

## Durable & high performance PEM catalyst design

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Polymer electrolyte membrane fuel cells (PEMFCs) can convert chemical energy to electrical energy through electrochemical reaction. These are believed to provide solutions for the energy sustainability and environmental pollution problems.

In the PEMFCs, the technical targets for PEMFC electrocatalysts from the department of Energy (DOE) 2020 report are membrane electrode assembly (MEA) performance over 1000 mW cm<sup>-2</sup> and Pt loading under 0.1 mg-PGM cm<sup>-2</sup> (PGM: Pt group metal).[1] It requires that both catalytic activity and durability with very low amounts of Pt.

To increase the mass activity of the catalyst, researchers have been studied modification of Pt surface composition and electronic structure change of d-band in the catalyst. Based on the theories, we pursued a design concept for Au(core)@Pt(shell) bimetallic catalyst via optimization of the particle size and shell thickness to substantially improve ORR activity and stability of conventional Pt.[2] Through this concept shows highly increased catalytic activity than pure Pt for ORR. But only progress in activity could not make a sufficient for the commercialization target.

Durability is another issues. Generally, carbon corrosion is occurred on the surface and it makes vacancies under the Pt nanoparticles. This mechanism gives rise to agglomeration and sinter of Pt particles via Ostwald ripening. Consequentially, carbon corrosion brings decreases of the electrochemical surface area (ECSA) and hinder long-term operations. Thus, electrochemically stable support materials need to be developed. We suggested a noble nanofibrous composite electrode which consist of carbon nanotube winded Pt/TiO<sub>2</sub> nanofiber (CNT-Pt/TiO<sub>2</sub>) catalyst. Our approach takes advantages of the electrochemical conductivity of CNT as well as better stability from the

corrosion resistivity of TiO<sub>2</sub> with strong metal-support interaction (SMSI) between the Pt nanoparticles and TiO<sub>2</sub> nanofibers for less Pt dissolution. [3]

The other important factors for the electrochemical properties of MEA are the ECSA and Pt utilization (U<sub>Pt</sub>) of the catalyst Pt nanoparticles at the exterior electrode surface. Recently, several research groups reported methods of designing an effective MEA by enhancing the membrane/electrode interface, considering better mass transfer and a higher interfacial site area. One of them is membrane patterning. In fuel cell applications, the use of membranes with a patterned structure provides a better interfacial contact between the electrode and membrane. Through this method, the best MEA performances is achieved, which exhibited a very high power density of 1906 mW/cm<sup>2</sup> at 75°C and Pt loading of 0.4mg/cm<sup>2</sup> with 73% improvement compared to the commercial membrane. The improved performance are attributed to the decreased MEA resistances and increased surface area for higher Pt utilization of over 80%. [4]

In summary, we can suggest the catalyst commercialization factor (CCF = activity x selectivity x lifetime) as an indicator for commercialization. By CCF approaches, we may suggest the possible ways for commercial catalyst development and can attain the DOE 2020 targets.

[1] DOE Hydrogen and Fuel Cells Program, (2015)

[2] Dorjgotov et al., *Electrochimica Acta* 228 (2017) 389–397

[3] Ji et al. *Applied Catalysis B: Environmental* 204 (2017) 421–429

[4] Jeon et al., *Scientific Reports*, (2015)