Supporting Information

# 3-D Nanoribbon-Like Pt-Free Oxygen Reduction Reaction Electrocatalyst Derived from Waste Leather for Anion Exchange Membrane Fuel Cell and Zinc-Air Battery

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1. **Calculations**: The number of electrons transferred in the ORR process was calculated using the following equations:

   **(a) Koutecky-Levich (K-L) equation**: The electrochemical and hydrodynamic properties of the rotating disk electrode are correlated by the Koutecky-Levich equation.[1] This equation is an important tool to determine the kinetic parameters such as kinetic limiting current ($j_k$) and standard rate constant (k) for the kinetically sluggish reactions. Also, the diffusion coefficient of the species can be measured by Levich treatment in RDE experiments. In this experiment, current values (j) in the limiting region at a particular value (0.5 V *vs*. RHE) are recorded at different rotation speeds in the RDE experiments which are then plotted against the reciprocal of the square root of the rotation speeds. The different parameters are then calculated from the K-L equation. The K-L equation is given below.

$$\frac{1}{j} = \frac{1}{j_k} + \frac{1}{j_l}$$

where,

j = total current

$j_l$ = Diffusion limiting current = $0.62\, nFACD^{2/3}v^{-1/6}\omega^{1/2}$

$j_k$ = $nFAkC$

where, n= number of electrons

F = Faraday constant

C= oxygen concentration

D = diffusion coefficient of oxygen

*v* = kinematic viscosity

$\omega$ = angular velocity

*k* = rate constant

**(b) Rotating Ring Disk Electrode (RRDE) Analysis[2]**: RRDE experiments were conducted to calculate the number of electrons transferred in oxygen reduction by the leather derived catalyst. The experiments were conducted on an electrode with a glassy carbon disk and Pt ring in 0.1 M KOH electrolyte solution at a rotation speed of 1600 rpm using Hg/HgO as the reference and carbon rod as the counter electrodes. The $H_2O_2$ that is formed in the reaction is detected at the ring which helps to determine the reaction mechanism. The current measured at the ring and the disk of the rotating electrode is related to the number of electrons transferred by the following equation.

$$n = \frac{4I_D}{I_D + \frac{I_R}{N}}$$

where, $n$ = number of electron tranfer

$I_D = Disk\ current$

$I_R = Ring\ current$

N = Collection efficiency

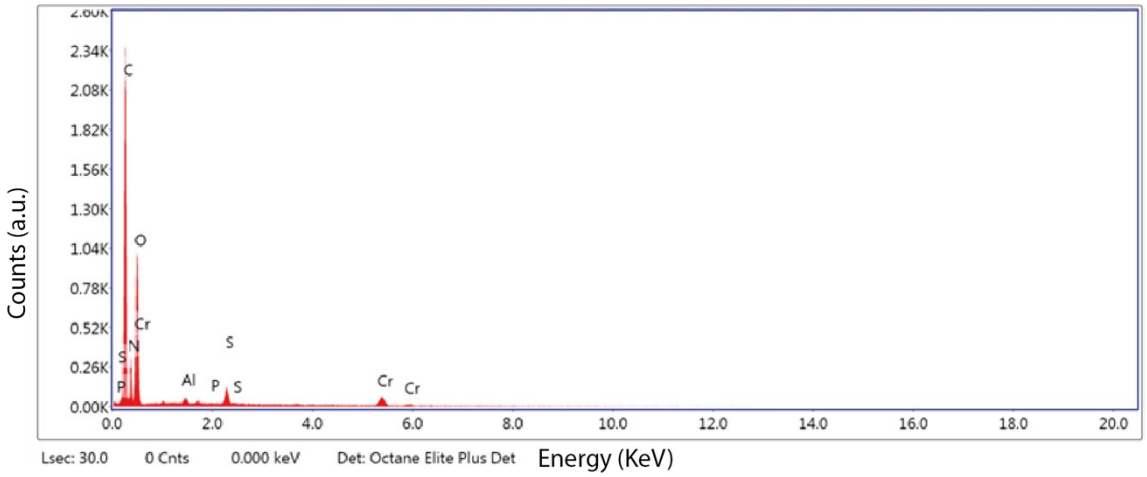


**Fig. S1**. EDAX data of the pristine leather sample.

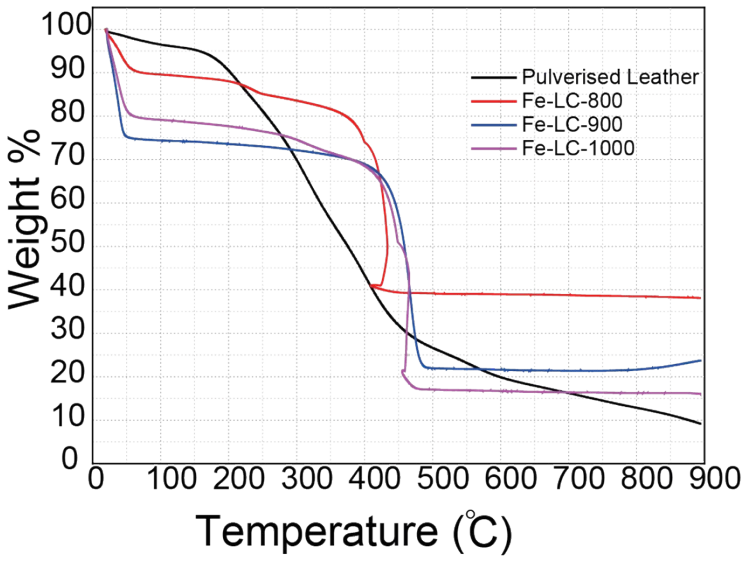


**Fig. S2**. Thermograms recorded for the samples under air atmosphere at a temperature ramp of 10 $^{o}$C min$^{-1}$.

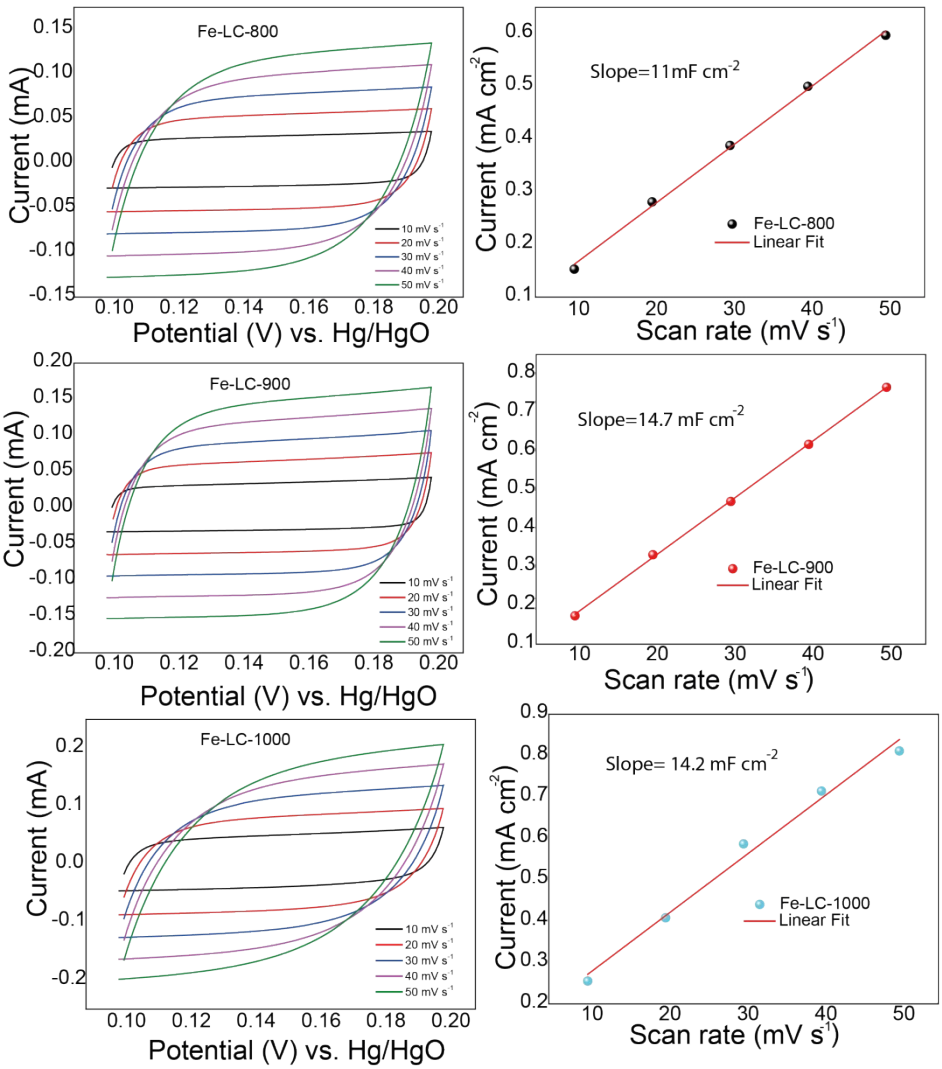


**Fig. S3**. Electrochemical double layer capacitance measurement of the catalysts prepared at different temperatures.

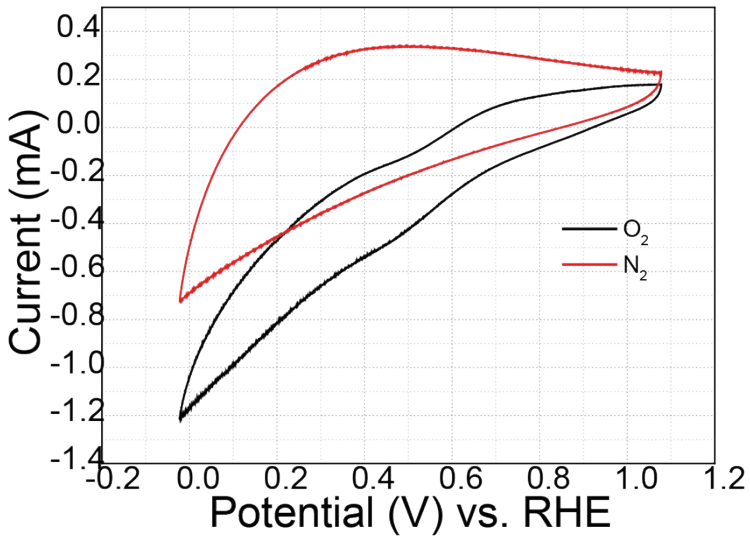

**Fig. S4**. Cyclic voltammograms recorded for the carbon derived from the pulverised leather sample prepared at 900 °C.

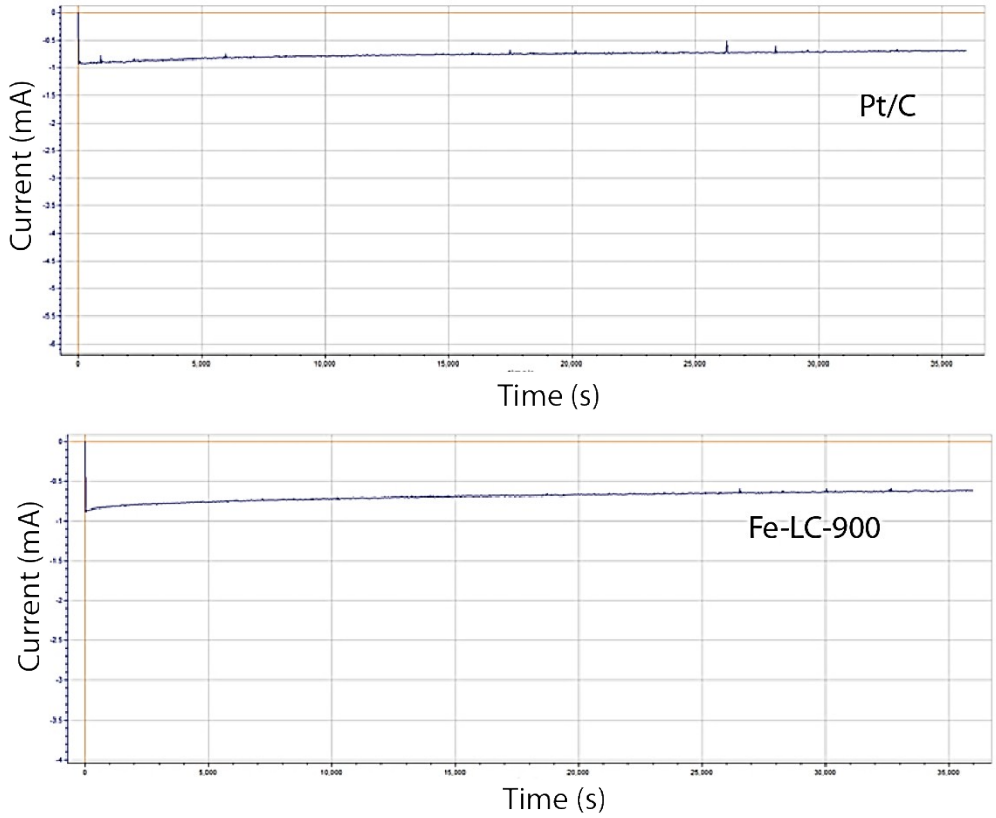


**Fig. S5**. Chronoamperometry plots recorded for a) Pt/C and b) Fe-LC-900.

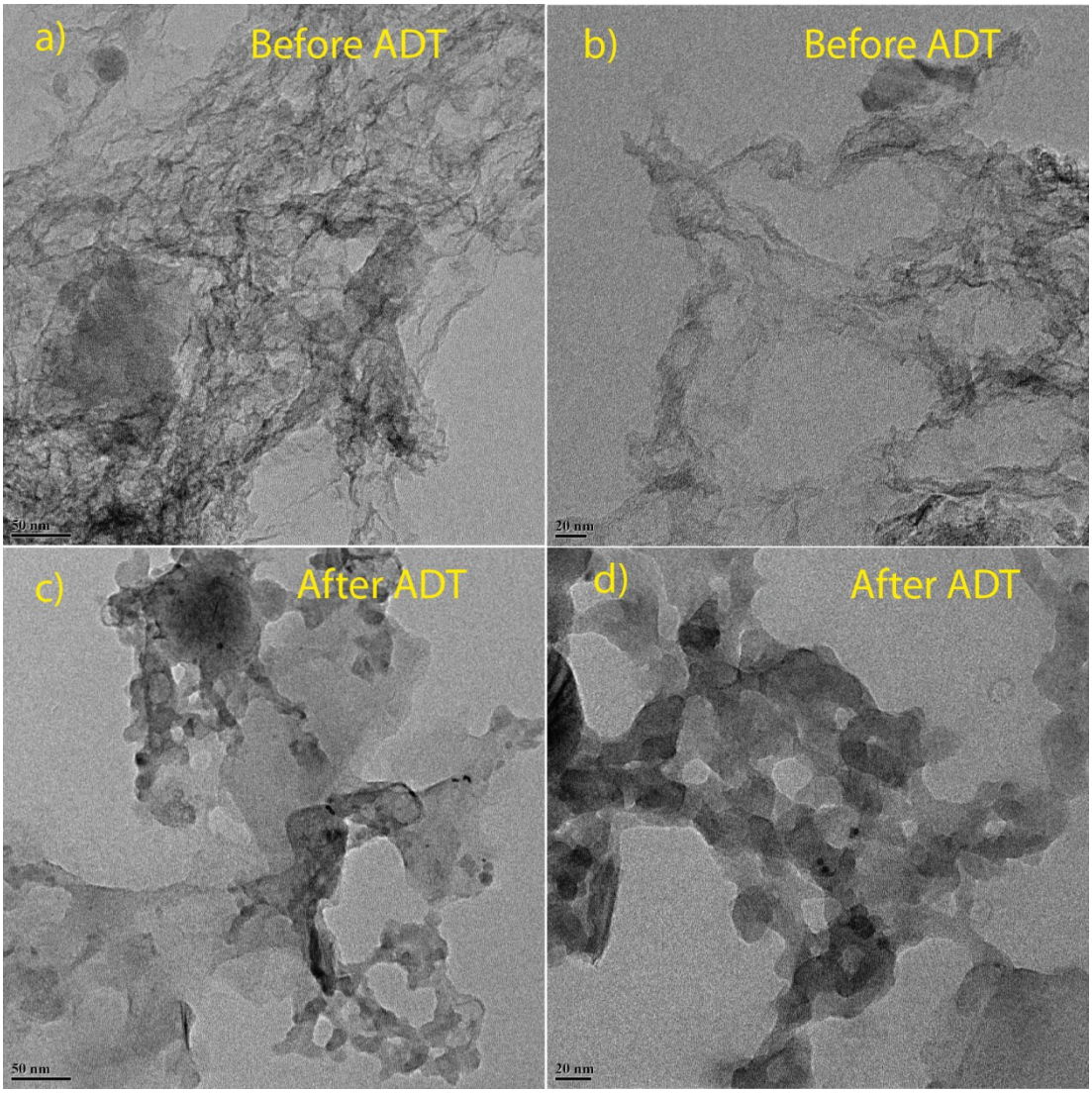


**Fig. S6**. Morphological changes after cycling of Fe-LC-900: a) and b) show the TEM images of Fe-LC-900 before ADT; c) and d) are the TEM images recorded after the ADT (5000 cycles) of Fe-LC-900.

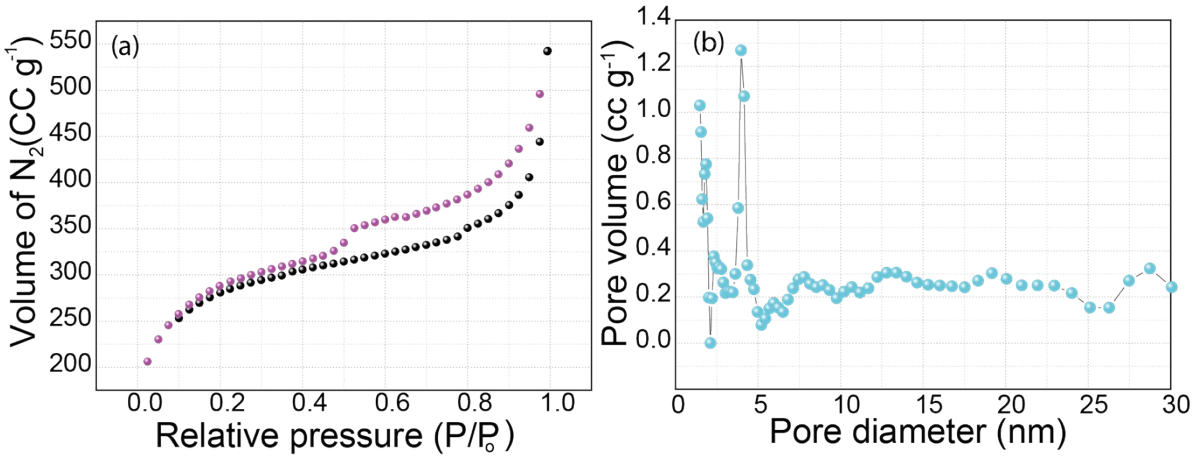

**Fig. S7**. BET analysis of Fe-LC-900: (a) adsorption isotherm and (b) pore size distribution profile.

**Table S1**. The percentage content of the elements present in the leather derived catalysts.

| Catalyst | Carbon % | Oxygen % | Nitrogen % | Sulphur % | Iron % |
|---|---|---|---|---|---|
| **Fe-LC-800** | 77.96 | 16 | 2.92 | 2.61 | 0.29 |
| **Fe-LC-900** | 81.09 | 15.85 | 2.80 | 0.69 | 0.04 |
| **Fe-LC-1000** | 85.17 | 11.62 | 1.64 | 1.50 | 0.0 |

**Table S2**. Percentage composition of the different types of nitrogen present in the catalysts prepared at different temperatures.

| Catalyst | Pyridinic N % | Pyrrolic N % | Graphitic N % | N-oxide % |
|---|---|---|---|---|
| **Fe-LC-800** | 13.65 | 63.47 | - | 22.88 |
| **Fe-LC-900** | 10.63 | 66.17 | - | 23.20 |
| **Fe-LC-1000** | 10.06 | - | 89.94 | - |

**References**


1. A. Bard and L. Faulkner, *Electrochemical Methods: Fundamentals and Applications*, John Wiley & Sons, Inc, 2001.
2. X. Ge, A. Sumboja, D. Wuu, T. An, B. Li, F. W. T. Goh, T. S. A. Hor, Y. Zong and Z. Liu, *ACS Catalysis*, 2015, **5**, 4643-4667.