474c Nano Colloid Coating of Micro-Porous Electrode Membrane by Precision Electrospray Deposition

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A precise and contactless method for depositing metal catalyst crystallites on micro-porous electrodes is reported using a special DC electrospray technique. Compared with the regular chemical vapor deposition (CVD) method, which needs high vacuum conditions and complex solid evaporation and ionization sources, the electrospray technique is a facile and reproducible method that allows atmospheric-pressure ionization or atomization of nano-particle suspensions such as catalytic crystallite solutions and carbon nanotube solutions.

The spraying of a Pt/Ru nano-colloid solution was done with an imposed electric potential bias (> 1kV) across a hollow metal needle with blunt tip and an uncoated Ni porous membrane which also serves as an electrode. A micron-sized filament of solution protrudes from the needle tip under the influence of high electric field and ejects sub-micron charged drops of the solution. In mid-flight, the solvent within the droplet evaporates but the charge remains. As the drop volume decreases very rapidly, the surface tension is unable to oppose the repulsive forces from the charges, and the droplet explodes into many smaller droplets. These so-called Coulomb fissions or Raleigh fission occurs until nanosized charged droplets are generated, which contain no more than 100 metal colloids each. These charged droplets are then propelled through the gas phase by the electric field towards the counter electrodes and into the micron-sized pores. As the droplets are guided by the electric field, there is more loading at the edges of micropores (strong field region) rather than inside the pores (weak field region). It has been verified that this distribution that favors the pore edge produces a high catalytic activity for a micro-fuel cell as the current density is highest there when the fuel cell is in operation. The crystallite density at the edge can be controlled by adjusting the flow rate through the needle, the spray time and the solution concentration. The goal is to produce high edge activity but not to block the pores.

Due to the electric fields during coating, the drops can also penetrate the entire pore. Moreover, the small number of nano-colloids within the nano-drops results in very small crystallite clusters on the surface. The average size of these clusters can be controlled by changing spray voltage, which sensitively affects the drop size. This new precision spraying technique hence offers deep penetration coating and high crystallite dispersion: all important features for high catalytic activities. SEM images of the coated electrode by electrospray illustrate a very uniform crystallite coating within the pore, with the sponge morphology of the porous electrode preserved.

Gas pressurized spray was also tried as a comparison. The droplets generated by gas pressurized spray are much larger (visible, >50 micros) than that of the electrospray such that the entire electrode surface is covered by large crystallites without any deposition within the pores. The performance of the coated electrode was investigated by cyclic voltammetry. A remarkable increase in current density for methanol oxidation and oxygen reduction is observed when compared to catalytic crystallite coating by gas pressurized spray.