Mesoporous non-precious metal cathode catalysts for anion-exchange membrane fuel cells prepared via template-assisted synthesis

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Fuel cells are promising clean energy sources, thanks to their high energy efficiency and zero emissions. As compared to already commercialised proton exchange membrane fuel cells, anion exchange membrane fuel cells (AEMFCs) could be more cost-effective, as they enable the utilization of less expensive cell components and non-precious metal electrocatalysts on the electrodes. Nanostructured carbon materials doped with nitrogen and transition metals (M-N-C catalysts) have proven to be particularly advantageous in alkaline conditions. A simple strategy to prepare such materials is high-temperature pyrolysis of organic carbon precursors along with nitrogen and metal sources, during which the N-doping occurs simultaneously with the formation of graphitic carbon structures. In order to tailor the porous structure of carbon materials, synthesis methods based on hard templates, most commonly silica nanoparticles, are often employed. Sustainable alternatives to these are more easily removable inorganic nanoparticles, e.g. NaCl, MgO, $CaCO_3$, ZnO, etc., which can also be produced in situ during the pyrolysis from thermally instable precursors, such as Mg acetate.[1] In this work, a facile method for preparation of mesoporous M-N-C catalysts (M= Fe or both Fe and Co) for the oxygen reduction reaction (ORR) from various organic precursors, dicyandiamide and transition metal salts is presented.[2] Mg acetate was used as a precursor for a sacrificial template, which was removed after the pyrolysis using weak acid and significantly enhanced the specific surface area of the catalysts. Lignin, alkylresorcinols, and rapeseed press cake were employed as sustainable carbon sources.

The physicochemical analyses of the catalysts revealed uniform dispersion of various nitrogen moieties and transition metal centres on sheet-like carbon structures, along with some carbon-encapsulated metal-rich nanoparticles consisting of Fe carbide or FeCo alloy. Rotating disc electrode (RDE) tests in alkaline solution showed that the ORR activity was higher for the catalyst materials prepared with the template as compared to non-templated materials and the activity depended on the transition metal content in the catalysts. The Fe-containing and bimetallic catalysts showed rather similar electrocatalytic activities in RDE mode, which were close to that of a commercial Pt/C catalyst. The ORR activity was also rather similar for the materials prepared from different organic precursors. Very promising results on the stability of the catalysts were obtained in the short-time potential cycling tests over 10000 cycles. In AEMFC tests, the bimetallic lignin-derived catalyst outperformed the Fe-containing material, achieving a promising peak power density of 675 mW cm^{-2} at 60 °C and 833 mW cm^{-2} at 80 °C. These results demonstrate that highly active non-precious metal catalysts for ORR can be obtained by a simple high-temperature pyrolysis from various different sustainable carbon sources.

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