Electrochemical and Physical Characterization of Ru Activated Carbon Supported Electrodes in Alkaline Solution

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Polymer electrolyte fuel cells (PEMFC) are promising energy sources for stationary and portable fuel cell applications [1-3]. However, the slow oxygen reduction reaction (ORR) on different catalysts is one of the most limiting factors in the energy conversion efficiency of PEMFC. Alternative materials are therefore intensively sought for fuel cell applications. Improved cathode catalysts could have a dramatic impact on the fuel cell efficiency. Therefore, platinum, platinum-ruthenium and other alloys deposited onto various carbon supports have been studied to find materials with higher ORR activity [2, 4-6].

The following work examines the impact of ruthenium nanoparticles (20 wt%), deposited onto various carbon supports prepared from α-WC and Vulcan, on ORR kinetics in 0.1 M KOH aqueous solution. Experiments show that in this medium there is an important contribution of the nanoparticles to the electroreduction process of O2.

Scanning electron microscopy (SEM), energy dispersive x-ray spectroscopy (EDX), high resolution transmission electron microscopy (HRTEM) and low temperature N2 adsorption experiments were carried out to characterize the structure of the prepared materials.

Table. Results of the N2 adsorption measurements, calculated using t-plots. \( S_{BET} \) - multipoint BET surface area, \( S_{mic} \) - micropore area, \( S_{mes} \) - mesopore area, \( V_{mic} \) - micropore volume, \( V_{tot} \) - total pore volume.

<table>
<thead>
<tr>
<th>Sample</th>
<th>( S_{BET} ) (m² g⁻¹)</th>
<th>( S_{mic} ) (m² g⁻¹)</th>
<th>( S_{mes} ) (m² g⁻¹)</th>
<th>( V_{tot} ) (cm³ g⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(WC)[7]</td>
<td>1580</td>
<td>1550</td>
<td>30</td>
<td>0.89</td>
</tr>
<tr>
<td>20% RuC (WC)</td>
<td>1224</td>
<td>1179</td>
<td>45</td>
<td>0.70</td>
</tr>
<tr>
<td>Vulcan</td>
<td>240</td>
<td>144</td>
<td>96</td>
<td>0.52</td>
</tr>
<tr>
<td>20% RuC (Vulcan)</td>
<td>205</td>
<td>165</td>
<td>41</td>
<td>0.53</td>
</tr>
</tbody>
</table>

EDX studies show that Ru nanoclusters have been deposited into/onto carbon support quite uniformly. A comparison of the N2 adsorption data (table) and SEM images show that ruthenium forms mesoporous clusters on the surface of the supporting material (illustrated on the figure). SEM images show also that small ruthenium nanoparticles were uniformly observed on the support material, which means that deposition doesn’t take place quite homogeneously.

The electrochemical measurements were carried out in a three-electrode electrochemical cell. Electrochemical characteristics for various Ru-modified micro- and mesoporous carbons have been established by cyclic voltammetry and rotating disc electrode (RDE) methods. RDE data were measured at rotation rates from 0 to 3000 rpm (\( v = 10 \text{ mV s}^{-1} \)) and in the region of potentials from +0.17 to -0.50 V vs. Hg|HgO|0.1 M KOH. Cyclic voltamograms were measured at potential scan rates (v mV/s) 5, 10, 20, 30, 50, 70, 100, 150 and 200, in both Ar and O2 saturated solutions. The solutions were saturated with Ar or O2, respectively, between measuring of each voltammogram. A glassy carbon disk electrode (GCDE) was used as a catalyst support for electrochemical measurements. Catalyst ink was prepared by suspending the catalyst powders in isopropanol. Milli-Q water and Nafion dispersion solution (Aldrich) mixture (5 wt%) and pipetted onto GCDE.

It was established that the ORR activity for 20%Ru-C(WC) is higher but comparable to 20%Ru-Vulcan. Ru-metal loadings play a dominant role in the kinetics of the ORR on both electrodes in alkaline solution. After correction for Ar saturated supporting electrolyte current densities, very nice diffusion current plateaus have been observed at E < -0.28 V vs. Hg|HgO|0.1 M KOH for 20%Ru-C(WC) and 20%Ru-Vulcan systems. Cyclic voltammetry data demonstrate that 20%Ru-C(WC) exhibits higher capacitance values than 20%Ru-Vulcan, which is in a good agreement with N2 adsorption data.

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References