CHAPTER V

CONCLUSIONS

PEM Fuel Cell technology is rapidly emerging as a viable energy source, alternative to the internal combustion engine due to its inherent advantages of low emission, high efficiency, fuel flexibility, and continuous operation. This thesis work focuses on progress achieved to reduce the quantity of Platinum with high performance. One of the critical challenges in commercializing Polymer Electrolyte Membrane Fuel Cell (PEMFC) is its high cost. The cost factors mainly depend on the components of PEMFC like carbon paper, Electrocatalyst, Polymer Electrolyte Membrane, Gas manifold plate, etc. The major part is concentrated on catalyst due to high cost of Platinum, Platinum alloy, and Platinum composite material. Lot of fundamental research work on the Electrocatalyst is in progress. In the Catalyst layer, expensive Platinum is used for preparing the high performance HOR and ORR electrodes. Hence, the Pt loading must be decreased and the utilization of Platinum is to be maximized.

Much of the current research on catalysts for PEM fuel cells can be classified as having one of the two main objectives:

1) To obtain higher catalytic activity than the standard carbon-supported platinum particle catalysts used in current PEM fuel cells

2) To reduce the poisoning of PEM fuel cell catalysts by gaseous impurities present in fuel and oxidant feed.
The broad conclusions obtained from the studies conducted in this work are presented as follows:

- The incorporation of WO$_3$ and TiO$_2$ binary molecules and WO$_3$-TiO$_2$ into the Platinum particles are achieved through a novel method of preparation i.e., by precipitation (Salt reduction process) method. 16 different stoichiometric compositions of
  
  (a) Pt-WO$_3$/C (Pt-W 0:10, 2:8, 4:6, 6:4, 8:2).
  
  (b) Pt-TiO$_2$/C (Pt-Ti 0:10, 2:8, 4:6, 6:4, 8:2) of binary nano-composite Electocatalysts.
  
  (c) Pt-WO$_3$-TiO$_2$/C (Pt-W-Ti 0:5:5, 2:4:4, 4:3:3, 6:2:2, 8:1:1) of ternary nano-composites.
  
  (d) 10 % Pt/C electrocatalysts.

were prepared by precipitation method (Salt reduction process).

- The Membrane electrode assemblies were fabricated using nano composites prepared during this work and as control (for reference) electrode prepared using commercial electrocatalysts.

- Electrochemical performance evaluation of Single Cell current – voltage polarization has been carried out for optimization of the electrocatalysts.

- Optimized catalysts were further characterized using XRD, SEM, EDX, TEM and Long term stability tests.

- The cyclic voltammogram studies were done to assess the Electrochemical surface area and electrocatalytic performance of the prepared catalysts.
All prepared catalysts exhibited particle size from 2 nm to 3 nm.

The effective utilization of platinum is much higher than Pt/C, when WO₃ or TiO₂ as binary molecule with Pt and WO₃-TiO₂ as ternary molecules were introduced within Pt nano particles,

This study has successfully developed a novel method for the preparation of three types of carbon supported Pt-WO₃, Pt-TiO₂, and Pt-WO₃-TiO₂ electrocatalysts with various compositions at different weight percentages, Pt-W 0:10, 2:8, 4:6, 6:4, 8:2 of Pt-WO₃/C, Pt-Ti 0:10, 2:8, 4:6, 6:4, 8:2 of Pt-TiO₂/C of binary nano-composite electocatalysts, Pt-W-Ti 0:5:5, 2:4:4, 4:3:3, 6:2:2, 8:1:1 for Pt-WO₃-TiO₂/C of ternary nano-composites and 10% Pt/C. These anode electrocatalysts were prepared by precipitation method (Salt reduction process). The performance of prepared catalysts and that using commercial catalyst were optimized through single cell evaluation and characterization methods. The optimized catalysts Pt-WO₃ (Pt-W 6:4) Pt-TiO₂ (Pt-Ti 8:2) and Pt-WO₃-TiO₂ (Pt-W-Ti 4:3:3), 10% Pt/C and 10% Pt/C (commercial) were further characterized using XRD, SEM, EDX, TEM techniques and Long term electrochemical stability tests.

The electrocatalytic activities of optimized Pt-WO₃/C (Pt-W 6:4), Pt-TiO₂ (Pt-Ti 8:2) and Pt-WO₃-TiO₂ (Pt-W-Ti 4:3:3) nanocomposites have shown better performances than 10% Pt/C and commercial 10% Pt/C in PEMFC. Through experimental results it was established that, even lower amounts of platinum catalyst enhances the power density of electrodes. Through this work, it is further established that, the presence of WO₃ molecule enhances the proton transport within the platinum surface through the inclusion of WO₃ into the Platinum particles. The novel approach followed for
doping WO₃ and TiO₂ into the Pt particles has been fully established in the present work and this method has not been reported so far. The technique followed in this work for the inclusion of second and third elements into Platinum prevents the agglomeration of platinum particles.

Another novel approach established through the present work was based on Nafion emulsion for the incorporation of TiO₂ and WO₃ particles into the ionomer. The metal oxide provides an internal humidification to retain water within the ionomer, enhances the proton conductivity at the anode side and ensures long-term stability of the catalyst.

The quantity of Platinum content was reduced from 1.76 to 1.056 mg cm⁻² for Pt-WO₃/C, 1.408 mg cm⁻² for Pt-TiO₂/C and 0.706 mg cm⁻² for Pt-WO₃-TiO₂/C compositions. The optimized Pt-WO₃/C (Pt-W, 6:4), Pt-TiO₂/C (Pt-Ti, 8:2) and Pt-WO₃-TiO₂/C (Pt-W-Ti, 4:3:3) catalysts have shown better catalytic activity for anodic oxidation (HOR) due to the non-aggregated dispersion of Pt particles and the presence of metal oxide prevents the agglomeration of Platinum particles.

The experimental results establish that even lower amount of platinum catalyst enhances the power density of electrodes. The effective utilization of platinum is much higher than Pt/C, when WO₃ or TiO₂ as binary molecules and WO₃-TiO₂ as ternary molecules were introduced within the Pt nano particles which is the main scope of this work.

To conclude that, the Pt-WO₃/C (Pt-W 6:4), Pt-TiO₂/C (Pt-Ti, 8:2) and Pt-WO₃-TiO₂/C (Pt-W-Ti 4:3:3) are used as highly promising, cost effective, very stable and enhanced performance anode electrocatalysts for Polymer
SCOPE OF THE FUTURE WORK

Proton exchange membrane fuel cell catalyst design issues

- In the present studies, the prepared anode electrocatalysts were used for Polymer Electrolyte Membrane Fuel Cell and these catalysts could be further investigated for other fuel cell applications like Direct Methanol Fuel Cell, Phosphoric Acid Fuel Cell and Borohydride Fuel Cell.
- The prepared catalysts can be used for cathode preparation.
- There is lot of Scope to prepare various compositions of electrocatalysts with different elements so that the loading of Platinum is still reduced without affecting the performance.
- In 2002, typical fuel cell systems costed US$ 1000 per kiloWatt of electric power output. In 2009, US DOE reported that the cost of 80-kW automotive fuel cell system during volume production (projected to 500,000 units per year) will be $ 61 per kiloWatt. The goal is $ 35 per kiloWatt. The goal is to reduce the cost in order to compete with current market technologies including gasoline and internal combustion engines. Many companies are working on techniques to reduce cost in a variety of ways. Reducing the amount of platinum per kW of Fuel cell will only provide the needed cost benefit.