# Supplementary Information

# Controllable construction of Pt/CNT catalyst layers to improve the Pt utilization in PEMFC

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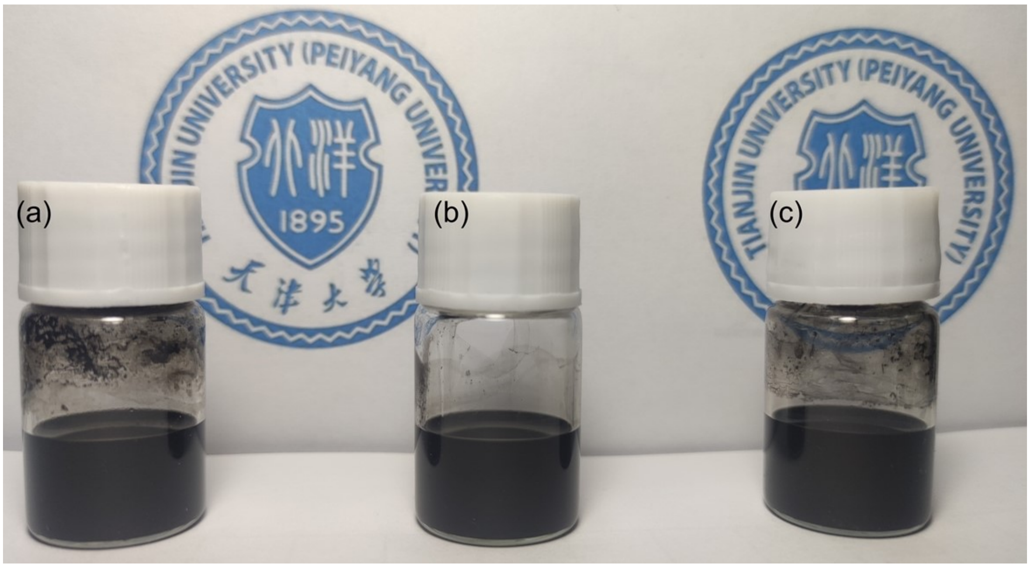


**Fig. S1.** Dispersion state of CNTs with different aspect ratios in solvents, length (0.5-2 μm), diameter: (a) 5-15 nm, (b) 30-50 nm, (c) 30-80 nm.

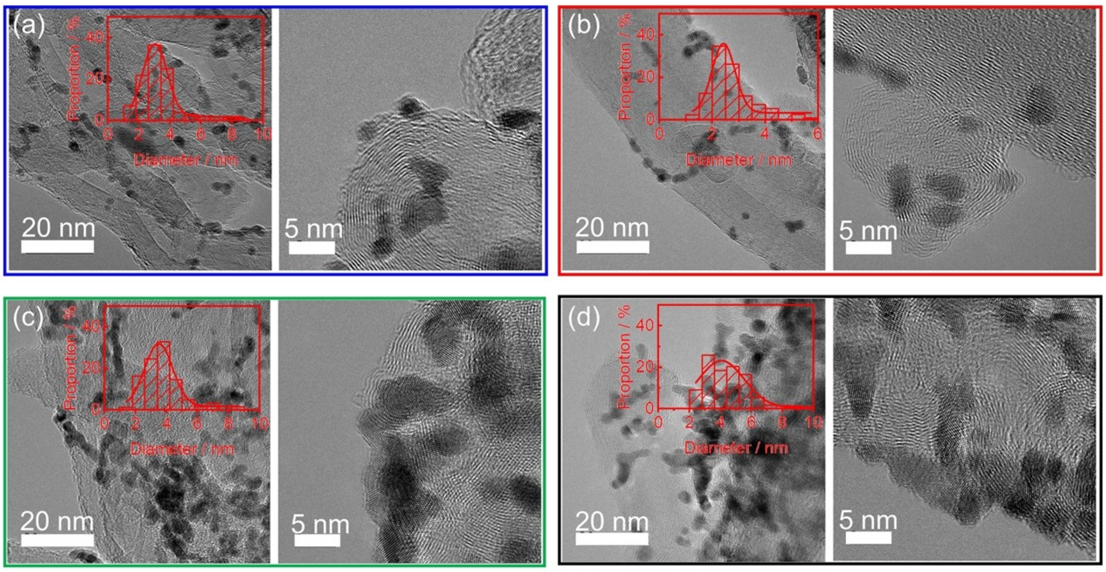


**Fig. S2.** TEM micrographs and Pt particle size distribution histograms (Insets) of (a) Pt/CNT-90, (b) Pt/CNT-120, (c) Pt/CNT-150 and (d) Pt/CNT-180.

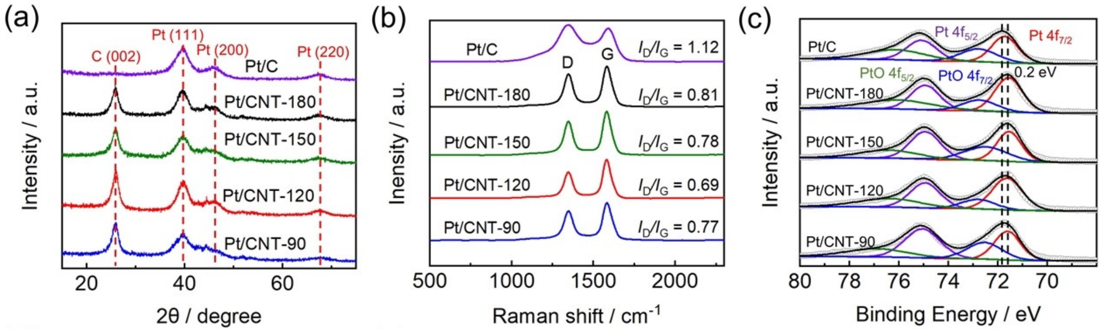


**Fig. S3.** (a) XRD patterns, (b) Raman spectra, (c) XPS spectra of different catalysts, respectively.

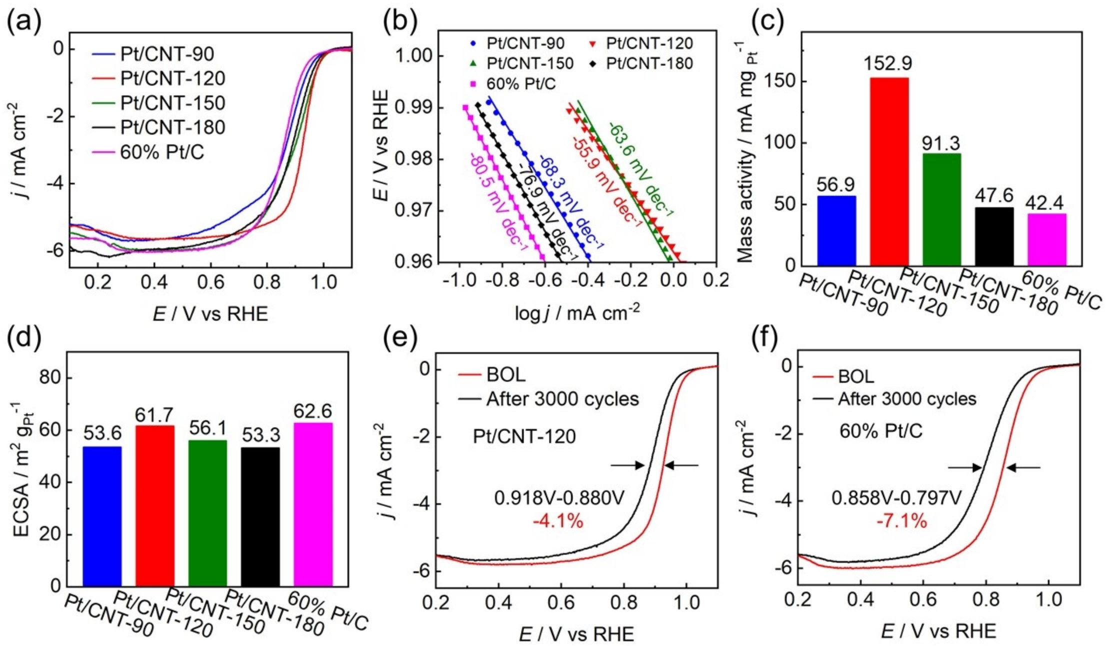


**Fig. S4.** (a) LSV curves, (b) Tafel slopes, (c) Mass activity, and (d) ECSA of different catalysts, respectively. The durability tests of (e) Pt/CNT-120 and (e) commercial 60% Pt/C catalysts in $O_2$-saturated 0.1 M $HClO_4$ before and after 3000 potential cycles.

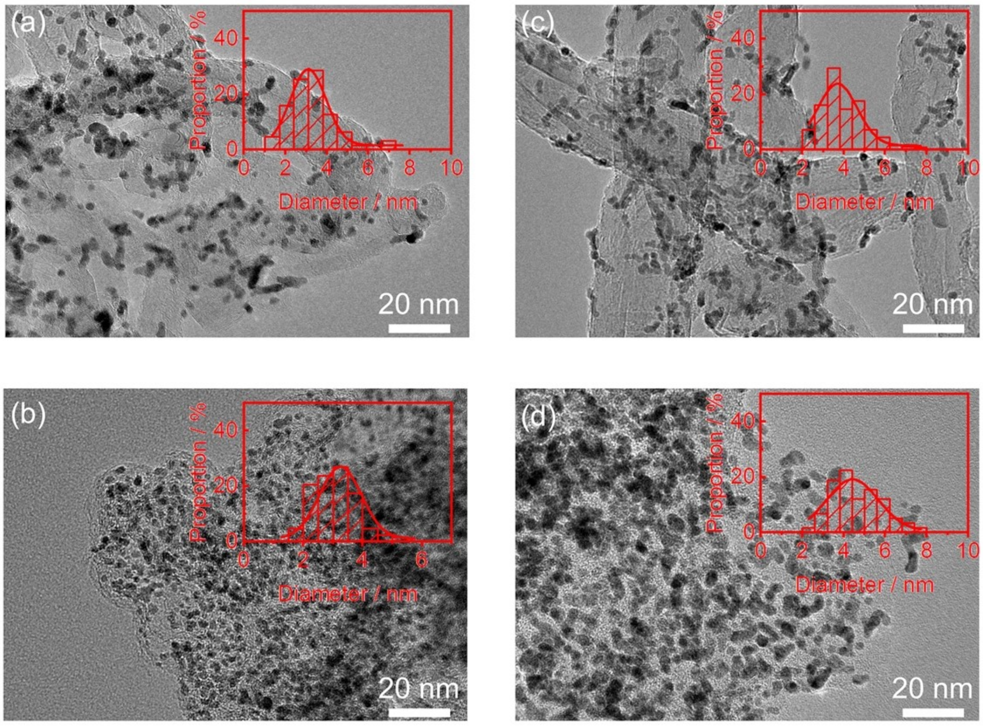


**Fig. S5.** TEM images of different catalysts before and after AST of 10000 potential cycles. (a) and (b) are the Pt/CNT-120 and Pt/C of BOL, (c) and (d) are the corresponding images after AST, respectively.

**Table S1.** The Pt Content of Pt/CNT catalysts by ICP.

| Catalysts | Pt/CNT-90 | Pt/CNT-120 | Pt/CNT-150 | Pt/CNT-180 |
|---|---|---|---|---|
| Pt content (wt.%) | 13.35 | 13.15 | 13.52 | 13.27 |

**Table S2.** The values of $E_{onset}$, $E_{1/2}$ (vs SCE), Tafel slope, Mass activity, and ECSA for various catalysts in 0.1 M $HClO_4$.

| Catalysts | $E_{onset}$ / V | $E_{1/2}$ / V | Tafel slope / mV $dec^{-1}$ | Mass activity / mA $mg_{Pt}^{-1}$ | ECSA / $m^2$ $g_{Pt}^{-1}$ |
|---|---|---|---|---|---|
| Pt/CNT-90 | 1.00 | 0.88 | -63.6 | 56.9 | 53.6 |
| Pt/CNT-120 | 1.02 | 0.92 | -55.9 | 152.9 | 61.7 |
| Pt/CNT-150 | 1.01 | 0.89 | -68.3 | 91.3 | 56.1 |
| Pt/CNT-180 | 1.01 | 0.89 | -76.9 | 47.6 | 53.3 |
| Pt/C | 0.99 | 0.86 | -80.5 | 42.4 | 62.6 |

**Table S3.** Comparisons of the performance and mass PPD based on cathodic/total PGM loading (mass $PPD_{cathode}$ / $PPD_{total}$) in fuel cells.

| Anode PGM loading ($\mu g\ cm^{-2}$) | Cathode PGM loading ($\mu g\ cm^{-2}$) | Membrane | Anode/ cathode gas | Back pressure (kPa) | PPD ($mW\ cm^{-2}$) | Mass $PPD_{cathode}$ ($W\ mg_{PGM}^{-1}$) | Mass $PPD_{total}$ ($W\ mg_{PGM}^{-1}$) | Ref. |
|---|---|---|---|---|---|---|---|---|
| Pt/CNT (50) | Pt/CNT (50) | Gore M788.12 | $H_2/O_2$ | 100 | 1015 | 20.3 | 10.2 | **This work** |
| Pt/CNT (50) | Pt/CNT (50) | Gore M788.12 | $H_2$/Air | 200 | 570 | 11.4 | 5.7 | **This work** |
| Pt/C (200) | Pt/VACNT (50) | Nafion 211 | $H_2/O_2$ | 150 | 1610 | 32.2 | 6.4 | [1] |
| Pt/C (200) | Pt/VACNT (50) | Nafion 211 | $H_2$/Air | 200 | 860 | 17.2 | 3.4 | [1] |
| Pt/Pd NNC (40.6) | Pt/Pd NNC (40.6) | Nafion 211 | $H_2/O_2$ | 200 | 1210 | 29.8 | 14.9 | [2] |
| Pt/C (160) | Pt-Ni nanotube (66) | Nafion 212 | $H_2/O_2$ | 100 | 787 | 11.9 | 3.5 | [3] |
| Pt/C (200) | PtCo/VACNT (65) | Nafion 211 | $H_2/O_2$ | 150 | 1410 | 21.7 | 5.3 | [4] |
| Pt nanocrowns (37.2) | Pt nanocrowns (53.3) | Nafion 211 | $H_2/O_2$ | 200 | 1010 | 19.1 | 11.1 | [5] |
| Pt/C (300) | Pt nanotrough (42) | Nafion 212 | $H_2/O_2$ | 200 | 935 | 22.4 | 2.7 | [6] |
| Pt/C (200) | PtCo NTAs (52.7) | Nafion 212 | $H_2/O_2$ | 200 | 758 | 14.3 | 3.0 | [7] |
| Pt/C (100) | Pt-Tube (77) | Nafion HP | $H_2/O_2$ | 150 | 462 | 6.0 | 2.6 | [8] |
| PtRu/C (60) | PtCo@CNTs-MOF (60) | Nafion HP | $H_2/O_2$ | 100 | 1020 | 17.0 | 8.5 | [9] |
| Pt/C (200) | $Pt_A@Fe_{SA}$-N-C (130) | Nafion 211 | $H_2/O_2$ | 100 | 1310 | 10.1 | 4.2 | [10] |
| Pt/C (101) | PANI nanowires (95) | Nafion 212 | $H_2/O_2$ | No | 542 | 5.7 | 2.8 | [11] |
| PtNi Nanobelt (108.9) | PtNi Nanobelt (108.9) | Gore M740.18 | $H_2$/Air | 200 | 598 | 5.5 | 2.8 | [12] |
| Pt/C (100) | Pt-9.3@NPC (50) | Nafion 211 | $H_2$/Air | 200 | 860 | 17.2 | 5.7 | [13] |
| Pt/C (100) | Pt-Ni BNSs/C (150) | Nafion 212 | $H_2$/Air | 207 | 920 | 6.1 | 3.9 | [14] |

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