

## Enhanced catalytic activity and stability of copper and nitrogen doped titania nanorods supported Pt electrocatalyst for oxygen reduction reaction in polymer electrolyte fuel cells

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**Table 1S: Optimization of Rutile TiO<sub>2</sub> during preparation of nanorods**

Name	Temperature	Solution	Phase formation	Nanostructure
P-25 (TiO <sub>2</sub> )	180 °C/ 4h	10 M KOH	Anatase	Spherical
P-25	180 °C/ 8h	10 M KOH	Anatase	Spherical+ wires
P-25	180 °C/ 24h	10 M KOH	Anatase	nanowires
Titanium isopropoxide	180 °C/24h	10 M KOH	Anatase	Irregular shape
Titanium isopropoxide	180 °C/4h	5 M HCl ITO plate	Rutile	Spherical + Nanorods
Titanium isopropoxide	180 °C/6h	5 M HCl ITO plate	Rutile	Nanorods
Titanium isopropoxide	180 °C/6h	5 M HCl Glass plate	Rutile	Nanorods

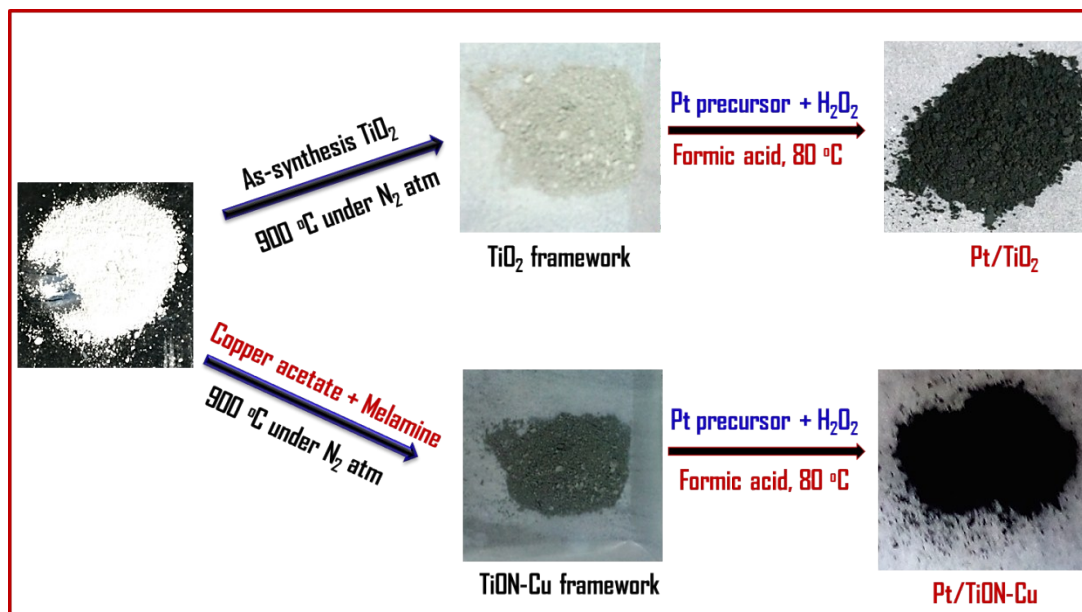
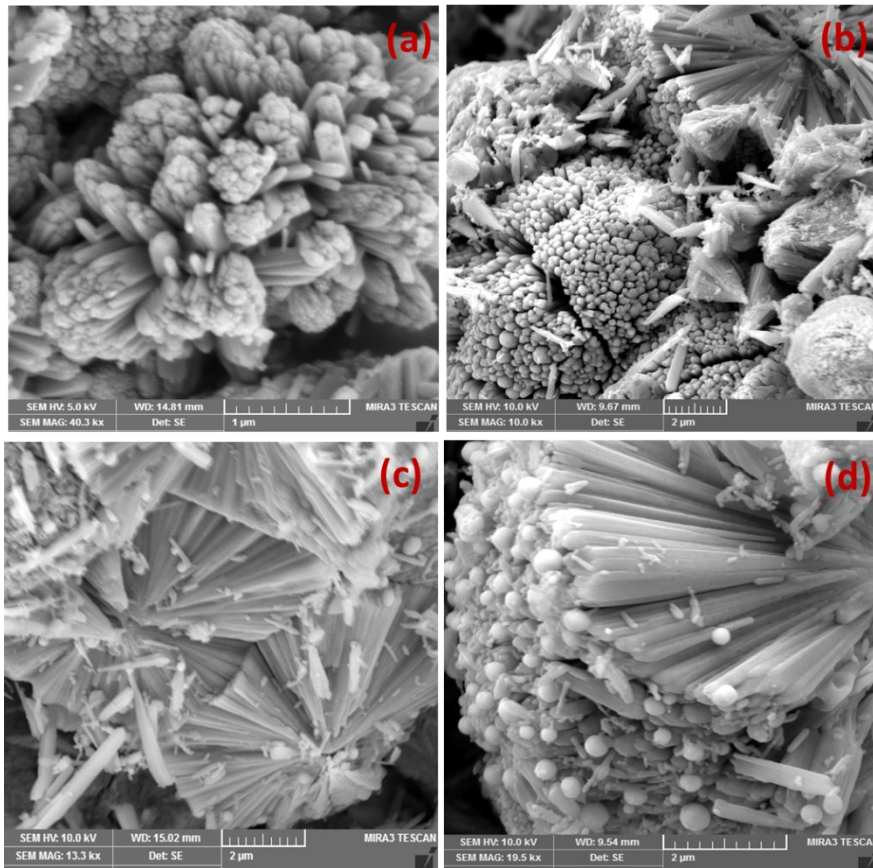
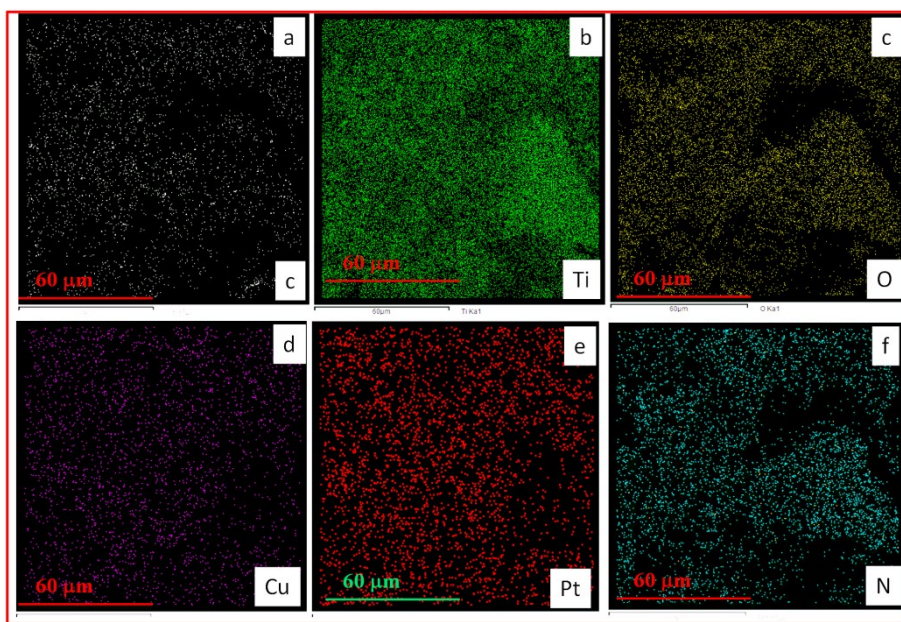


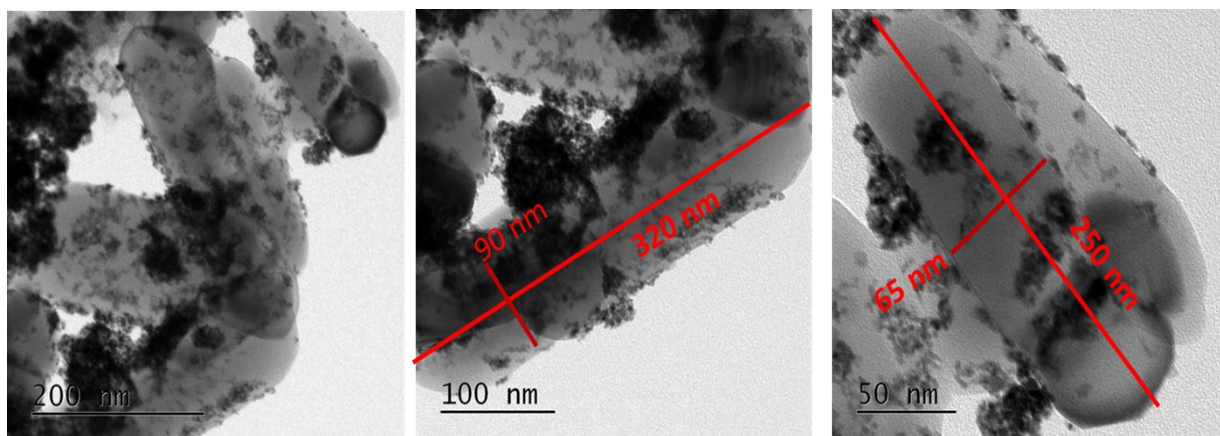
Fig. 1S Various stages of colour change observed during preparation of ORR catalyst.



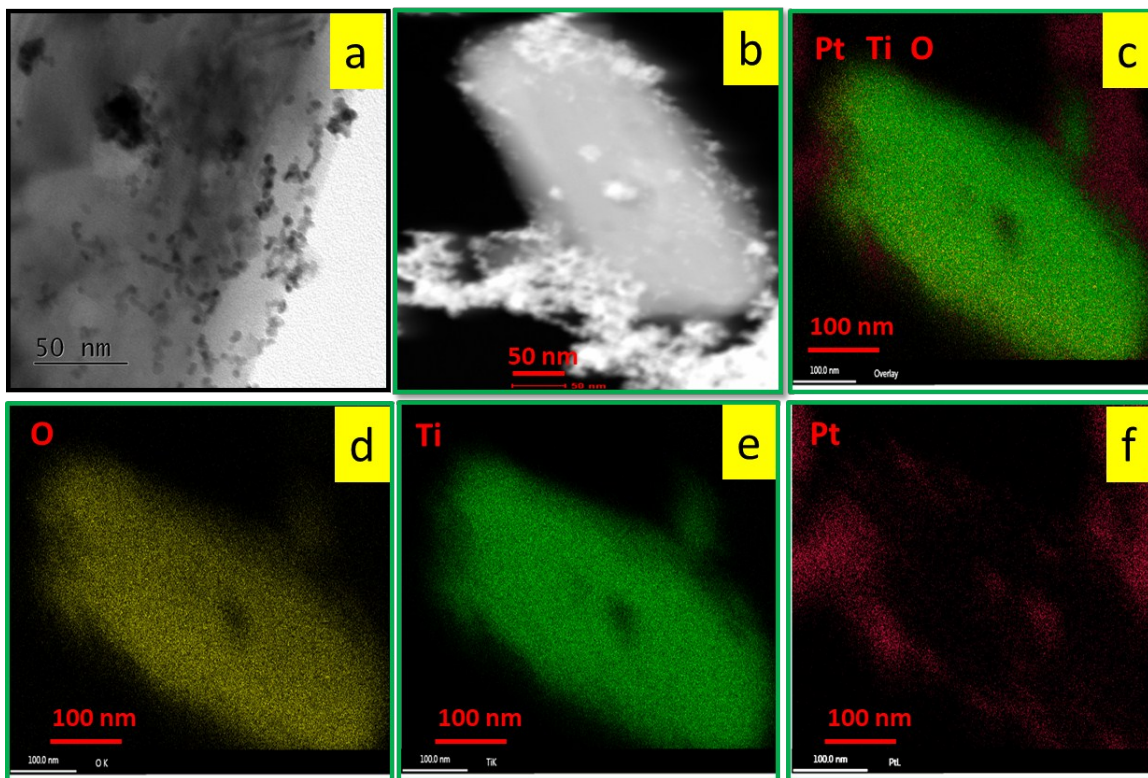
**Fig. 2S** (a) FE-SEM image for (a)  $\text{TiO}_2$ , (b)  $\text{TiON}$ , (c)  $\text{TiON-Cu 1}$  and (d)  $\text{TiON-Cu 3}$ .



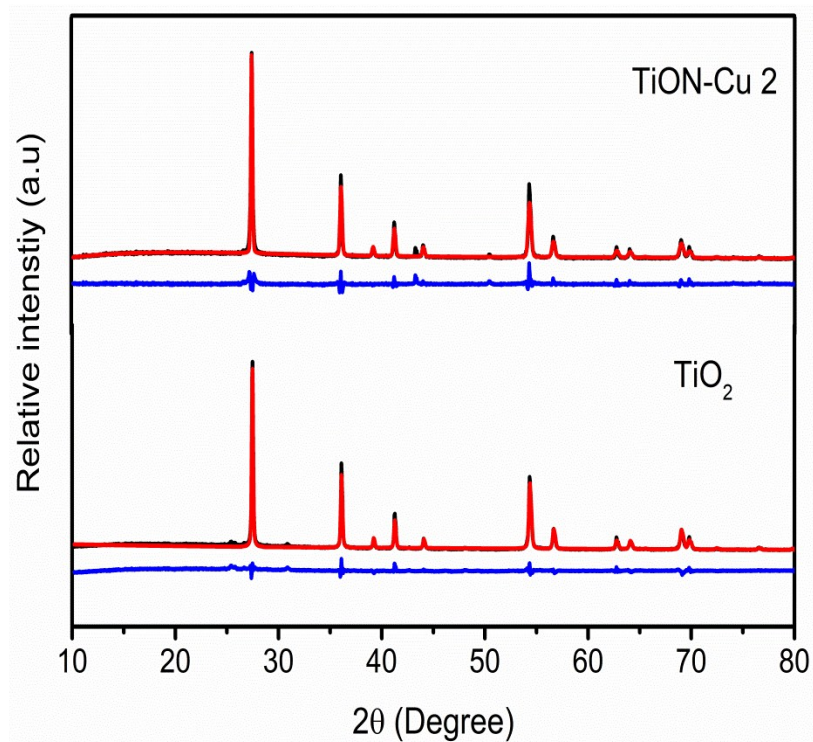
**Fig. 2S (b)** FE-SEM mapping for Pt deposited on TiON-Cu 2 nanorods support.



**Fig. 3S (a)** TEM of Pt deposited on TiO<sub>2</sub> nanorods with different scale.



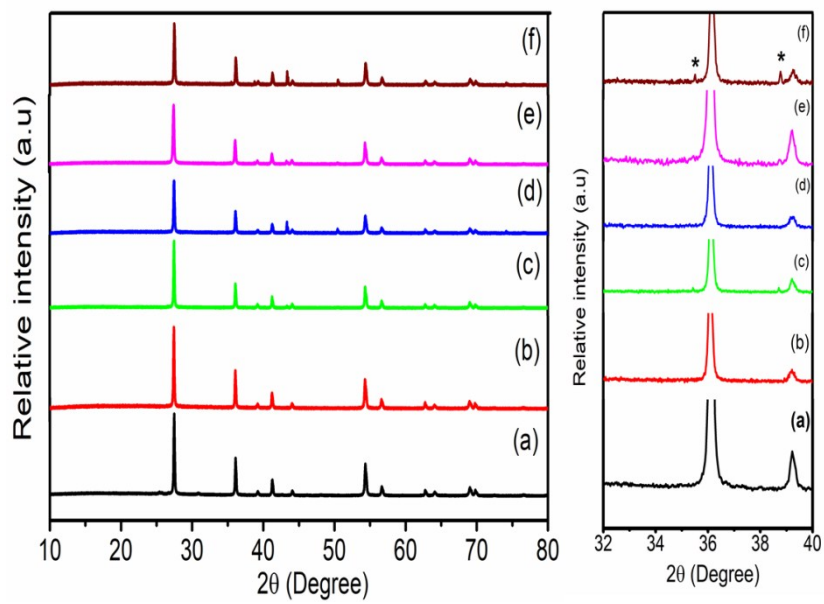
**Fig. 3S (b)** TEM and STEM image of Pt deposited on TiO<sub>2</sub> nanorods. (a & b) Pt/TiO<sub>2</sub>, (c) overall elemental mapping image and individual STEM mapping (d) Oxygen, (e) Titanium and (f) Platinum.



**Fig. 4S (a)** XRD refinement for both  $\text{TiO}_2$  and  $\text{TiON-Cu 2}$  framework.

The refined structural parameters of  $\text{TiO}_2$  and  $\text{TiON-Cu 2}$  sample.

Parameter	$\text{TiO}_2$	$\text{TiON-Cu 2}$
Space group	136	136
Hermann-Mauguin symbol	P42/mnm	P42/mnm
Hall symbol	-P 4n 2n	-P 4n 2n
Crystal structure	Tetragonal	Tetragonal
a	4.6013	4.5946
b	4.6013	4.5946
c	2.9587	2.9610
$\alpha$	90	90
$\beta$	90	90
$\gamma$	90	90
Volume	62.39	62.37
Bragg R-factor	3.82	3.86
RF-factor	3.58	3.62
$X^2$	3.16	3.26



**Fig. 4S (b)** XRD pattern for (a)  $\text{TiO}_2$ , (b)  $\text{TiON}$ , (c)  $\text{TiO}_2\text{-Cu 2}$ , (d)  $\text{TiON-Cu 1}$ , (e)  $\text{TiON-Cu 2}$  and  $\text{TiON-Cu 3}$  framework. Right side expanded region from 32 to 40 ( $2\theta$ ) asterisks peak indicated that un-doped Cu in the form of  $\text{CuO}$  (confirm from JCPDS No:89-5899).



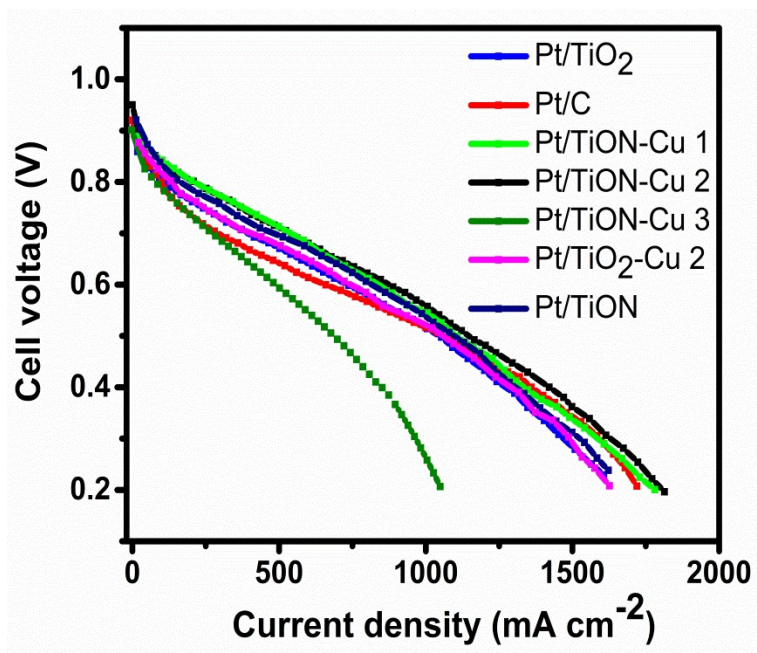
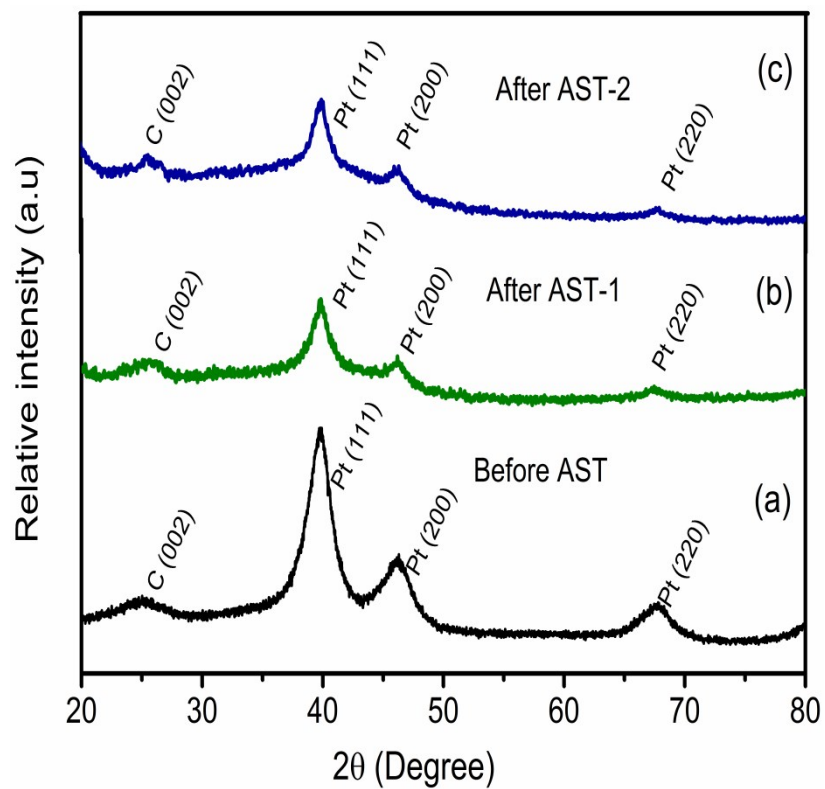
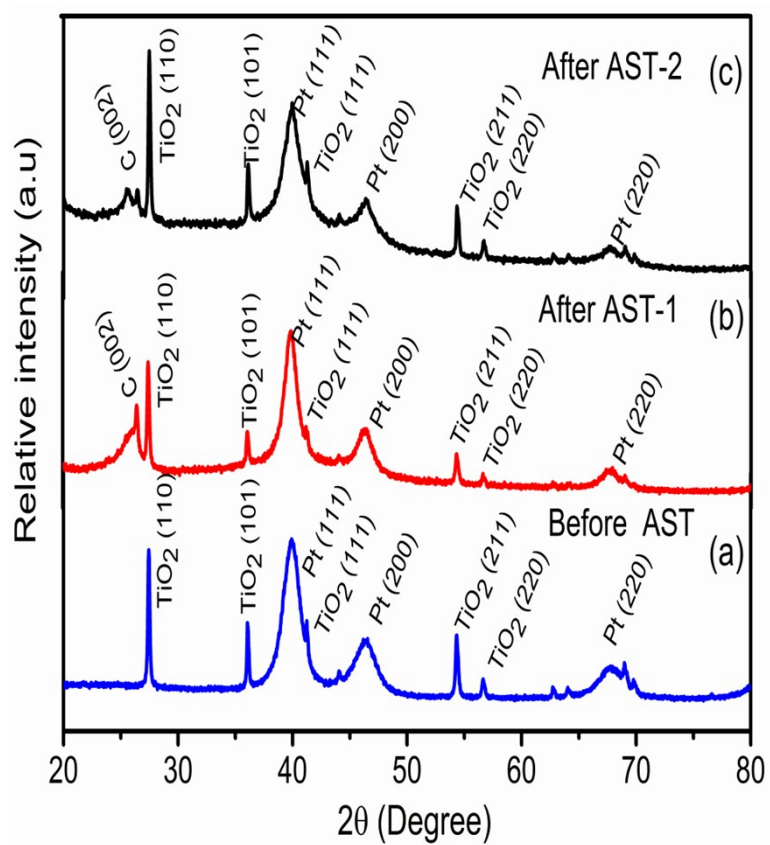


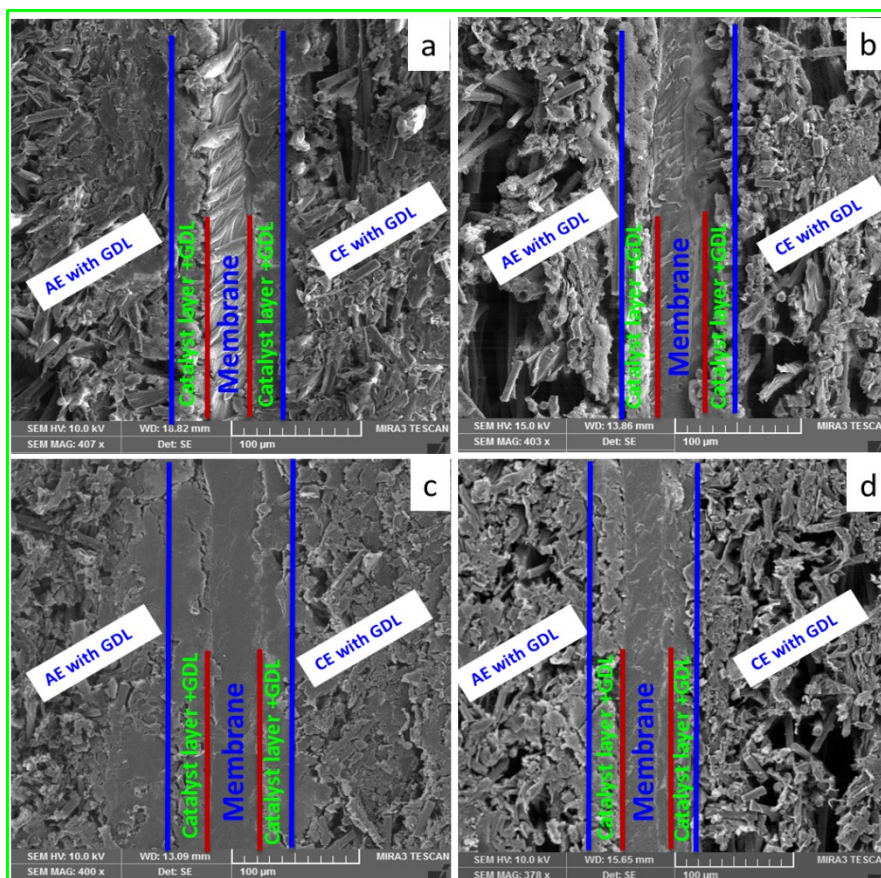
Fig. 5S Steady state polarization of different prepared electrocatalysts.



**Fig. 6S** XRD pattern for (a) Pt/C before AST, (b) after AST-1 for support durability and (c) after AST -2 catalyst durability.

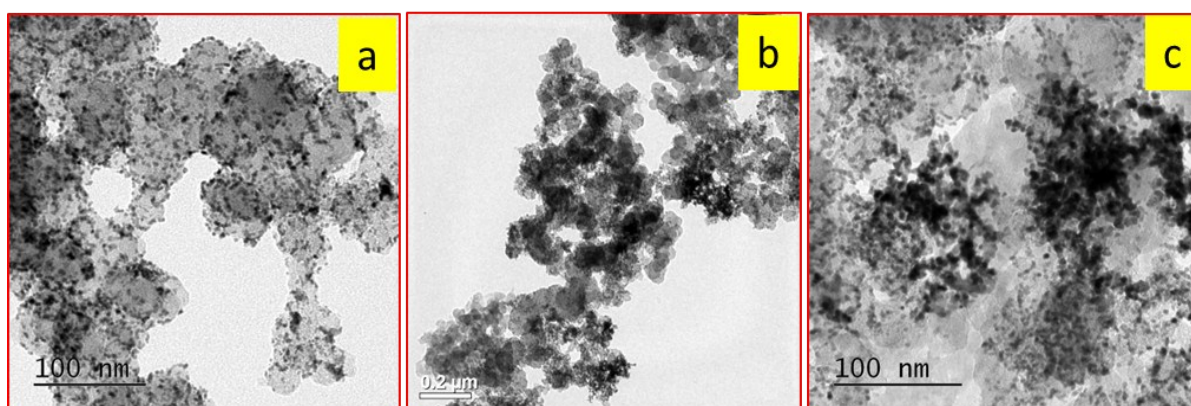


**Fig. 7S** XRD pattern for (a) Before AST for Pt/TiON-Cu 2 nanorods, (b) after AST-1 and (c) after AST-2.

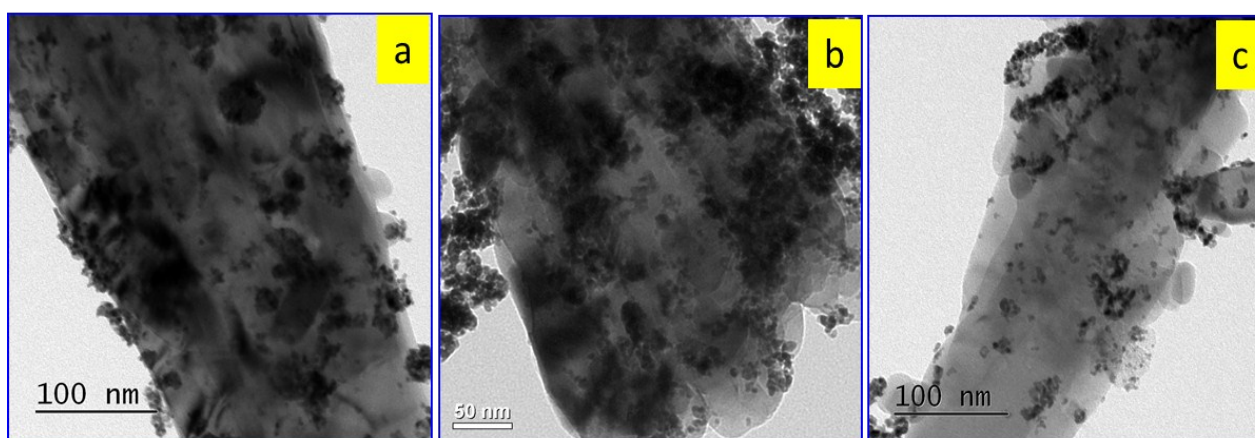


**Fig. 8S** FE-SEM cross sectional image of MEAs comprising Pt/C before and after AST-1 (a & b) and Pt/TiON-Cu 2 nanorods before and after AST-1 (c & d).

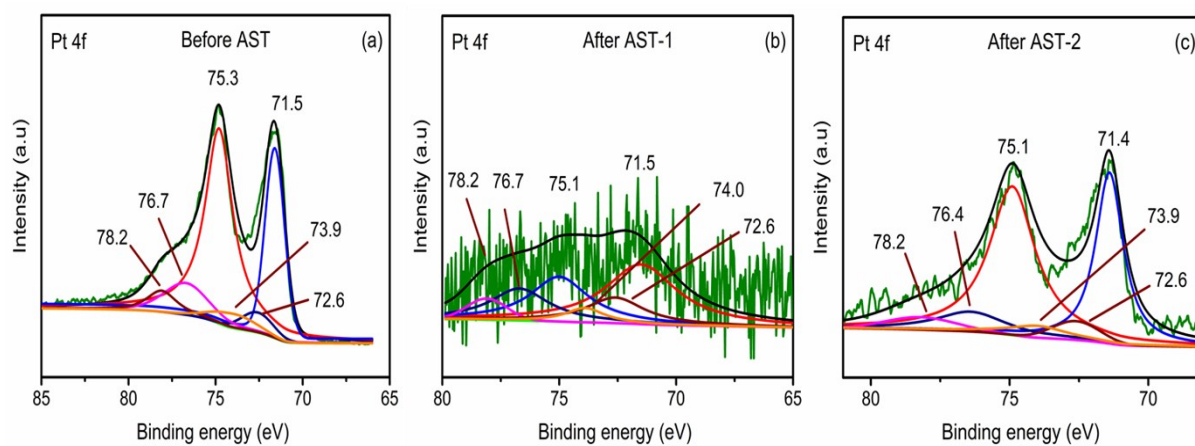




**Fig. 10S** TEM image for (a) Pt/C before AST, (b) after 1,000 AST-1 cycles and (c) after 10,000 AST-2 cycles.

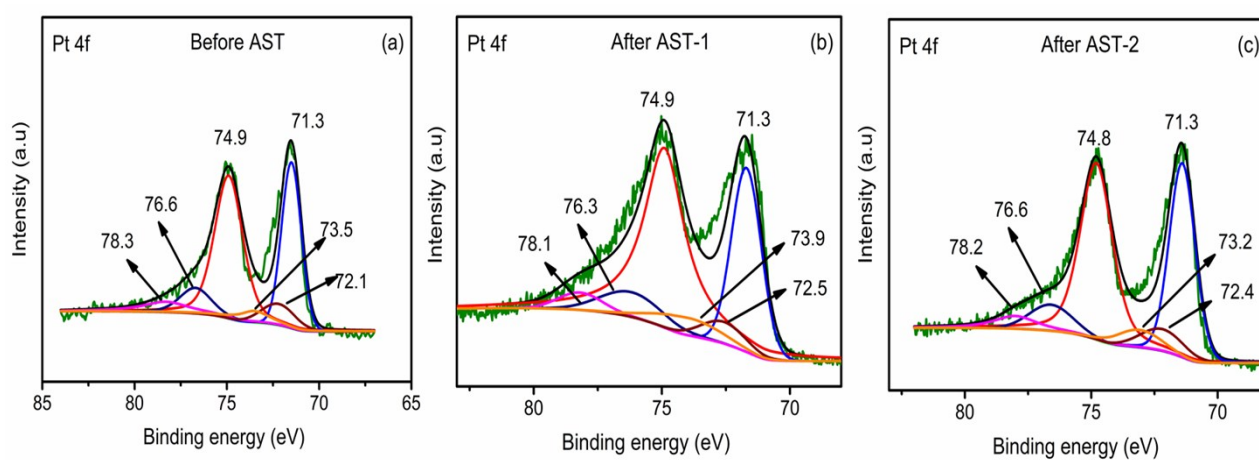


**Fig. 11S** TEM image for Pt/TiON-Cu 2 nanorods (a) Before AST, (b) AST-1 after 6,000 cycles and (c) AST-2 after 18,000 cycles (for catalyst).



**Fig. 12S** XPS spectra of Pt 4f orbital state for Pt/C: (a) Before AST, (b) AST -1 after 1,000 cycles and (c) AST-2 after 10,000 cycles.





**Fig. 13S** XPS spectra of Pt 4f orbital state for Pt/TiON-Cu 2: (a) before AST (b) AST-1 after 6,000 cycles and (c) AST-2 after 10,000 cycles.