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Synthesis and characterization of bimetallic platinum nanoparticles for use in catalysis

Mathe, Ntombizodwa Ruth

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ABSTRACT

Bimetallic platinum nanoparticles were synthesized for application as anode catalysts for low temperature fuel cells such as direct methanol fuel cells (DMFCs). Two distinct synthesis procedures were used; namely conventional synthesis with post-synthesis heat treatment, and secondly polyol microwave-irradiation without further heat-treatment. The aim was to synthesize interesting and novel bimetallic nanostructures and relate their shape and morphologies to their methanol oxidation reaction (MOR) activities and their CO tolerance.

Due to the high cost of the conventional synthesis processes as well as their use of harmful solvents, microwave-irradiation was explored as a possible synthesis procedure. It is a greener and more environmentally friendly approach with possibilities of mass production of the nanoparticles. For both the synthesis procedures, the reducing agent, the precursor salts, surfactants, pH of the solution and molar ratios were varied to determine the effect on the shape, size and ultimately the electrocatalytic activities of the Pt-Co and Pt-Ni nanoparticles.

For the conventional synthesis procedure, the main parameter of comparison was the strength of the reducing agents, where $NaBH_4$ and N_2H_4 were used under the same reaction conditions. In this study, the strength of the reducing agent affected the properties of the Pt-Co and Pt-Ni nanoparticles, such that, the stronger the reducing agent, the higher the degree of alloying and the more electrocatalytically active the materials. The drawback in the conventional synthesis was however low

current outputs, in the microamps range, which necessitates a need to explore other synthesis procedures.

Microwave-irradiation was thus used as an alternative synthesis procedure in an attempt to produce more active bimetallic platinum nanoparticles. Different reaction parameters were changed in this process to optimize the synthesis process, namely the pH of the solution, the amount of surfactant and the Pt-Ni molar ratio. In changing the reaction parameters, there was an observed change in the structure of the nanoparticles, with an average size in the order of 5 nm and different MOR activities. Furthermore, it was found that the activity was highest for the optimum amount of PVP and NaOH concentration of 500 mg and 1.0 M NaOH. In general, the MW synthesized nanoparticles achieved current values in the microamps to amps range, making it a more attractive synthesis procedure compared to the conventional method.

The CO tolerance of the materials is an important aspect, as one of the main drawbacks of the commercial application of fuel cells is the propensity of Pt to get poisoned by CO during the methanol dissociation process. Therefore CO stripping measurements were performed on the MW-irradiated catalysts. The catalysts produced in this work showed good resistance towards CO. In general, the behaviours of the catalysts were dependent on the amount of surfactant and the molar ratio of the starting solution. The mechanism of CO tolerance in this case was determined as the bifunctional model, where the Ni-oxide and Ni-hydroxide species donate O to the electrooxidation of CO to CO_2. In conclusion, the study of microwave-irradiated bimetallic nanoparticles performed here, resulted in highly active catalysts, which are even more active than commercial Pt/C nanoparticles.