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Hollow Multicavity Carbon Spheres (HMCS) as a Ni Electrocatalyst Support for Alkaline Water Electrolyser Cathodes

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To transition to a hydrogen economy, where hydrogen is used in industries such as transportation, ammonia production, steel manufacturing, and for the storage of surplus solar and wind produced electrical energy, cost reductions in hydrogen production are essential. Water electrolysis has been identified as a promising solution to produce green hydrogen[1]. However, such produced hydrogen is still not cost-competitive to hydrogen produced from natural gas, partly due to the non-satisfactory performance of electrode materials. Consequently, by developing cost-effective and efficient non-precious electrocatalysts and better electrocatalyst supports, large-scale green hydrogen production *via* water electrolysis can become more viable, reducing carbon emissions across multiple sectors.

In acidic polymer-electrolyte-membrane (PEM) and alkaline anion exchange membranes (AEM) water electrolysers for hydrogen production, nanostructured cathode electrocatalysts are immobilized on a carbon black support [2]. The primary purpose of the support is to maximize the utilization of the nanostructured electrocatalyst and minimize its agglomeration. Herein, we present our recent work on the fabrication of hollow multiactivity carbon spheres (HMCS) and their use as a support for nickel electrocatalyst in alkaline water electrolysis cathodes.

The HMCS were synthesized by first fabricating Polymer Hollow Carbon Spheres (PHCS) employing Pluronic F127, aniline and pyrrole, followed by their carbonisation at 700°C in an Ar atmosphere to produce HMCS[3]. Consequently, Ni nanoparticles were immobilized on HMCS by chemical reduction of $NiSO_4 \cdot 6H_2O$ employing $NaBH_4$. Two types of HMCS were used: 'as-prepared' and 'activated', the latter representing HMCS activated by oxidation in a mixture of sulphuric and nitric acid. Ni/HMCS materials with various loadings of Ni were produced. Such prepared Ni/HMCS electrocatalysts were tested as a cathode material for hydrogen evolution in 1M KOH. Linear polarisation measurements were performed in a three-electrode cell, with the Ni/HMCS as a cathode material, platinum as a counter (anode) materials, and a Hg/HgO as a reference electrode. A flat nickel plate was used as a control cathode. Scanning and transmission electron microscopy, energy-dispersive X-ray spectroscopy, Raman and X-ray diffraction spectroscopy, BET and H_2-chemisorption measurements were performed in order to characterize surface, structural and chemical properties of the produced materials.

It was determined that the diameter of the produced HMCS ranged from 45 to 200 nm, depending on their post-treatment (as-prepared vs. activated), and their structure was found to be amorphous. The HMCS exhibited a high specific surface area (up to 284±10 m^2g^{-1}) and pore diameter of 17±5 nm, rendering them a good support for immobilization of electrocatalysts. The distribution of the immobilized Ni nanoparticles was found to be uniform, with the average particle size of 15 nm. The Ni nanoparticles were also found to be amorphous. Chemisorption measurements revealed that the specific area of Ni nanoparticles was up to 0.896 m^2g^{-1}, depending on the post-treatment of HMCS. Electrochemical measurements revealed excellent electrocatalytic properties of the produced Ni/HMCS cathodes, yielding a significantly higher electrocatalytic activity when compared to the Ni-plate control. These results highlight HMCS as a promising metal-catalyst support for water electrolysis in alkaline media.

References

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