

## Electrospraying method to prepare ultra-low Pt loading cathodes for PEM fuel cells

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Recently, an electrospray method has been applied to generate catalyst layers for fuel cells with high dispersion of the catalyst (Baturina & Wnek, 2005). The purpose of the present work is to explore the potential of this method for achieving ultra-low Pt loadings (less than  $0.1 \text{ mg}_{\text{Pt}} \text{ cm}^{-2}$ ). Although vacuum deposition methods (CVD, PVD, sputtering, etc) have been successful in achieving ultra-low Pt loading, the vacuum conditions make them relatively expensive and not easily adaptable to serial production. Unlike these methods, the electrospray technique has not vacuum requirements; it is easily scalable and based on a simple experimental set up.

Catalyst inks were prepared as suspensions of Pt/C 10 wt.% nanoparticle catalyst in Nafion-alcohol solutions. The electrospray setup consists of a needle and a collector connected to a DC high voltage power supply (Bertan 205B-10R). A syringe pump (KDS 100) drives the catalyst ink through a capillary tube into the needle at the selected flow rate. Charged droplets are formed at the needle tip and forced by the electric field to move toward the collector while the alcohol content evaporates during the flight. Depending on the operating conditions, aggregates or even single particles can be deposited leading to catalytic layers with different morphologies (Loscertales *et al.*, 2007). Suspensions of  $7 \text{ mg}_{\text{Pt/C}} \text{ ml}^{-1}$  were electrosprayed at  $0.3 \text{ ml h}^{-1}$  flow rates in the steady cone-jet mode, the needle to collector distance was 7 cm and the potential difference was 9 kV. Fractal-like catalytic layers of  $5 \text{ cm}^2$  area were built on carbon paper sheets and used as cathodes in PEM fuel cells. Cathodes with platinum loads of 0.1, 0.05, 0.025 and  $0.0125 \text{ mg}_{\text{Pt}} \text{ cm}^{-2}$  were made in this way.

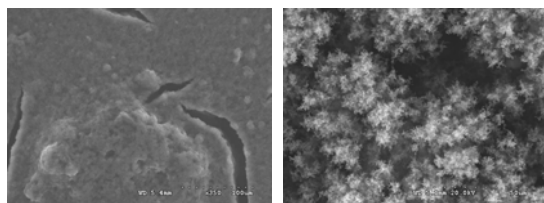


Figure 1. SEM micrographs of electrodes prepared by impregnation (left) and by electrospray (right).

On the other hand, some reference electrodes (anodes) were prepared by impregnation with  $1 \text{ mg}_{\text{Pt}} \text{ cm}^{-2}$  loading and 30% Nafion content. For

comparison, magnified views of the surface of both types of electrodes are shown in Figure 1.

Depending on the platinum loading, the surface of the electrosprayed catalytic layers shows different characteristics as seen in Figure 2. For  $0.1 \text{ mg}_{\text{Pt}} \text{ cm}^{-2}$  the catalyst covers completely the carbon paper resulting in a rough but continuous catalytic layer. However for a lower loading of  $0.0125 \text{ mg}_{\text{Pt}} \text{ cm}^{-2}$ , the catalyst covers individually the carbon fibres that constitute the paper, resulting in large unused portions of the cathode area.

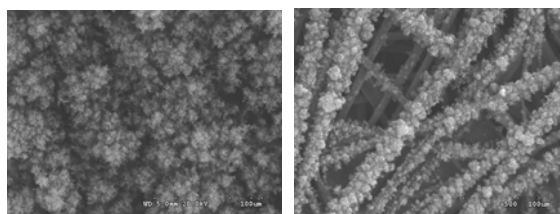


Figure 2. SEM images of the catalyst layer applied by electrospray with platinum loading of  $0.1 \text{ mg}_{\text{Pt}} \text{ cm}^{-2}$  (left) and  $0.0125 \text{ mg}_{\text{Pt}} \text{ cm}^{-2}$  (right).

Membrane-electrode assemblies (MEAs) were prepared with these electrodes by hot-pressing each anode-cathode pair with a Nafion 112 membrane sheet sandwiched between them at 10 MPa and  $120^\circ \text{ C}$  for 2 min. These MEAs were tested in a commercial single fuel cell hardware (FC05-01SP Electrochem, inc.) connected with an external electronic load (Hoher & Hackl PL306).

The electrosprayed cathode performance turns out to be a function of the Nafion content in the catalyst ink showing a maximum performance at a given Nafion content which depends on the platinum loading.

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