Plasma Processing for Fuel Cell Technology

Proton Exchange Membrane Fuel Cell

A PEMFC is an electrochemical cell that is fed hydrogen, which is oxidized at the anode, and oxygen, which is reduced at the cathode. The protons released during the oxidation are conducted through the PEM to the cathode while the electrons travel along an external circuit and are available to do work.

There are three critical transport processes, (a) protons from the membrane to the catalyst, (b) electrons from the current collector to the catalyst through the GDL and (c) reactant to and catalyst layer from the gas channel. Part of the optimization of the electrode design is to correctly distribute catalyst and collector to the catalyst through the GDL and (c) reactant to travel along an external circuit and are available to do work.

Toward a plasma PEM fuel cell

The Membrane Electrode Assembly (MEA) of PEM fuel cells (two electrodes and an ion membrane) is usually produced by wet chemical processes and assembled by hot pressing. During the last few years, some laboratories have developed low power micro-PEM fuel cell by plasma deposition processes. These PEM fuel cell, powered in general by methanol, are not yet optimised for industrial manufacture. Through our expertise in plasma physics, our aim is to build an optimised nano-structured PEMFC by plasma depositing ultra thin films of platinum and plasma polymerisation of new membranes which allow proton diffusion while reducing poisoning and degradation of the PEM from methyl groups.

Plasma processing for fuel cell electrode deposition

1 - Platinum catalyst deposition on GDL by plasma sputtering

2 - Carbon nano-fibres (CNF) deposition by PECVD

Plasma membrane deposition on catalysed GDL

1 - High electrochemical activity due to the high electrode active volume.
2 - Plasma membrane is dense (high permeability) and thin (high conductivity).

Ion and neutral beam modification of Nafion

Results on H₂ fuel cell tests:
1 - Better proton conductivity at high deposition pressure due to the porous catalyst layer (SEM and TEM)
2 - Better active surface area at low deposition pressure due to smaller catalyst nano-particles (SEM and TEM)
3 - Voltage drop at high current density due to catalyst absence at the GDL : catalyst diffusion length is around 200 nm (PEC electrode model)

Platinum and carbon nano-structures must be mixed / deposited together in around a 1 µm thickness.