# Preparation of Platinum catalysts for PEM Fuel cells

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**Abstract**

In this work, we have prepared platinum catalyst by various methods, investigated fuel cell performance and compared performance with commercially available 20% Pt supported on carbon (Pt/C) catalyst. We have found that Pt/C prepared by reduction of chloroplatinic acid in mixed solvent (water+ ethylene glycol) gives better performance compared to that produced by reduction of aqueous chloroplatinic acid, which can be attributed to smaller catalyst particle size and lower agglomeration in the mixed solvent. We have also prepared a novel platinum electrocatalyst by depositing platinum on Nafion coated carbon powder and it shows great promise. The performance of electrode prepared using 20%Pt on Nafion coated carbon mixed with Pt/C was found to be higher than the performance of electrodes using commercially available 20% Pt /C, up to a current density of about 1100mA/cm$^2$. The cell voltages obtained were respectively 621 and 603mV, at a current density of 1000mA/cm$^2$, in a single cell using 0.25mgPt/cm$^2$ and Nafion 1035 membrane at 80$^0$C using hydrogen/oxygen reactants at 1 atm pressure.

**Introduction:**

Proton Exchange Membrane Fuel Cell (PEMFC) technology is based on platinum as a catalyst for both hydrogen and oxygen electrodes. It is important to reduce the platinum loading, enhance the platinum catalyst utilization and improve the catalyst performance so that the cost of fuel cell can be reduced, which is one of the major impediments for PEMFC commercialization. Lot of research efforts is being focused to prepare platinum catalysts by various methods with a view to improve performance of fuel cell electrodes. It is realized that better utilization of platinum could be obtained by having better dispersion of catalyst. Various methods like microemulsion, electrodeposition, platinum coating on the membrane etc. have been attempted.

Objective of the present work was to prepare high performance fuel cell Pt catalysts by a very simple process, amenable for mass production. We have prepared Pt catalyst by various methods. We have

prepared platinum supported on carbon (Pt/C) catalyst by reduction of aqueous chloroplatinic acid using sodium borohydride, as reported in the literature. The problem with this method is that Pt catalyst tends to agglomerate and hence the surface area and catalytic activity will be less. Polymers and surfactants are usually added to reduce particle agglomeration. However, complete removal of the additives is sometimes not possible and also difficult, which may affect the catalyst performance. We have attempted to prepare Pt/C catalyst by reduction of chloroplatinic acid in a mixed solvent (water+ ethylene glycol), without polymers and surfactants. We have also attempted to prepare a novel Pt catalyst by depositing platinum on Nafion ionomer coated carbon powder, since such a catalyst is expected to have large number of three phase interfaces required for electro catalytic activity. Fuel cell electrodes were prepared using the above Pt catalysts and fuel cell performance was compared with commercially available Pt catalyst.

**Experimental**

Platinum supported on Vulcan XC (Cabot corporation, USA) catalyst (Pt/C) was prepared by two methods. In the first method (catalyst#1), carbon powder was suspended in water by ultrasonication, required quantity of 1wt% chloroplatinic acid (GR grade supplied by Kojima Chemicals Co. Ltd) was added and Pt/C was obtained by reduction of the Pt salt with 1wt% sodium borohydride solution, as reported elsewhere. In the second method (catalyst#2), Pt/C was prepared by suspending the carbon powder in a mixture of water, ethylene glycol and chloroplatinic acid and reducing the Pt salt in the mixed solvent.

Another platinum catalyst (catalyst#3) for PEM fuel cell was also prepared by supporting platinum on Nafion coated carbon powder. Carbon powder was first dispersed in Nafion ionomer solution, and dried to fix Nafion ionomer on the carbon surface. Pt catalyst was then coated on the Nafion ionomer coated carbon powder by dispersing the powder in Pt salt and reducing with sodium borohydride

Fuel cell electrodes were prepared using the above catalysts with a Pt loading of 0.25mg/cm$^2$ and also using commercially available 20% Pt/C (Vulcan XC-72) from E-TEK, USA. Electrodes were also prepared using mixture of Pt/C and Pt/Nafion ionomer coated carbon. MEA was fabricated with Nafion 1035 membrane (Dupont, USA), fuel cell was assembled in a 5cm$^2$ single cell test fixture (Electrochem Inc, USA) and cell performance was evaluated at 80°C, using humidified hydrogen-oxygen reactants, at 1atm pressure.

**Results and Discussion**

A comparison of the current voltage characteristics of 20% Pt/C catalysts prepared by reduction of chloroplatinic acid in the aqueous medium (catalyst#1) and in the mixed solvent (catalyst#2) is presented in Fig.1. Performance of electrode prepared with 20% Pt/C from E-Tek is also presented. It can be seen that the performance of the electrode with Pt/C prepared by reduction of chloroplatinic acid in the mixed solvent gives better performance compared to that produced by reduction of aqueous chloroplatinic acid,

though it is lesser than with commercial 20% Pt/C from E-Tek. The higher performance of Pt/C prepared in the mixed solvent can be attributed to smaller catalyst particle size and lower agglomeration in the mixed solvent. Work is in progress to optimize the solvent composition and reduction conditions for the preparation of better catalysts and more detailed evaluation of catalysts.

The performance of electrodes using Pt/Nafion coated carbon powder (catalyst#3) was very good, even better than E-Tek catalyst, in the very low current density region (activation region) indicating high catalytic activity. This can be attributed to large three phase interfaces generated, which facilitates higher electro catalytic activity. However, the cell performance was very low at high currents, and the impedance study indicated a very high ohmic resistance, which may be due to high coverage of Nafion film on carbon. It was decided to prepare an electrode using Pt/Nafion coated carbon powder mixed with Pt/C, to reduce the impedance, and its performance is also included in Fig.1. It can be seen that performance of the above catalyst mixture is higher than performance of electrodes using E-Tek catalyst, up to a current density of about 1100mA/cm$^2$. The cell voltages obtained were respectively 707mV and 696mV at a current density of 500mA/cm$^2$ and 621mV and 603mV at a current density of 1000mA/cm$^2$.

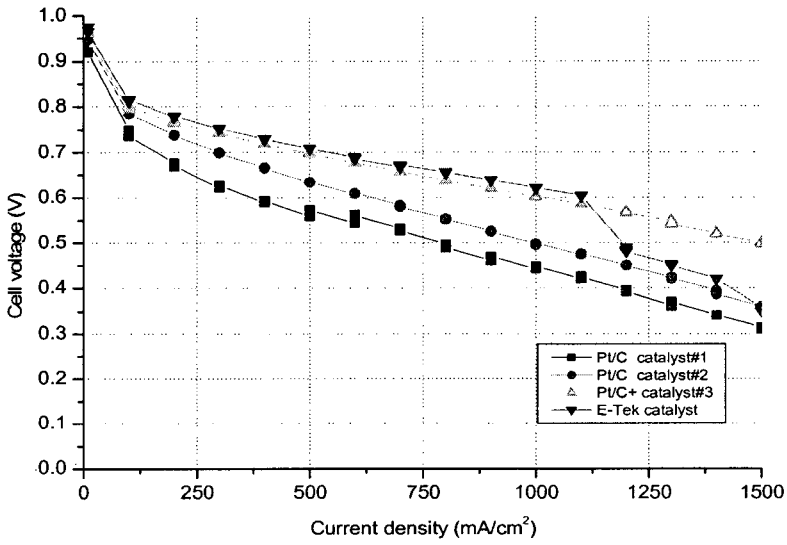


Fig.1 Current-voltage characteristics of fuel cell with Nafion 1035 membrane, using various electrcatalysts, at 80$^0$C using hydrogen/oxygen at 1 atm.

**Conclusion**

Platinum supported on carbon catalysts were prepared by reduction of chloroplatinic acid in the aqueous medium and in the mixed solvent. It can be concluded from the results obtained that Pt/C catalyst prepared

in the mixed solvent (water+ ethylene glycol) gives better performance compared to that produced by reduction of aqueous chloroplatinic acid, which can be attributed to smaller catalyst particle size and lower agglomeration in the mixed solvent.

The novel platinum electrocatalyst prepared by depositing platinum on Nafion coated carbon powder shows great promise. Its performance in the low current density region was very good, indicating high catalytic activity. Fine-tuning is needed to improve its electrical conductivity. The performance of electrode prepared using 20%Pt/ Nafion coated carbon catalyst mixed with Pt/C was found to be higher than performance of electrodes using 20% Pt/C alone, up to a current density of about 1100mA/cm$^2$. The cell voltages obtained were respectively 621 and 603mV, at 1000mA/cm$^2$, in a cell using Nafion 1035 membrane at 80$^0$C using hydrogen/oxygen reactants at 1 atm pressure.

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