

Development of Graphitic-Carbon Nitride as a Catalyst Support for PEM Fuel Cells

N. Mansor¹, A. Belen Jorge², R. Jervis¹, F. Cora², C. Gibbs¹, P. McMillan², D. Brett¹

¹Electrochemical Innovation Lab, University College London, Torrington Place, London WC1E 7JE, UK

²Department of Chemistry, University College London, Gordon Street, London WC1H 0AJ, UK

Proton Exchange Membrane (PEM) fuel cells offer several advantages such as rapid start-up and shut-down, low temperature, high power density and fully solid state components. However, the high cost and low durability of the electrodes need to be addressed before commercialisation can be realised. It is well known that the activity of a catalyst depends on the particle size and dispersion pattern over the support structures. Therefore, catalyst support materials have a great influence on the cost, performance, and durability of PEM fuel cells. Carbon black is the most widely used catalyst support for state-of-the-art PEM fuel cells even though it is known to undergo carbon corrosion during operation. As carbon black corrodes, the metal nanoparticles detach and possibly agglomerate, resulting in electrochemical surface area loss, which consequently reduces the performance and durability of PEM fuel cells.

One strategy to reduce performance degradation due to carbon corrosion is to use a more robust carbon support. Recently, there has been great interest in nanostructured carbon nitride materials due to their unique properties such as extreme hardness, oxidation resistance, tunable bandgap and morphology, and chemical inertness[1]. The most exciting and stable material among them is graphitic carbon nitride (gCNM) which has great prospects in catalysis. It was reported to improve the performance of a direct methanol fuel cell by 78-83% when used as a catalyst support[2]. In addition, it has been shown to have intrinsic oxygen reduction activity (ORR) as well as excellent CO tolerance [2, 3].

The aim of this study is to investigate the potential application of the gCNM as a catalyst support in PEM fuel cells. A rotating disk electrode (RDE) system is employed to characterize the activity and durability of the catalysed and non-catalysed gCNM using accelerated start-stop and load cycling protocols, and compared with that of commercial Vulcan XC-72R carbon. The start-stop and load cycling are performed by cycling the potential between 1.0 V to 1.5 V and between 0.6 V to 0.95 V respectively, in 0.1 M HClO₄ at 60°C. The stability of the support is evaluated by measuring the change in capacitance, whereas the stability of the catalysed support is evaluated by monitoring the change in electrochemical surface area (ECSA) and electrocatalytic activity.

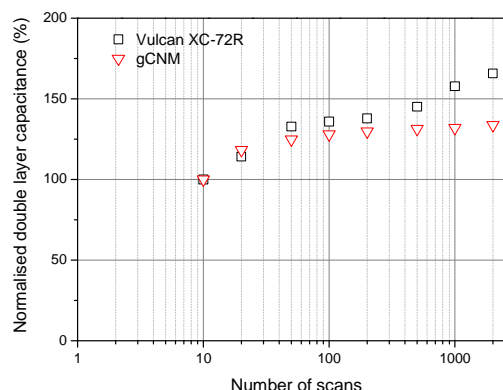


Figure 1 Effect of accelerated carbon corrosion (start-stop) cycling on double layer capacitance of the catalyst supports.

Figure 1 shows the stability data of the non-catalysed carbon supports upon performing the start-stop protocol. For the initial 100 cycles, both materials show similar degree of corrosion (increase in double layer capacitance). However, above 100 cycles, Vulcan XC-72R continues to corrode whereas gCNM is more resistant, exhibiting a near plateau behavior. At the end of the 2000 cycles, Vulcan XC-72R shows a 166% change in capacitance whereas gCNM only shows a 133% change. This suggests that the application of gCNM as a catalyst support is feasible from a durability perspective.

This study further investigates the degree of catalysed carbon corrosion under accelerated protocols and its effect on performance, as well as corroborating RDE measurements with in-situ characterisations.

References

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