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Low Energy X-ray Imaging Used to Quantify the Large-Area Thickness Variation of the Catalyst Loading on Carbon Cloth Based Electrodes for Fuel Cells.

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Introduction

Fuel cells based on polymer electrolyte membranes often have micro-porous carbon cloth electrodes. The necessary catalytic activity is established by coating the carbon cloth surface with a suitable catalyst material, typically nano-sized platinum particles imbedded onto a high-surface area carbon structure. From a production point-of-view, it is highly desirable to be able to investigate if the catalyst layer is distributed evenly over the whole electrode area of the fuel cell.

Method

In this study, we introduce an X-ray imaging technique, which can be used to characterize the thickness variation of the Pt-loaded catalyst over a large area of, say, 20 x 20 cm^2. Low energy X-ray (< 25 kV) imaging is characterized by a high level of grey-scale contrast. The image contract is mainly provided by the heavy element attenuation of the X-rays, in this case Pt being the heavy element. This makes this technique particularly suited for revealing even minute changes in the electrode's Pt-loading. A spatial image resolution in the sub-millimeter range is easily achieved, which also helps mapping out some coating artifacts.

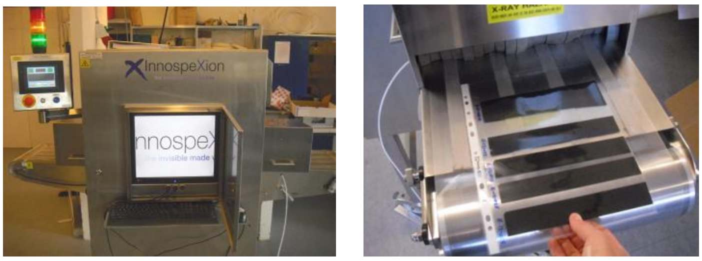

Figure.1. *Left* - The X-ray measurement system from InnospeXion®.
Right - Electrode samples at the entrance of the X-ray machine.

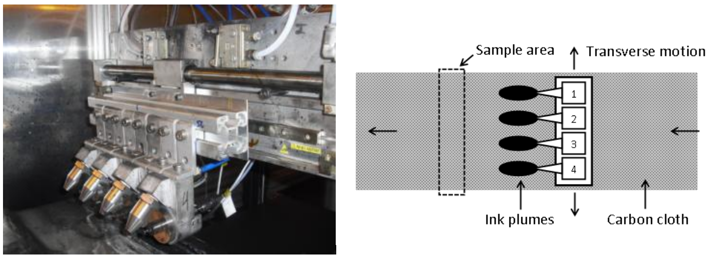

Figure 2. *Left* - A spray coater with four ultrasonic nozzles was used to spray a Pt/C-based catalyst ink onto a 200 cm long, 20 cm wide, rotating carbon cloth belt. The ink consisted of a commercial Pt/C catalyst, dispersed in pure formic acid.
Right - Schematic picture of the spraying arrangement.

Results

Image software (*Isee!* from BAM) was used to analyze the Pt distribution, see Fig. 3 and 4. An unsprayed piece of carbon cloth was used to established a reference level of the X-ray signal. This zero loading reference level is set as the top horizontal axis of Fig. 3 and 4. The average Pt loading was established by weighting the carbon cloth before and after the spraying. The loading levels were then compared to the average change of the X-ray signal. The results are plotted in Fig. 5.

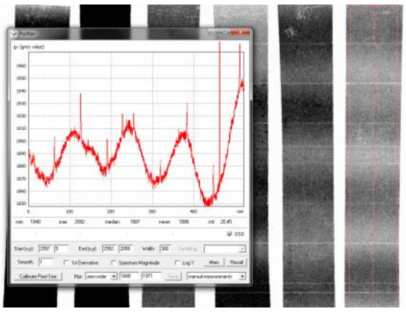

Figure 3. Example of the Pt distribution measured across the electrode by X-ray. In this example, the nozzles are fixed in a stationary position during the spraying process.

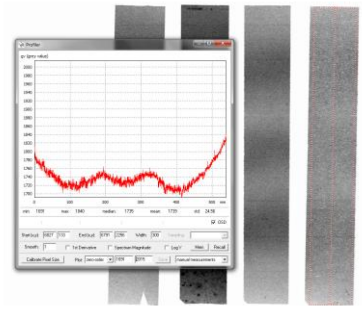

Figure 4. Example of the Pt distribution measured across the electrode by X-ray. In this example, the nozzles are moved in the transverse direction during the spraying process in order to average-out the nozzle's individual plume profiles.

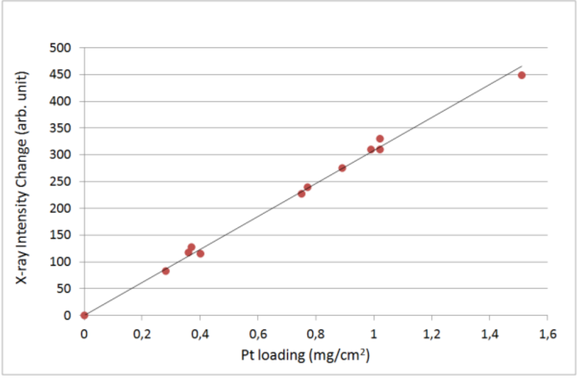

Figure 5. A linear relationship between the average Pt loadings and the average grey scale level of the digital X-ray images is demonstrated.

Conclusion

X-ray imaging of the electrode's catalyst loading gives clear pictures with good resolution. This technique was used to characterize and subsequently optimize the nozzle position. With transverse nozzle movement during spraying and proper adjustment of the nozzle position, it should be possible to obtain a thickness variation of the Pt loading < ± 5 % over the whole 200 x 20 cm^2 area. This will result in better electrode reproducibility and catalyst utilization in fuel cell production.

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