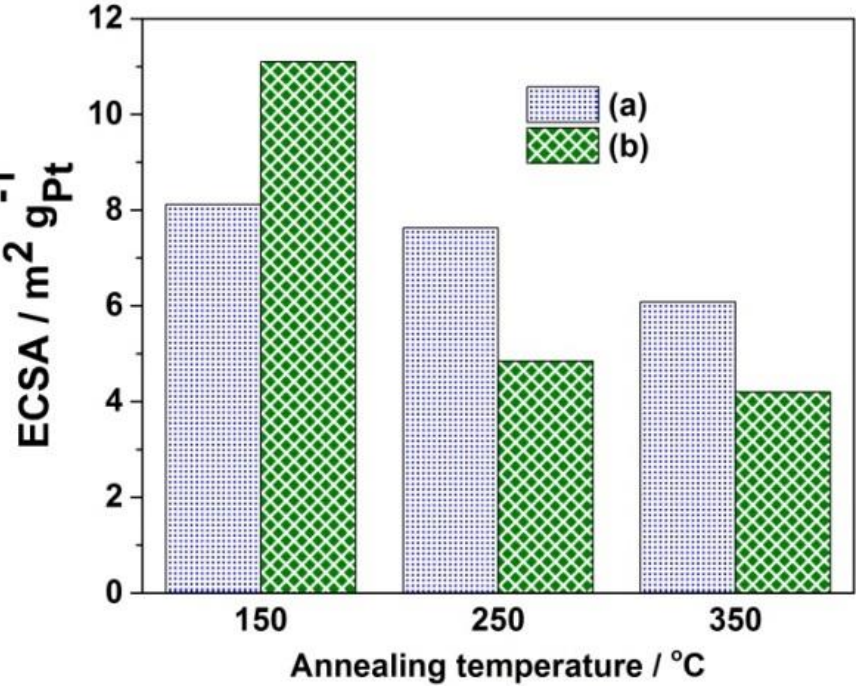
Degree of annealing – XRD

- Positive peak shift with higher annealing temperatures = Increase in degree of alloying.



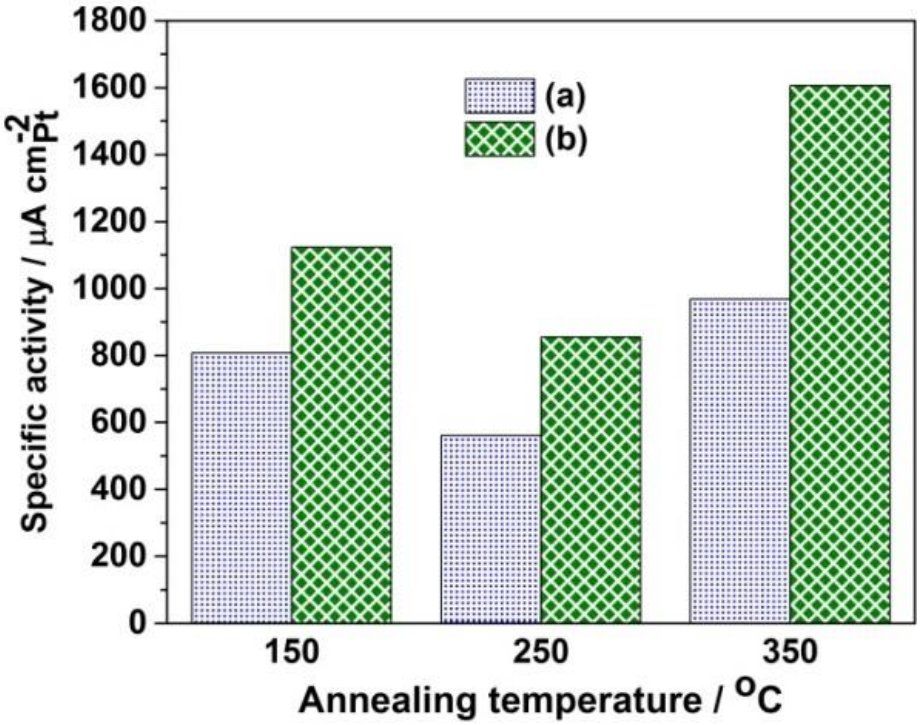
Rotating Disk Electrode - ECSA

(a) Pt NWs/C
(b) PtNi NWs/C



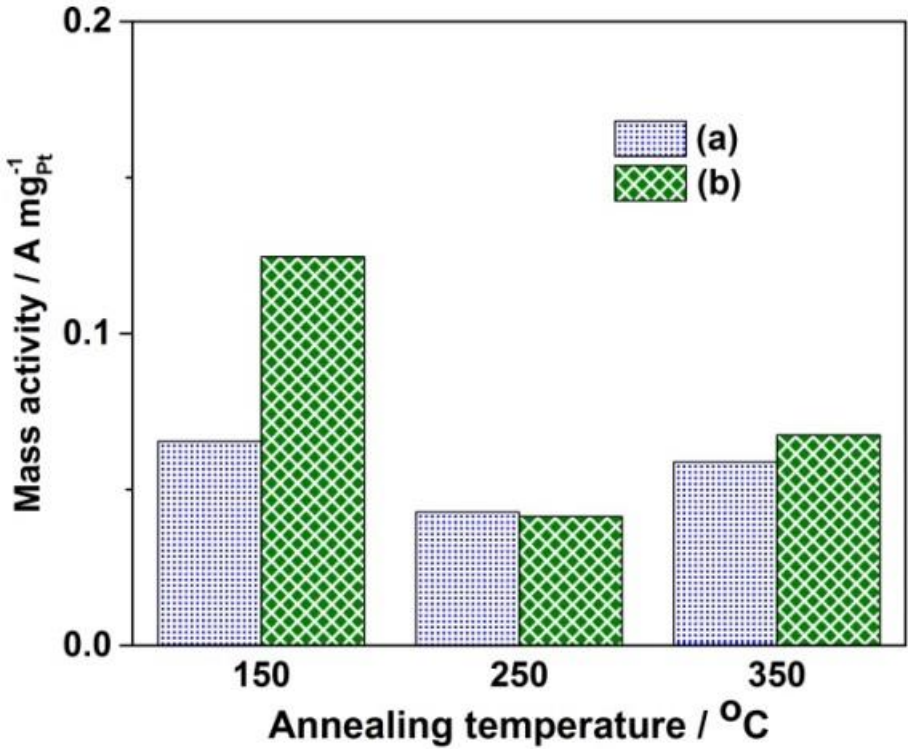
Rotating Disk Electrode – Specific activity

(a) Pt NWs/C
(b) PtNi NWs/C

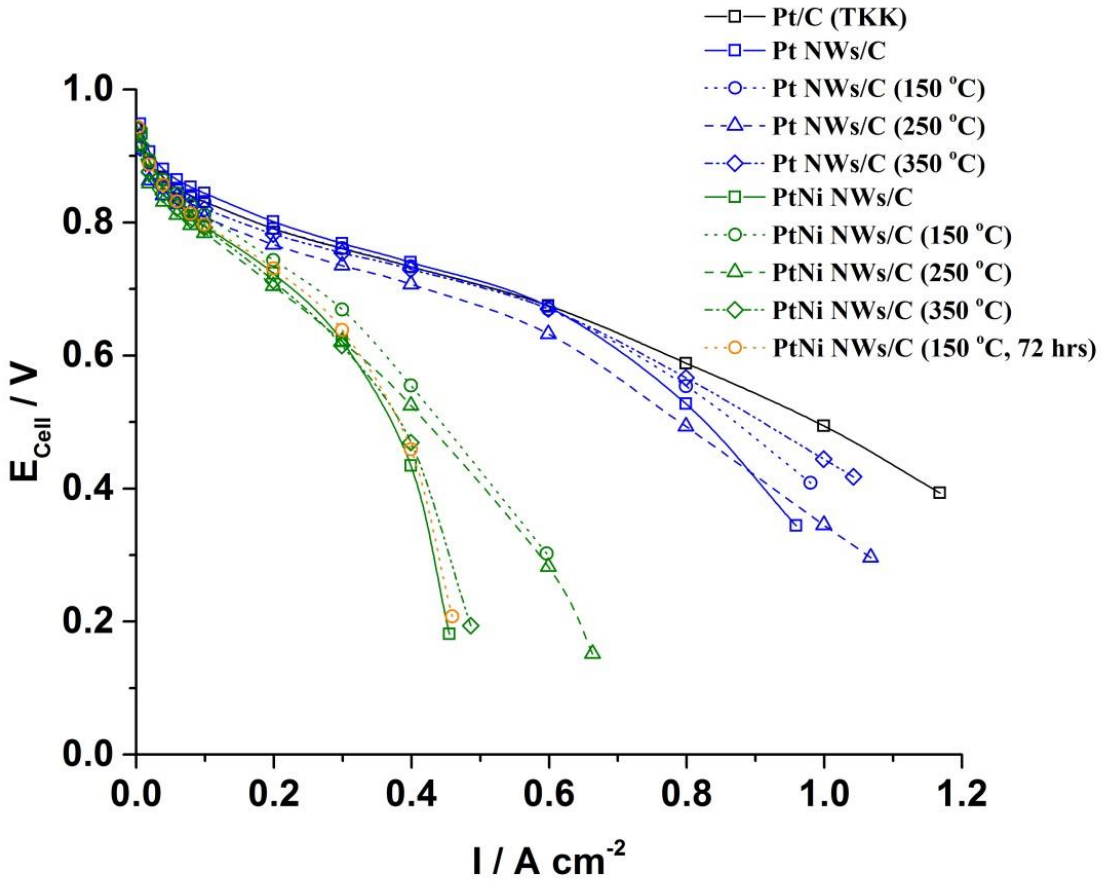


Rotating Disk Electrode – Mass activity

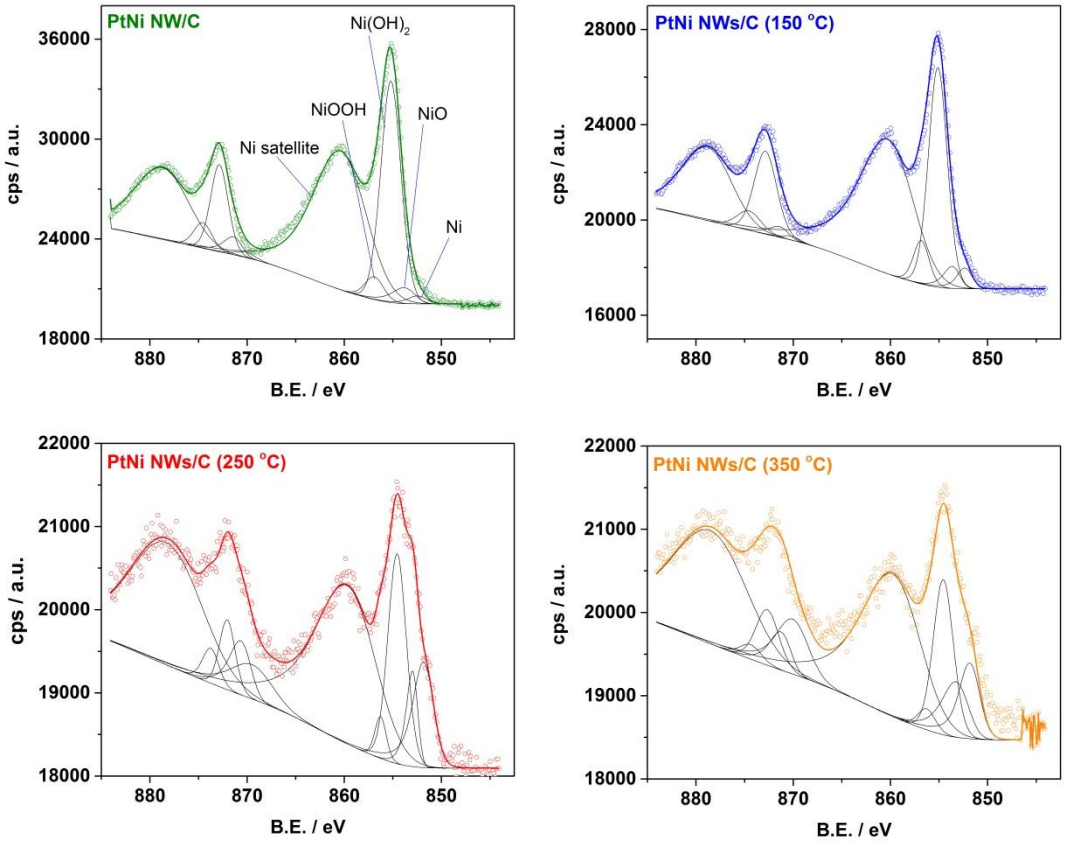
(a) Pt NWs/C
(b) PtNi NWs/C



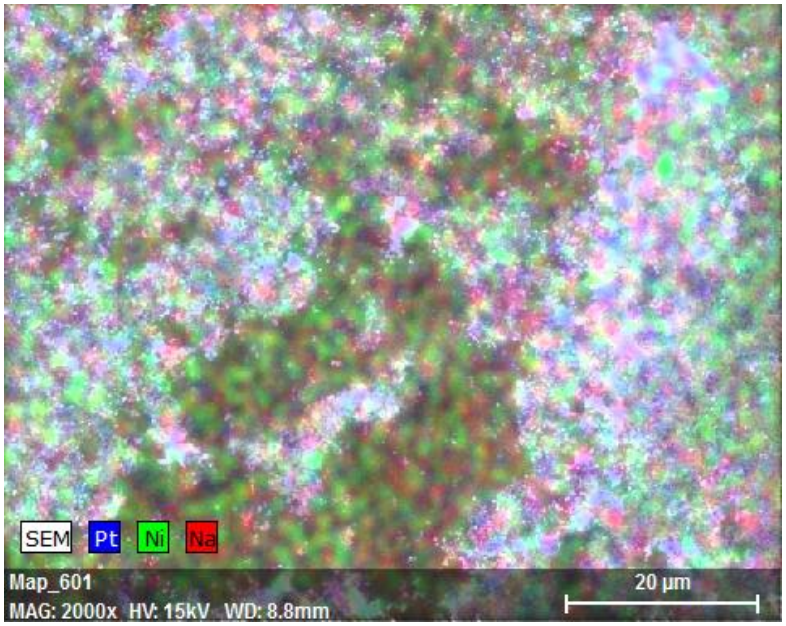
Single Cell Tests of PtNi NW/C catalysts



Why does PtNi perform badly? – XPS

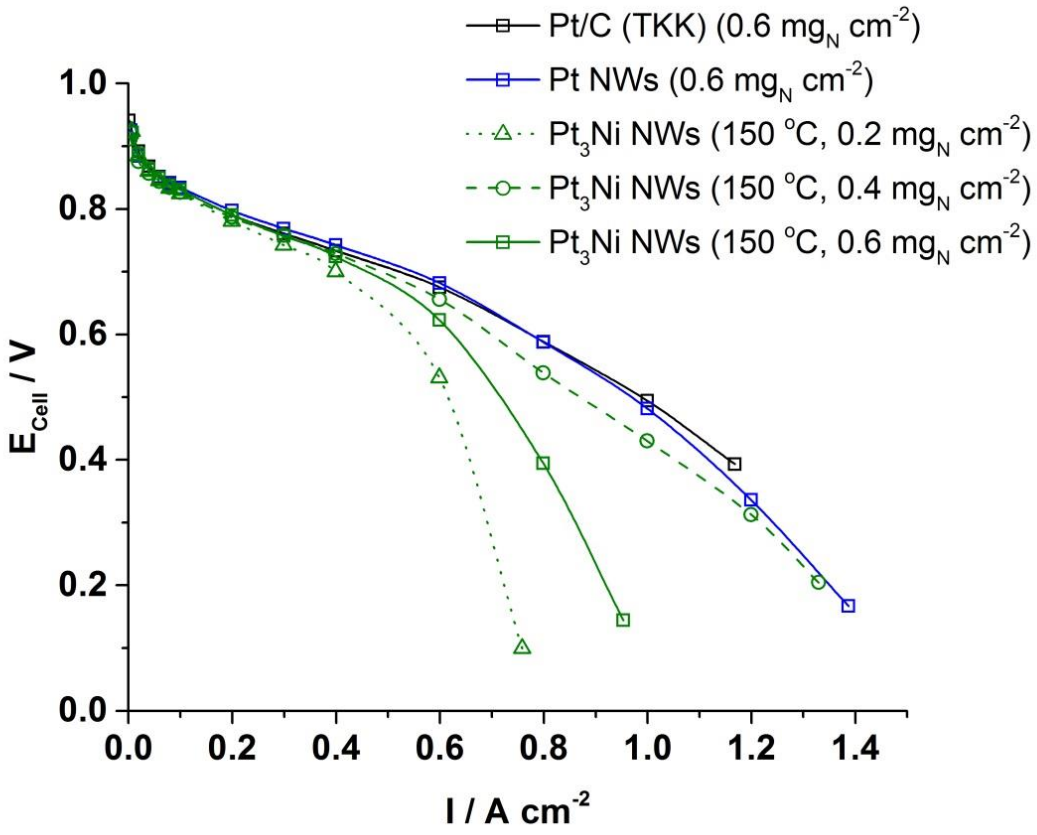


Moving on to PtNi NW arrays

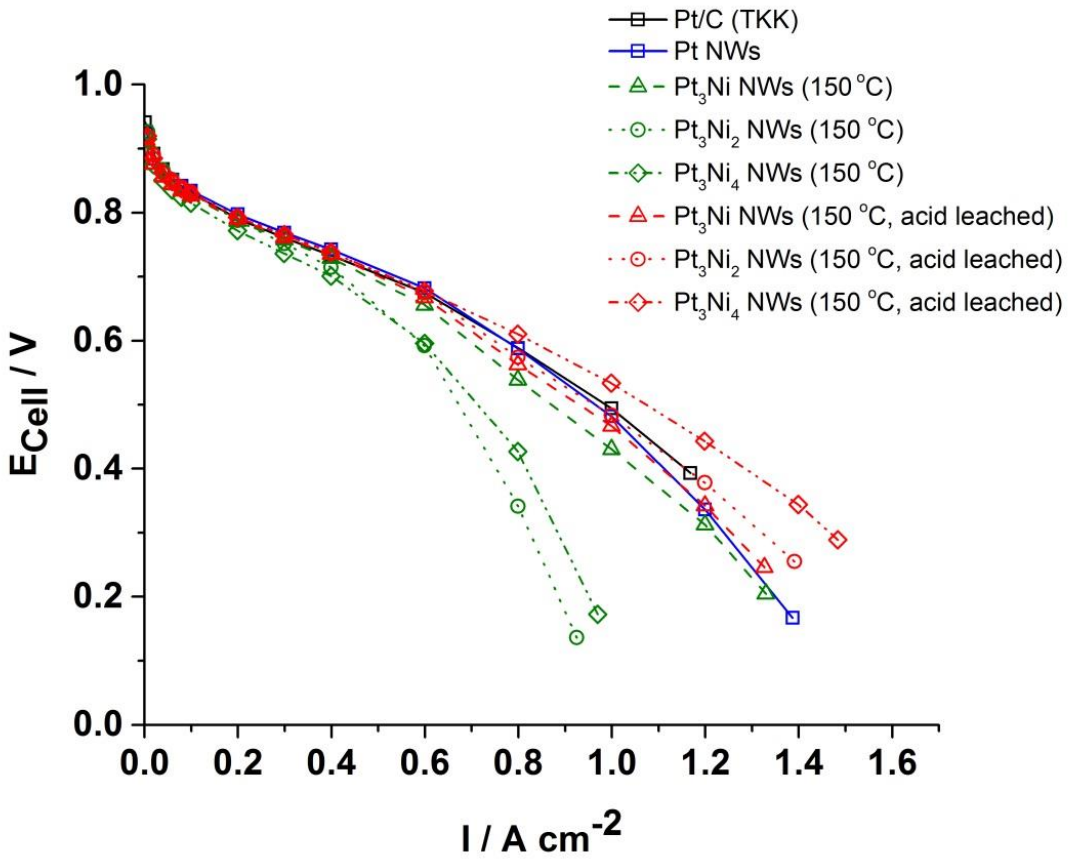


- An analogous Ni impregnation method can be used…however Ni does not impregnate selectively.
- Na is also present after use of $NaBH_4$ and cannot be simply washed away.

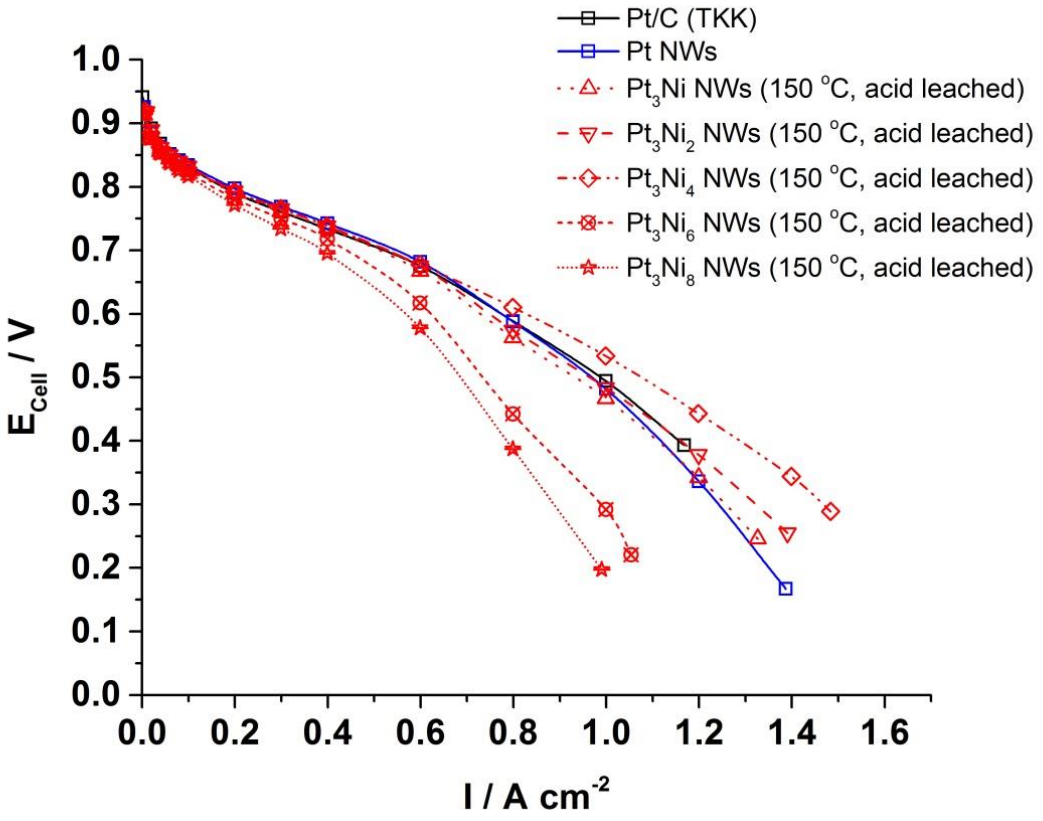
PtNi NW arrays - Ionomer content



PtNi NW arrays – Acid leaching



PtNi NW arrays - Ni content

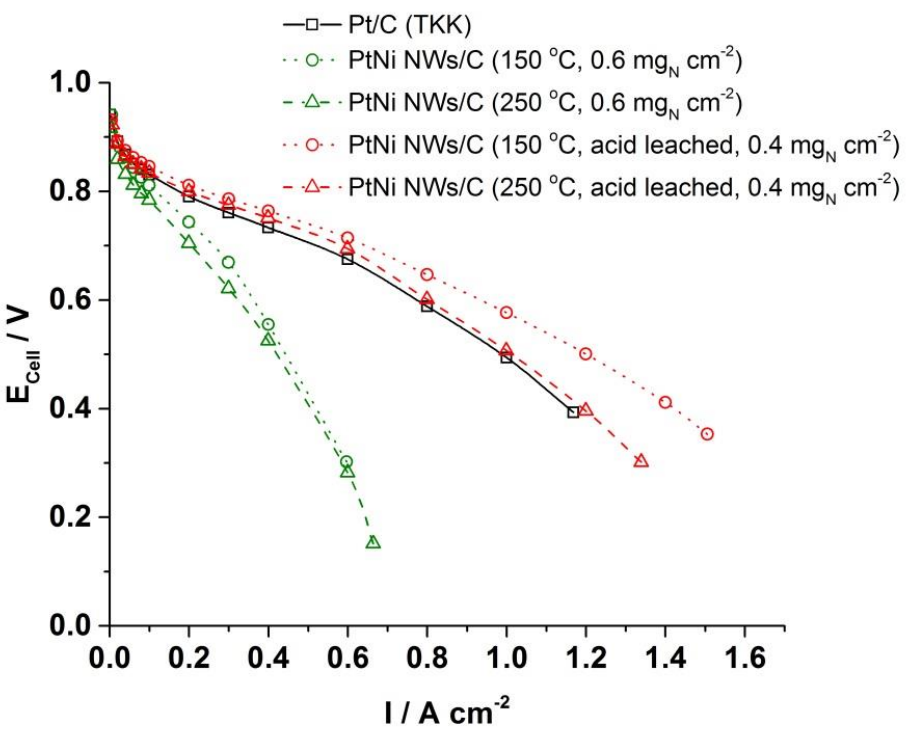


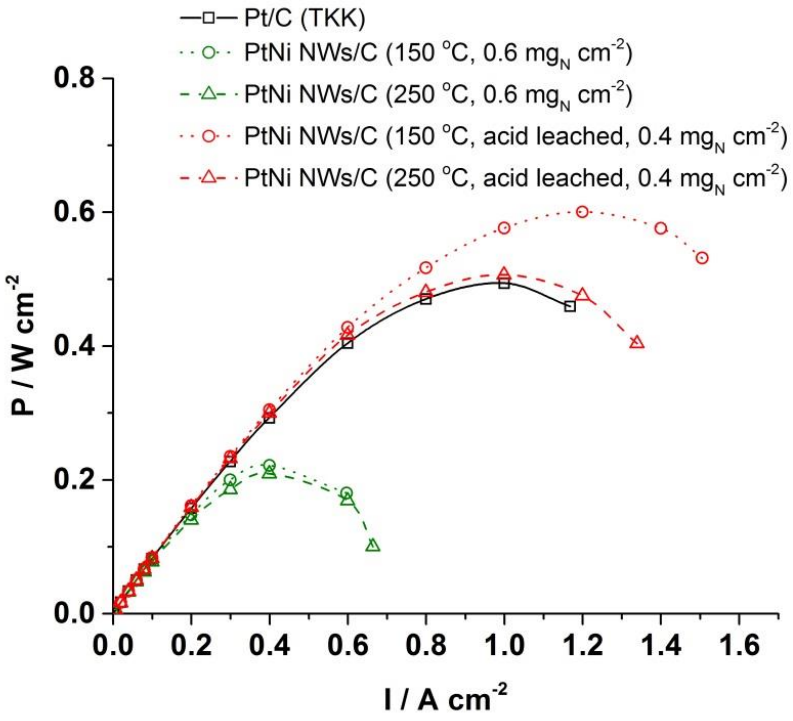
Two simple solutions to improve PtNi performance in PEMFCs

1. Use less ionomer (Ni contamination causes crosslinking, inhibiting O_2 diffusion).

2. Employ acid leaching to remove surface Ni.

Using this on PtNi NWs/C





Conclusions

- PtNi nanowires can be synthesised using an impregnation / annealing method.
- Loss of morphology at higher annealing temperatures limits the degree of alloying achievable.
- Control of other such as ionomer content, Ni content and use of acid leaching can be used to achieve a high performance electrode.
- While adjustments increase overall performance, catalytic activity remains unchanged.

Acknowledgements

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JM
Johnson Matthey

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Thanks for Listening!

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