Ruthenium Supported on Nitrogen-Doped Carbon Nanotubes for the Oxygen Reduction Reaction in Alkaline Electrolyte

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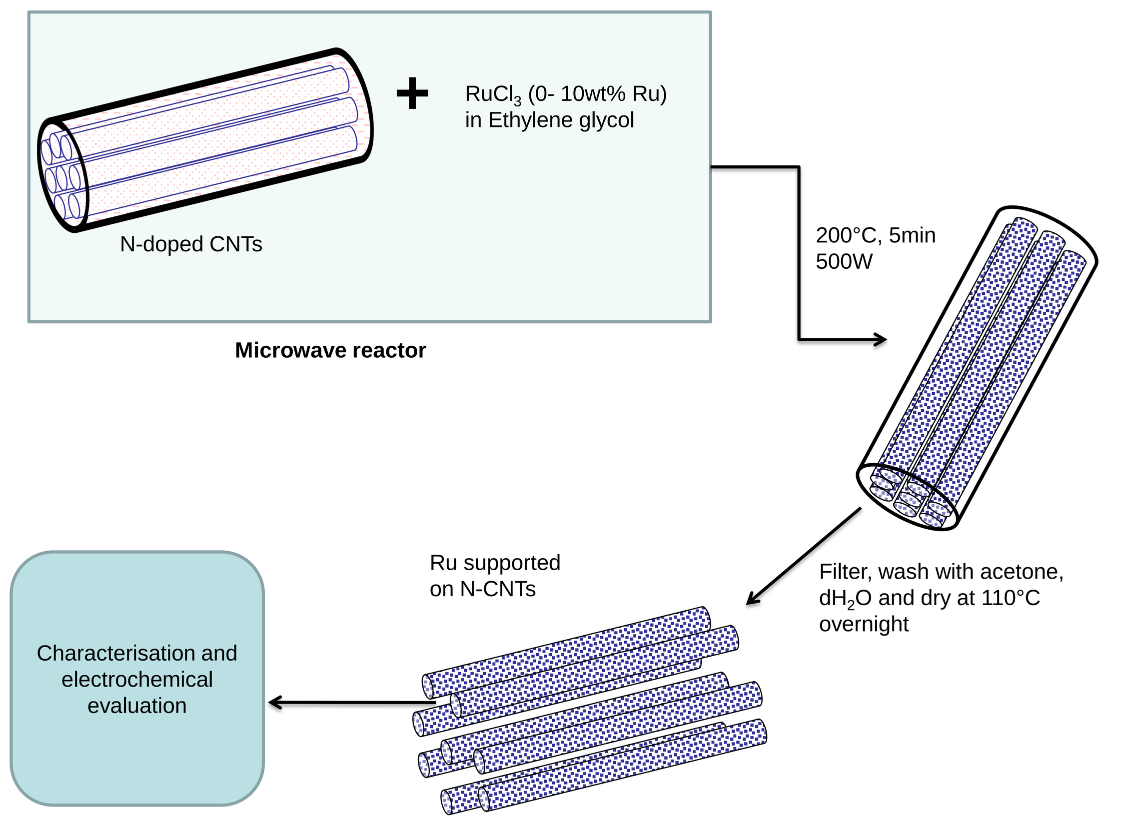
INTRODUCTION

The oxygen reduction reaction (ORR) at the cathode of fuel cells plays an important role in controlling the performance of a fuel cell but the poor kinetics of the ORR hinders this performance. Currently platinum-based metals are the best electrocatalysts for ORR. However, due to the high cost of platinum, the large-scale synthesis and commercialisation of this electrocatalyst is problematic [1]. Apart from its high cost, the Pt-based electrode also suffers from its susceptibility to time dependent drift, CO deactivation and it is unselective [2]. Hence, non-platinum electrocatalysts which are more active, stable, and more economical are developed [3]. The use of a support material that can increase efficiency and electrocatalytic activity is significant. Recently, several researchers have shown that nitrogen modified carbon nanotubes (CNTs) are good electrocatalyst supports and that they enhance the electrocatalytic activity for the ORR [1]. Nitrogen-doped carbon nanotubes (N-CNTs) prepared *via* thermal chemical vapour deposition (CVD), were used to support ruthenium (Ru) nanoparticles using a microwave assisted reduction technique.

EXPERIMENTAL



RESULTS AND DISCUSSION

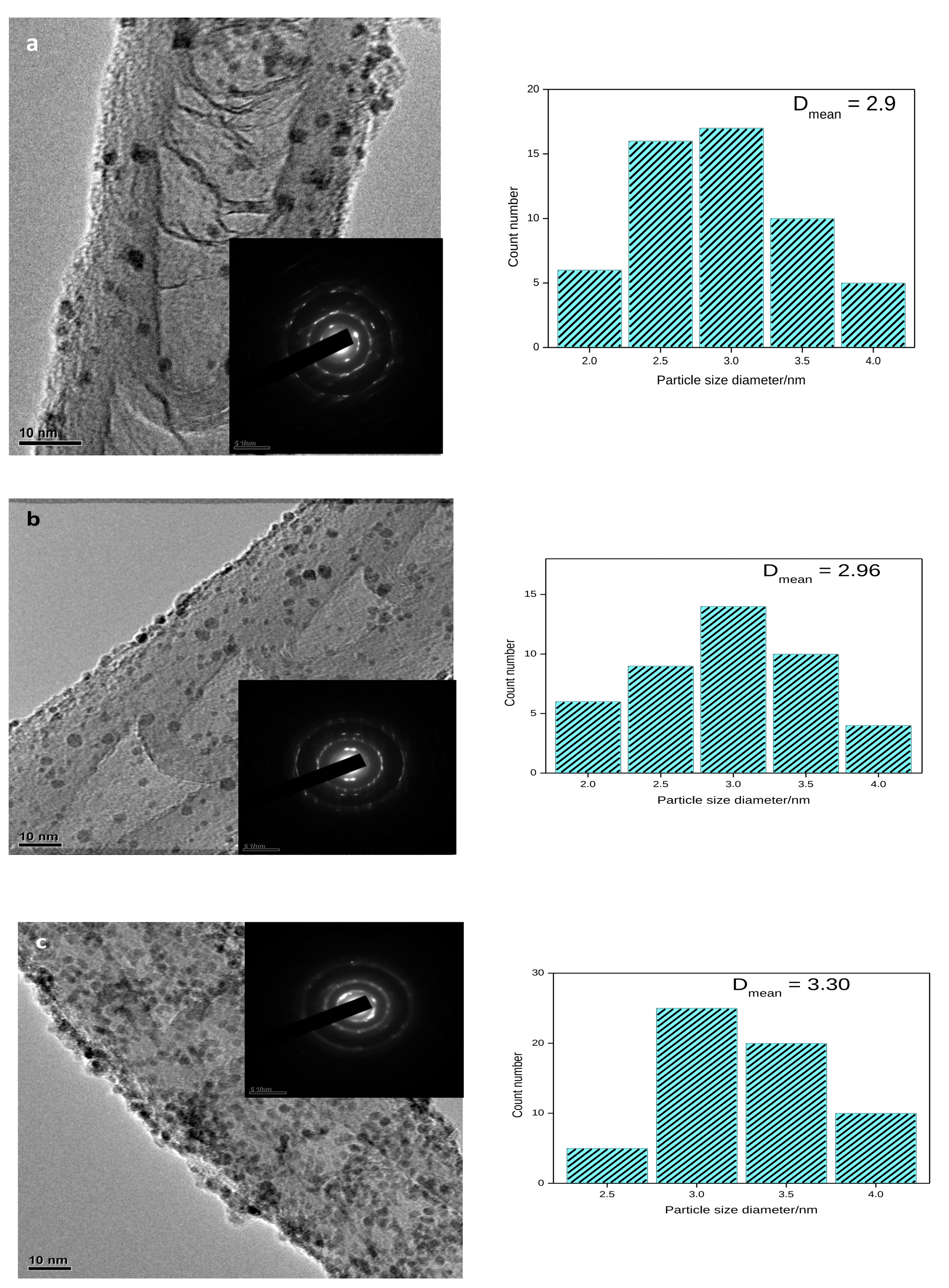


Fig. 1. Transmission electron microscopic images and corresponding diameter histogram of (a) 2Ru/N-CNTs, (b) 5Ru/N-CNTs, and (c) 10Ru/N-CNTs. Insets shows the selected area electron diffraction.

Table 1 Metal loading on the N-CNTs obtained using ICP

Catalyst	Ru loading wt.%	Fe %
2Ru/N-CNTs	2.13	< 0.2
5Ru/N-CNTs	5.20	< 0.2
10Ru/N-CNTs	9.97	< 0.2%

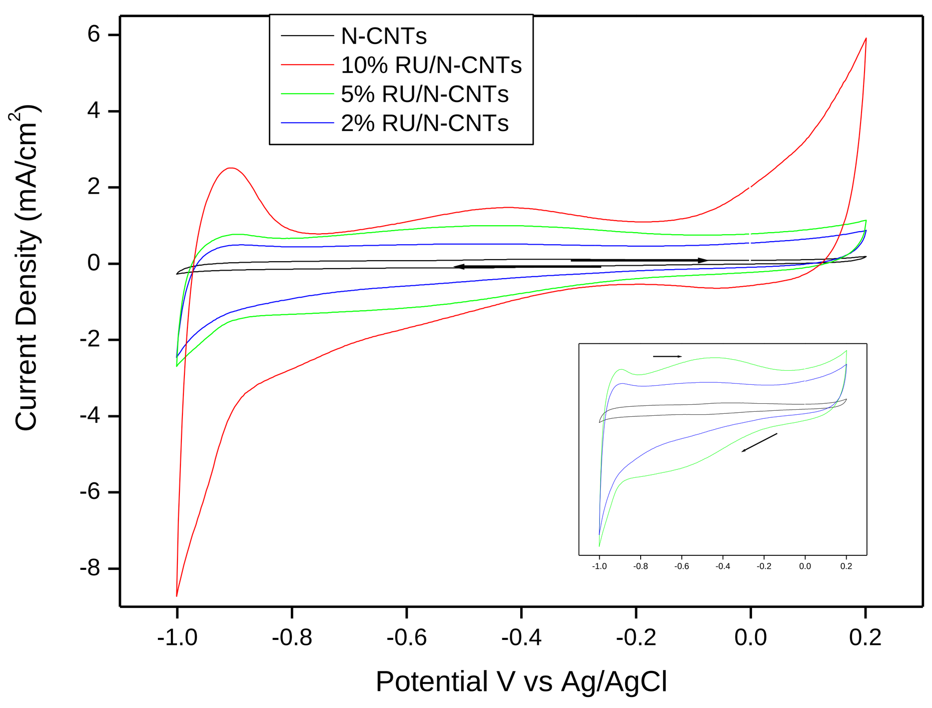


Fig. 2. Cyclic voltammograms of the Ru/N-CNT catalysts in nitrogen saturated 0.5 M KOH solution. Scan rate 10 mV/s.

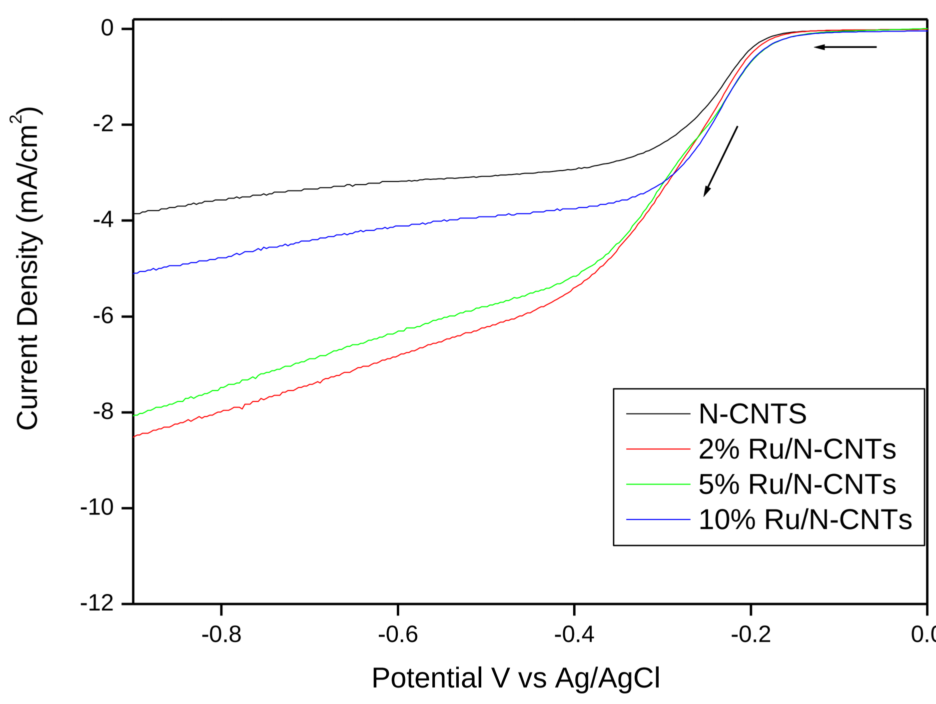


Fig. 3. Rotating disk electrode (RDE) linear sweep voltammograms of the Ru/N-CNT catalysts in oxygen-saturated 0.5 M KOH solution. Scan rate 10 mV/s at 1500 rpm

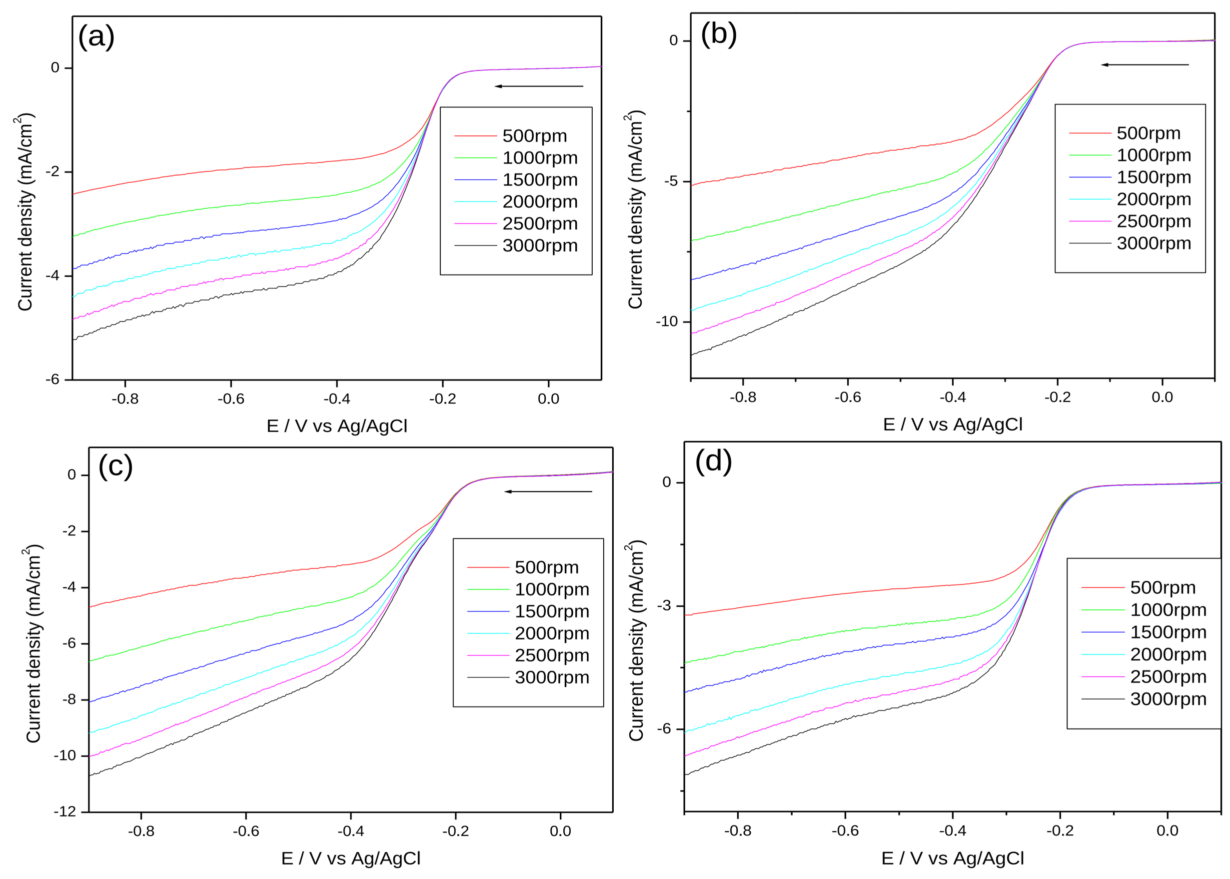


Fig. 4. RDE polarization curves at different rotation rates for (a) N-CNTs), (b) 2Ru/CNTs, (c) 5Ru/N-CNTs, and (d) 10 Ru/N-CNTs

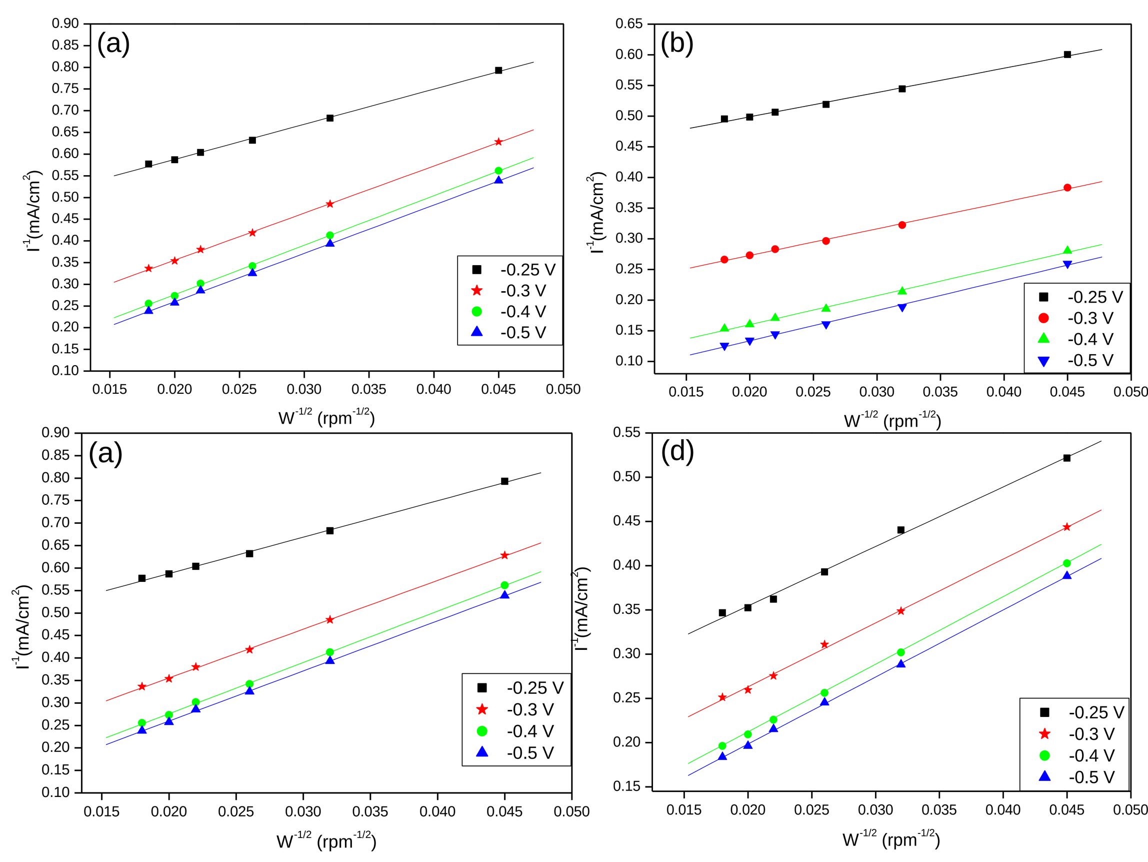


Fig. 5. Koutecky-Levich plots for: (a) N-CNT, (b) 2Ru/CNT, (c) 5Ru/N-CNT, and (d) 10Ru/N-CNT

$$\frac{I_d}{A} = i_d = 0.21 n F D_{O_2}^{2/3} \upsilon^{-1/6} C_{O_2} \omega^{1/2}$$

Table 2 Summary of the important activity indicator of ORR

Electrode	Onset potential V	No of electron transferred at (1500 rpm, -0.30V)	Limiting current density (mA/cm²)
N-CNTs	-0.166	2.4	-2.95
2Ru/N-CNTs	-0.158	3.9	-4.76
5Ru/N-CNTs	-0.153	3.7	-4.54
10Ru/N-CNTs	-0.148	3.2	-3.66

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CONCLUSION

The 4 electron reaction of ORR was found to be more favourable on 2Ru/N-CNTs and 5Ru/N-CNTs. The lower loading of Ru metal nanoparticles on the 2Ru/N-CNT catalyst proved to give a better catalyst, which makes it a potential material for the ORR catalysis in fuel cells in alkaline media.

ACKNOWLEDGEMENT

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