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Synthesis of a durable platinum catalyst for Proton Exchange Membrane Fuel Cells in bicontinuous microemulsion

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Platinum nanoparticles are considered as one of the best catalyst for Proton Exchange Membrane Fuel Cells (PEMFCs) due to high catalytic activity for oxygen reduction reaction and high stability in a harsh fuel cell conditions [1]. Various techniques (liquid-phase, gas-phase or vapor-phase) have been proposed for the production of the platinum nanoparticles, however obtaining monodisperse nanoparticles of a small size at a high yield is remaining an issue [2].

Here we report the synthesis of the monodisperse and small nanoparticles (2-4 nm) with a high yield in bicontinuous microemulsion that are later tested as a catalyst for PEMFCs. The bicontinuous microemulsion consisting of continuous water and oil nanostructures, acts as a template where a platinum salt precursor is chemically reduced at room temperature to form platinum nanoparticles [3].

High control over size of the catalyst nanoparticles was achieved by varying the microemulsion composition, surfactant molecules structuring the microemulsion, and the type of reducing agent (Fig. 1). These parameters also influenced the crystal structure of the obtained nanoparticles, and hence their activity towards the oxygen reduction reaction (ORR). The reaction rates of the formation of platinum nanoparticles were controlled by varying the strength of the reducing agent. Synthesized nanoparticles were absorbed on a carbon support, washed and then annealed at 300 ^{0}C. This process of the PEMFC catalyst production was optimized in order to achieve highest activity for the ORR and avoid agglomeration of the nanoparticles.

High monodispersity of the synthesized nanoparticles leads to reduced Ostwald ripening process of the catalyst degradation [4]. Therefore, synthesized nanoparticle exhibited superior durability compared to the commercially available platinum catalysts for fuel cells (Fig. 2). The morphology, the crystallite structure and sizes of the synthesized nanoparticles are studied by TEM and X-ray diffraction. The catalytic properties and utilization of the catalyst were studied with voltammetric techniques and compared to the commercial state of the art catalysts.

Ex-situ durability tests under potential cycling were performed to study the durability of the synthesized catalyst. Durability tests are performed ex-situ in and loss of the electrochemical surface area (ECSA) was monitored.

In this work, we show the versatility of the bicontinuous microemulsion method for metal nanoparticle synthesis using various reducing agents in a microemulsion with various constituents. By this means, the nanoparticle formation process, size and activity could be tuned. This method allows synthesis of monodisperse platinum nanoparticles at a high yield at room temperature, and the process can be easily scaled up. These make the bicontinuous microemulsion method industrially promising for the synthesis of metal nanoparticles.

REFERENCES

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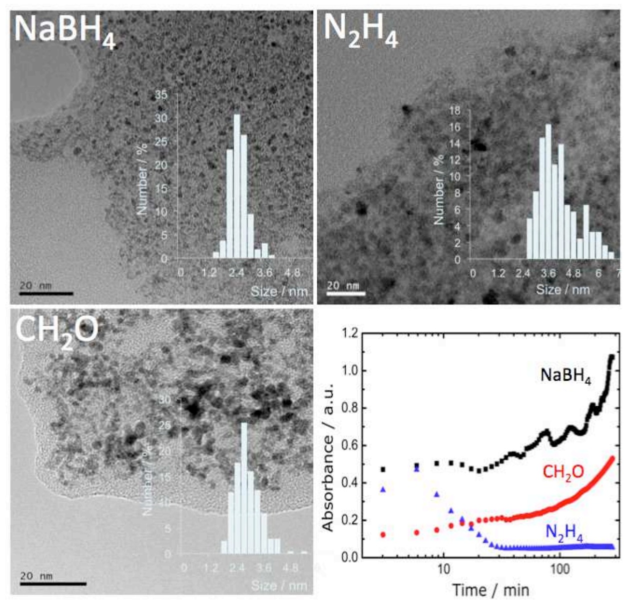

Figure 1 Platinum nanoparticles synthesized in bicontinuous microemulsion by chemical reduction using various reducing agents.

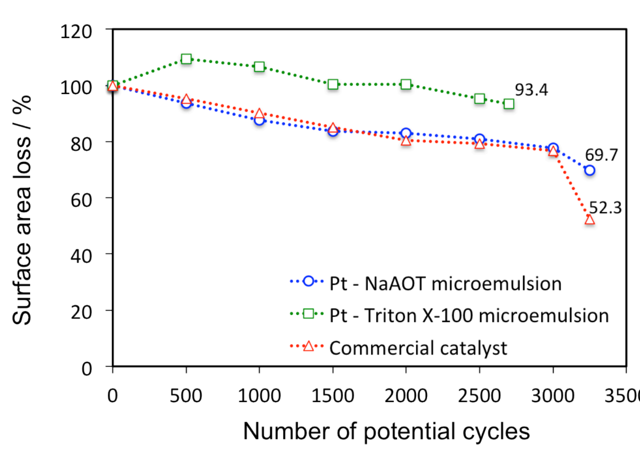

Figure 2 ECSA loss during durability test in 0.1 M $HClO_4$, 50 mV/s, 0.5-1.1 V, in N_2 (3000 cycles) and O_2 atmosphere (last 250 cycles)