



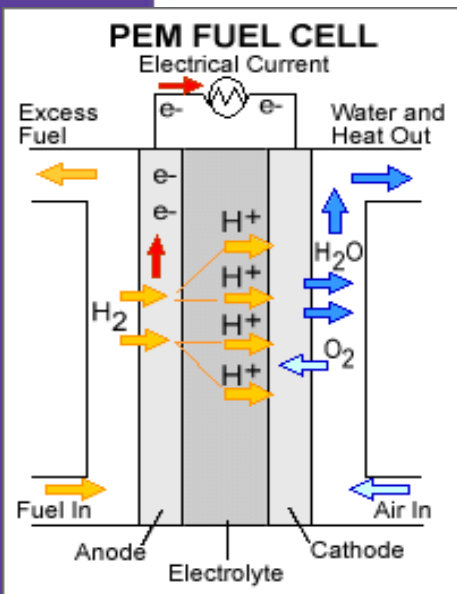
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# Synchrotron Based Techniques for Fuel Cell Applications

Mohammad Norouzi Banis

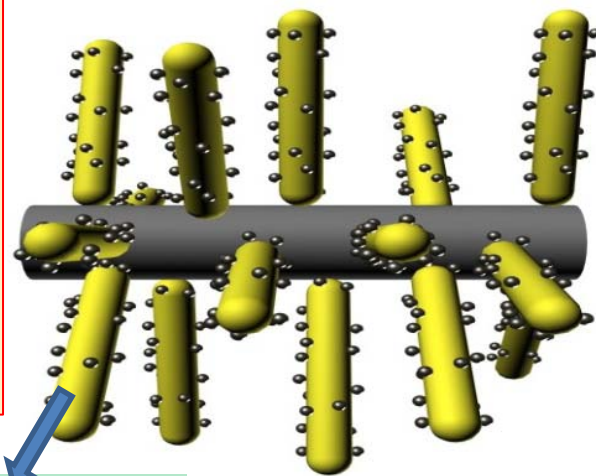


# Research Background



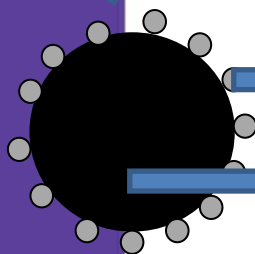
## Challenges:

- **High Cost**
  - Pt Price
- **Low Durability and Stability**
  - Pt Agglomeration
  - Support Degradation
- **Slow Reactions**
  - Oxygen Reduction Reaction



- ### Nanostructured Catalysts
- Nanostructured Pt: Nanoparticles, Nanowires, ...
  - Pt Alloys:  $Pt_xNi_y$ , PtRu, ...
  - Non-Nobel Catalysts

- ### Nanostructured Supports:
- Carbon Based: Nanotubes, Nanosheets
  - Metal Based:  $SnO_2$ , WC, ...
  - Composite Nanostructures



- ### Electrocatalyst
- Catalyst
    - Pt and Pt Alloys
  - Catalyst Support
    - Carbon Powder

Electrocatalyst



# Fuel Cell in Dr. Sun's Group

## ➤ Catalyst:

- Pt nanoparticles
- Pt nanowires
- Porous Pt nanostructures
- Pt Alloys: PtAu, Pt<sub>x</sub>Ni<sub>y</sub>
- Non-Nobel Catalysts: NCNTs,

## ➤ My Research

### ➤ Synthesis of Catalyst supports

- Metal Oxides,
- Silicides,
- Carbides
- Composites

### ➤ Synthesis of Catalysts

- Pt nanoparticles
- Pt nanowires
- Pt Sub Nano Clusters (atomic)

## ➤ Catalyst Supports:

### ➤ Carbon Based:

- Graphene, NCNTs, CNTs, Fibers,

### ➤ Metal Based:

- Oxides: TiO<sub>2</sub>, SnO<sub>2</sub>, MnO, W<sub>18</sub>O<sub>49</sub>
- Carbides: TiC, WC, TaC



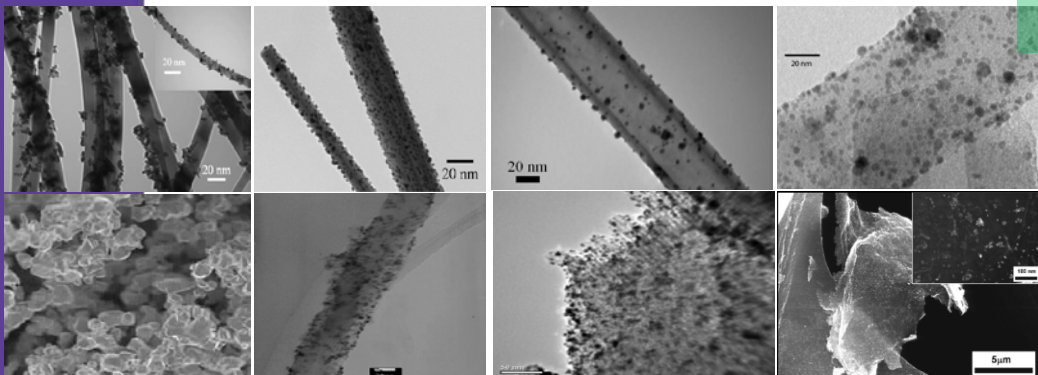
- Physical and Chemical Characterization
  - SEM, TEM, XRD, XPS



- Electrochemical Characterization and Fuel Cell Testing

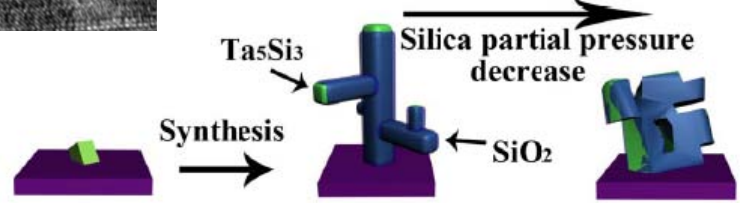
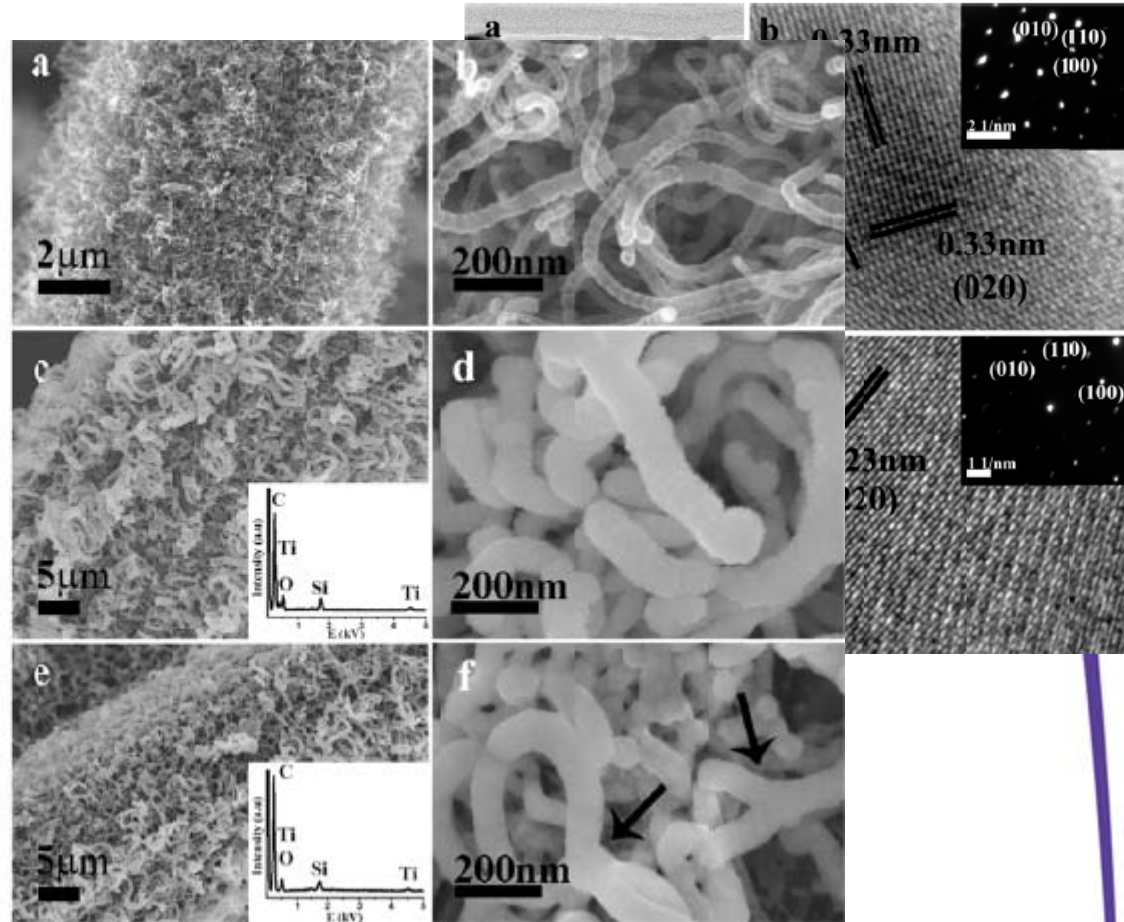
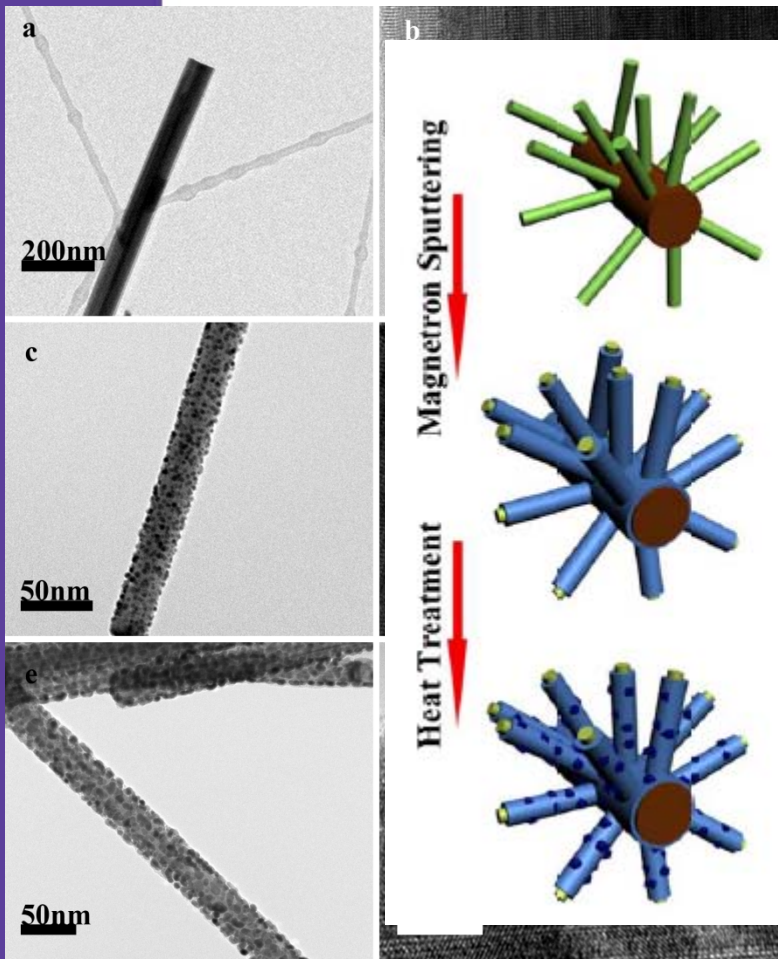


- In depth analysis of the Nanostructured System
- Synchrotron Based Techniques





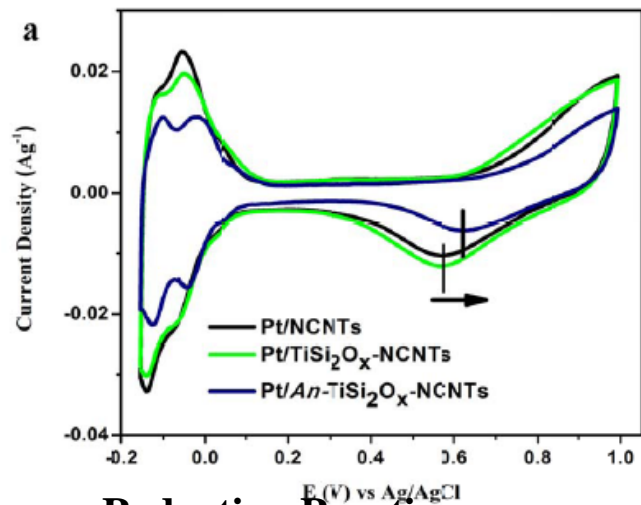
# Synthesis of Nanostructures



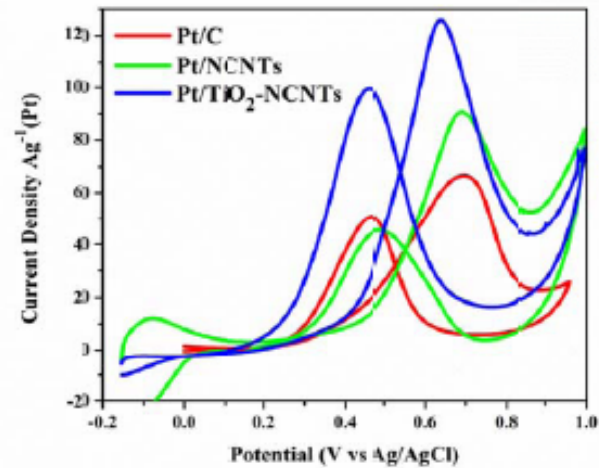


# Electrochemical Characterization

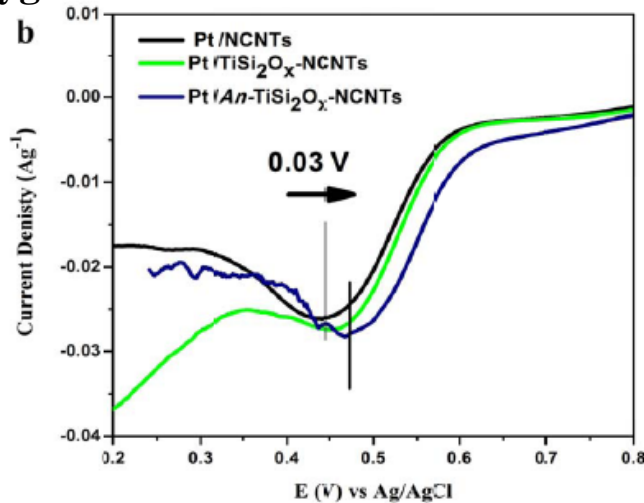
## Cyclic Voltammetry curves



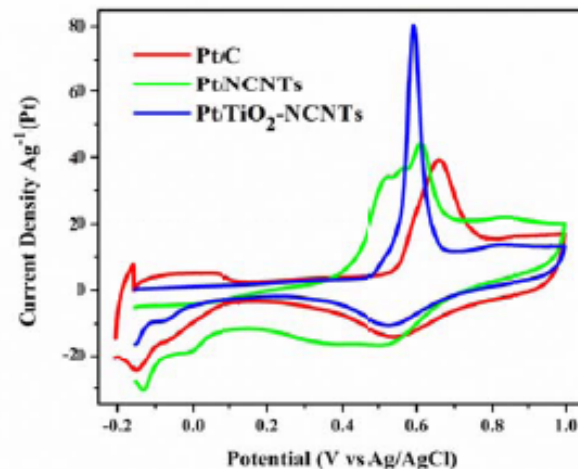
## Methanol Oxidation



## Oxygen Reduction Reaction



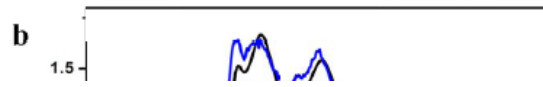
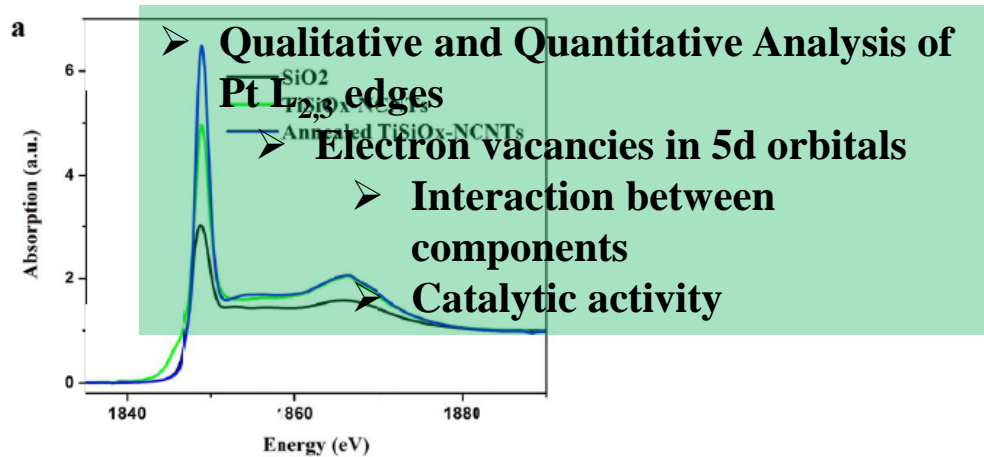
## CO stripping Curves





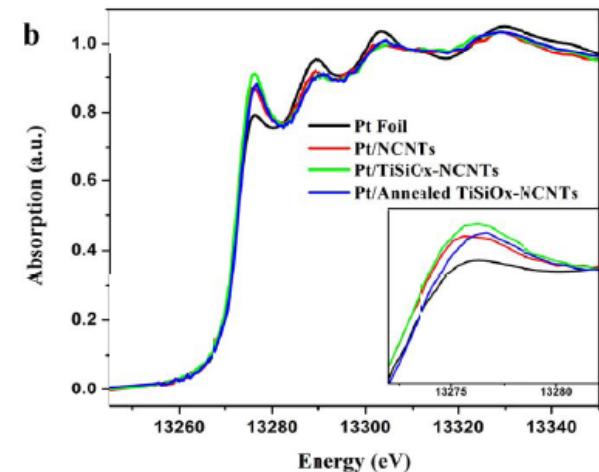
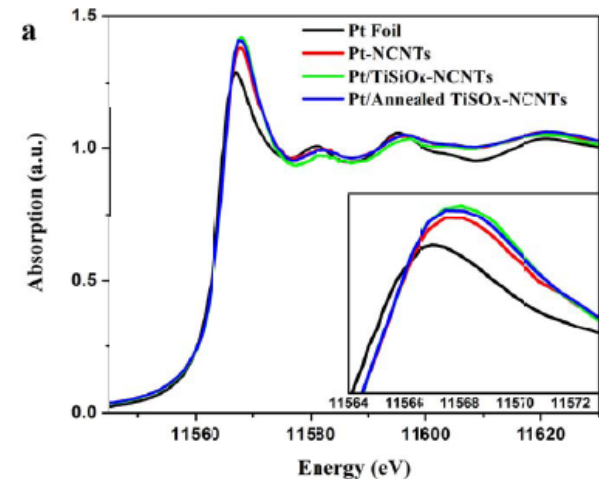
# Application of XAS

- Study the chemical state of elements
  - Amorphous structures
  - Low concentration elements
- Interaction between material



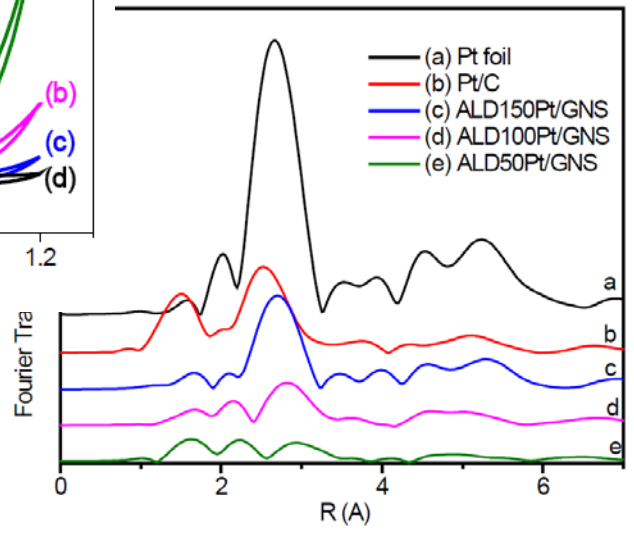
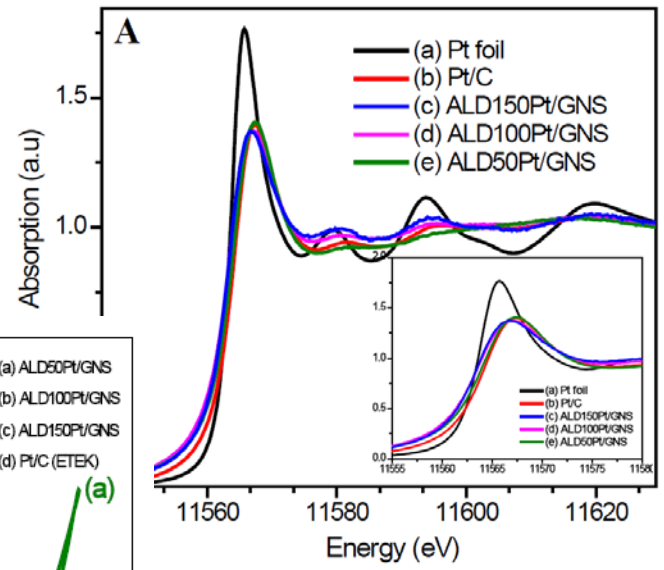
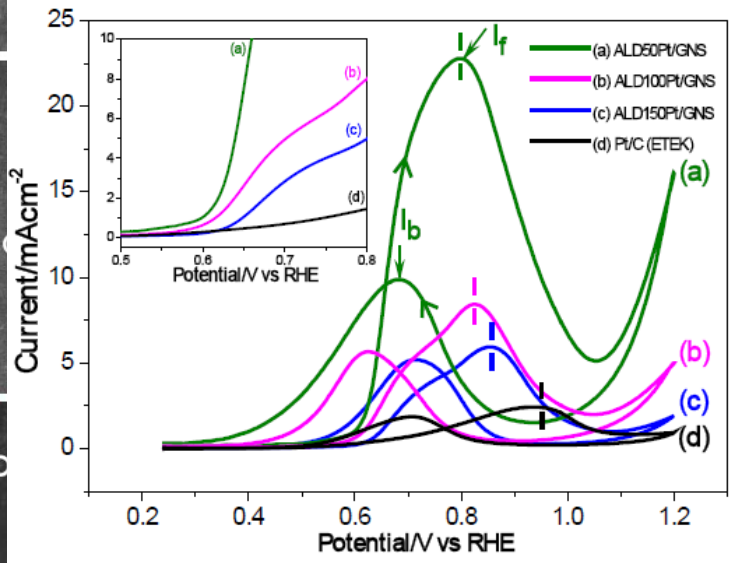
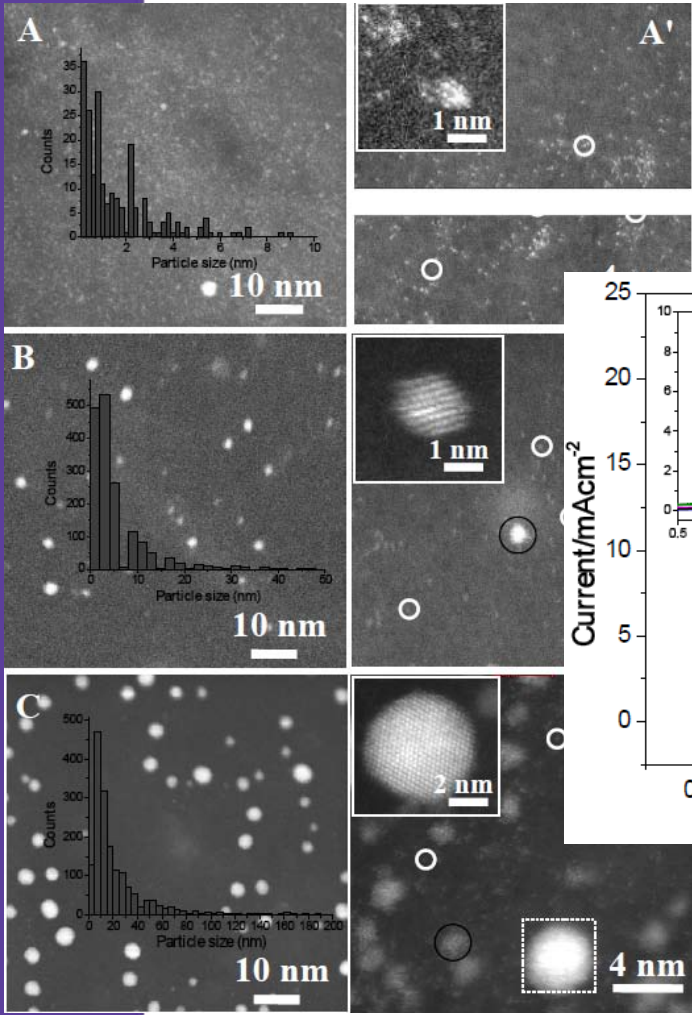
Sample	Pt L <sub>3</sub> edge WL				Pt L <sub>2</sub> edge WL				h <sub>3/2</sub>	h <sub>3/2</sub>
	E <sub>0</sub> (eV)	E <sub>Peak</sub> (eV)	Γ(eV)	ΔA <sub>3</sub>	E <sub>0</sub> (eV)	E <sub>Peak</sub> (eV)	Γ(eV)	ΔA <sub>2</sub>		
Pt Foil	11564.00	11567.00	6.00	4.87	13273.00	13276.30	6.60	2.26	0.00	0.00
Pt/NCNTs	11563.98	11567.50	7.04	5.09	13272.98	13275.58	5.19	2.60	0.00	0.00
Pt/TiSiOx-NCNTs	11563.94	11568.06	8.23	5.10	13272.98	13276.38	6.81	3.15	0.00	0.00
Pt/An-TiSiOx-NCNTs	11563.98	11567.50	7.04	5.22	13273.00	13276.28	6.56	2.57	0.00	0.00

Energy (eV)





# Application of XAS





# Future Opportunities

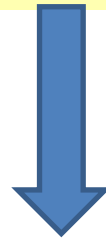
## ➤ Controlled Synthesis of Electrocatalysts:

- Alloyed Catalysts
- Composite Catalysts
- Composite Supports



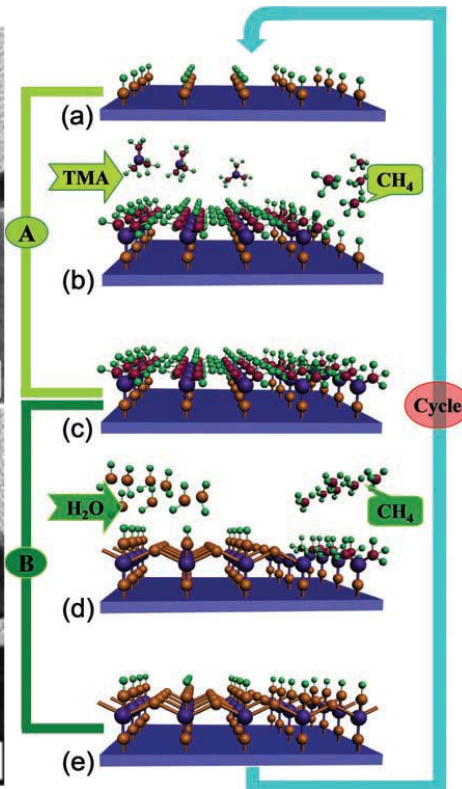
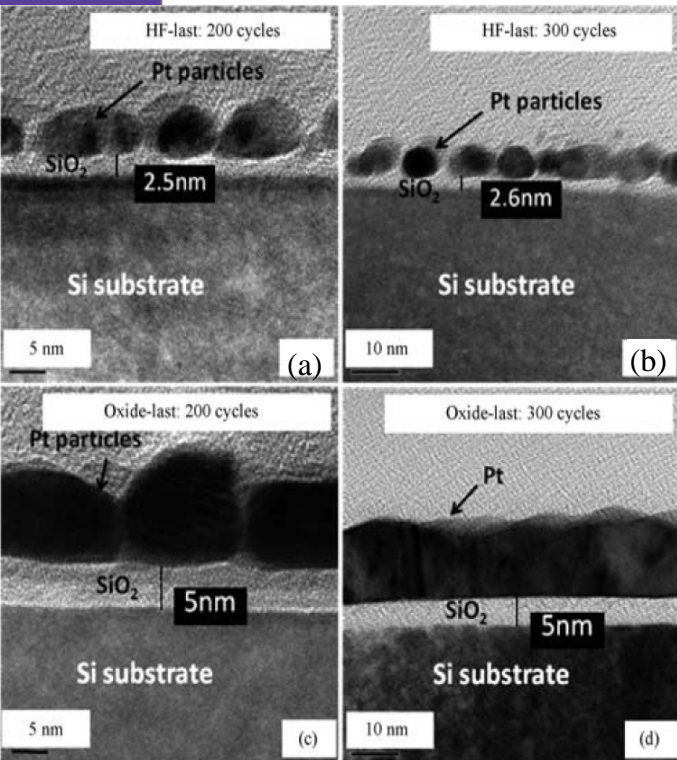
## ➤ Atomic Layer Deposition

- Study the interaction between supports
- Study the alloy and composite catalysts



## ➤ Proposed analysis methods:

- XAS (Hard and soft X-ray)
- Ultra HRTEM and EELS







# Future Opportunities

## ➤ Synthesis of Novel Nanostructures:

- Alloyed Catalysts
- Networked or Dendrite Catalysts
- Hollow Nanostructures

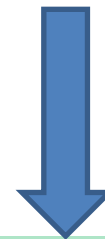


## ➤ Solution based:

- Replacement methods

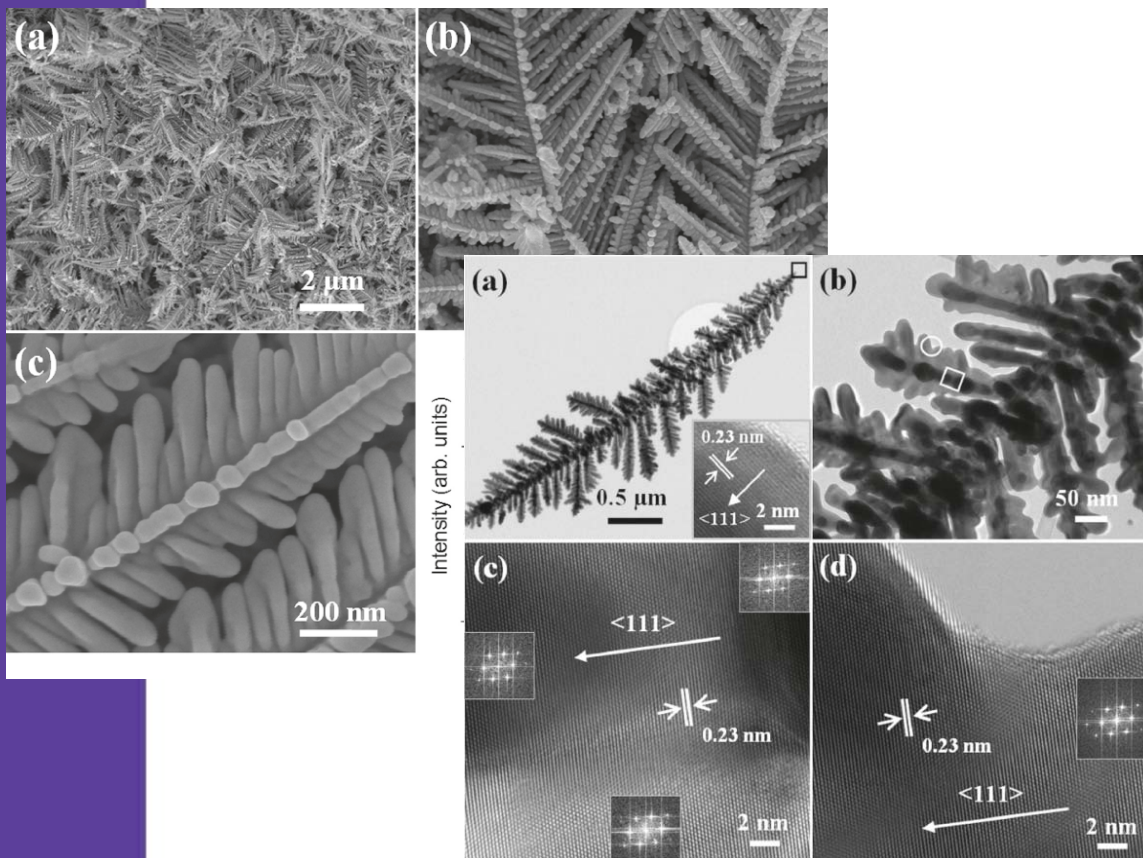
## ➤ Vapor based:

- PECVD and Sputtering



## ➤ Proposed Analysis Methods:

- XAS (Hard and Soft X-rays)
- STXM





# Summary

- **Application of Nanomaterials to Fuel Cell Challenges**
- **Interdisciplinary Research Field**
  
- **Synthesis and Characterization of Nanomaterials**
- **Electrochemical and Fuel Cell testing**
  
- **In Depth Study of Electrocatalyst Structure**
  - **Understanding the Underlying Mechanisms**
  - **Optimizing the Electrocatalysts Structure**
  
- **New Opportunities:**
  - **Atomic Layer Deposition**
  - **Replacement and PECVD Methods**



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# Thank You

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