**SUPPLEMENTRY INFORMATION**

**Synthesis and characterization cobalt phosphate embedded with N doped carbon for water splitting ORR and OER**

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1. **Characterizations**

The chemical of the nanocomposites was carried out using elemental analysis Perkin-Elmer -2000 elemental analyzer, Fourier transform infrared spectroscopy (FTIR) analysis was carried out KBr powder on a Bruker Tensor 27 FTIR spectrophotometer. The morphology and particles sizes details of Co3(PO4)2-NC were determined using the [field emission scanning electron microscopy](https://www.sciencedirect.com/topics/chemistry/field-emission-scanning-electron-microscopy) (FESEM, JEOL JSM 7600F) and [transmission electron microscopy](https://www.sciencedirect.com/topics/chemistry/transmission-electron-microscopy) (FE-TEM, JEM-2100F, JEOL). [X-ray diffraction](https://www.sciencedirect.com/topics/physics-and-astronomy/x-ray-diffraction) (XRD) analysis was carried out on a PANalytical X′pert PRO X-ray [diffractometer](https://www.sciencedirect.com/topics/physics-and-astronomy/diffractometers). [Specific surface area](https://www.sciencedirect.com/topics/chemistry/specific-surface-area) was calculated using Brunauer–Emmett–Teller (BET) method and the [pore size distribution](https://www.sciencedirect.com/topics/chemistry/pore-size-distribution) plot was derived based on the Barrett–Joyner–Halenda (BJH) method. XPS analyses were performed using a Kratos Axis Ultra DLD electron [spectrometer](https://www.sciencedirect.com/topics/physics-and-astronomy/spectrometers) (PHI, PHI5300 system). [Raman spectra](https://www.sciencedirect.com/topics/chemistry/raman-spectrum) were acquired on a RENISHAW in via instrument with an Ar laser source of 488 nm in a macroscopic configuration. Elemental analysis of Co was carried out by inductively coupled plasma-optical emission spectrometry (ICP-OES, Optima 7300D). Samples were prepared for ICP-OES analysis according to U.S. EPA Method 3015A, 167 “Microwave Assisted Acid Digestion of Aqueous Samples and Extracts” (U.S. EPA, 2007).

1. **Electrochemical Measurements**

**2.1 Cyclic voltammetry (CV)**

5 mg of catalyst and 30μl of nafion (5 wt% ethanol solution) were dispersed in 1 ml of propanol by at least 30 min sonication to form a homogeneous ink. Then 2.4 μl of the catalyst ink (containing 12 μg of catalyst) was loaded onto a glassy carbon electrode of 3 mm in diameter (loading ~ 0.17 mg/cm2). Electrochemical impedance spectroscopy (EIS) and Cyclic voltammetry (using the pontentiostat from CH660 Instruments) was conducted in a electrochemical cell using Ag/AgCl as the reference electrode, a platinum as the counter electrode and the glassy carbon electrode as the working electrode. Electrolyte was saturated with oxygen and nitrogen by bubbling of O2 prior to the start of each experiment. A flow of O2was maintained over the electrolyte during the recording of CVs in order to ensure its continued O2. The working electrode was cycled at least 5 times before data were recorded at a scan rate of 10mVs−1.

**2.2 Rotating disk electrode (RDE) measurement.**

For the RDE measurements, catalyst inks were prepared by the same method as CV’s. the ink was loaded on a glassy carbon rotating disk electrode of 5 mm in diameter (ALS Instruments+CHI600). The working electrode was scanned cathodically at a rate of 10 mVs−1 with varying rotating speed from 225 rpm to 2500 rpm. Koutecky–Levich plots (*J*-1 vs. ω-1/2) were analyzed at various electrode potentials. The slopes of their best linear fit lines were used to calculate the number of electrons transferred (*n*) on the basis of the Koutecky-Levich equation (R):

**Where:-**

*J* : current density, *A.cm–2, JK* : kinetic current density, *A.cm–2, J*L: diffusion-limiting current densities, *A.cm–2*, *F*: Faraday’s constant, 96485, C.mol–1 , *Do*: diffusion coefficient of O2 in 0.1 M KOH (1.93×10–5, cm2*.*s–1) (R), *ν*: kinematic viscosity of the electrolyte, 0.1 M KOH, (1.09×10–2, cm2s–1), *Co*: saturation concentration of O2 in 0.1 M KOH at 1 atm O2 pressure,1.26×10–6 , mol.cm–3), *ω*: rotation rate, rad.s–1

For the Tafel plot, the kinetic current was calculated from the mass-transport correction of RDE by:



Supplementary Figure SF-1. Schematic diagram of the synthesis of Co3(PO4)2-NC nanocomposite



Supporting Figure SF-2:  FTIR spectra of Co3(PO4)2-NC



Supporting Figure SF-3:  XPS spectra of N1s



Supporting Figure SF-4: XPS spectra of (a) O1s and (b) P 2p



Supporting Figure SF-5: electrochemical impedance spectroscopy (EIS) of Co3(PO4)2

and Co3(PO4)2-NC

**Supplementary Tables**

***Supplementary Table 2.*** Comparison of the ORR electrocatalytic activity of Co3(PO4)2-NC with some newly reported electrocatalysts.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Catalysts** | **Loading**  **(mg cm-2)** | **Onset potential (V)** | **Half wave potential (V)** | **CV peak potential** | **n** | **References** |
| **Co3(PO4)2-NC** | **0.18** | **0.964** | **0.831** | **0.834** | **3.99** | **This work** |
| PANI-Fe-C | 0.6 | 0.91 | 0.81 | N/A | 4 | *Science***2011**,332,443 |
| PANI-Co-C | 0.6 | 0.80 | 0.75 | N/A | N/A | *Science***2011**,332,443 |
| CNT/grapheme  hybrid | 0.49 | 0.89 | 0.76 | 0.75 | 4 | *Nat. Nanotech.*  **2012**,7,394 |
| Co3O4/rmGO | 0.17 | 0.88 | 0.79 | 0.83 | 3.9 | *Nat.Mater.***2011**,10,780 |
| MesoporousN-doped carbon | 0.1 | 0.978 | 0.85 | 0.83 | 3.97 | *Nat.Commun.*  **2014**,5,5974 |
| NCNT/carbon nanoparticle | 1 | 1.08 | 0.87 | N/A | 3.92 | *Nat.Commun*.**2013**,4,1922 |
| FeNx/C catalyst | 0.6 | 0.94 | 0.82 | N/A | N/A | *J.Am. Chem.*  *Soc.***2014**,136,  10882 |
| CNTs/carbon  hybrid | 0.6 | 0.92 | 0.82 | N/A | 3.8 | *Angew. Chem.*  *Int.Ed.***2014**,53,4102 |
| Graphene/Co3O4 | 0.6 | 0.95 | N/A | N/A | 3.9 | *Angew. Chem.*  *Int.Ed.***2013**,52,  12105 |
| N-doped  graphene/metals | 0.6 | 0.94 | N/A | 0.67 | 3.95 | *Angew. Chem.*  *Int.Ed.***2014**,53,1570 |
| Fe−N/C-800 | 0.1 | 0.92 | 0.80 | 0.85 | 3.96 | *J. Am. Chem.*  *Soc.***2014**,136,1102 |
| N-doped carbon  frameworks | 0.1 | 0.79 | 0.79 | N/A | 3.95 | J.Am. Chem.  Soc.**2013**,135,  16002 |
| graphene-MOF  composite | 0.16 | 0.91 | N/A | 0.74 | 3.82 | *J.Am. Chem.*  *Soc.***2012**,134,  6707 |
| MOF-derived  carbons | 0.2 | 0.9 | N/A | 0.77 | 3.61 | *Angew. Chem.*  *Int.Ed.***2014**,53,2433 |
| VNCNTarrays | N/A | N/A | N/A | 0.77 | 3.9 | *Science***2009**,  323,760 |
| Fe–N–CNTs–  OPC | N/A | N/A | N/A | 0.74 | 3.99 | *Adv.Mater.* **2014**,26,6074 |
| ZIF-derived  porouscarbons | 0.4 | 0.9 | 0.76 | N/A | 3.9 | *Adv.Mater.* **2014**,26,1093 |
| ZIF-derived  porous  carbon/graphene | 0.2 | 0.95 | N/A | 0.82 | 3.98 | *Angew. Chem.*  *Int.Ed.***2014**,  53,14235 |
| P-doped  graphene | 0.42 | 0.91 | N/A | 0.58 | 3.8 | *Adv.Mater.* **2013**,25,4932 |
| ZIF8-Te-1000 | 0.1 | 0.75 | 0.83 | 0.77 | 3.6 | *J.Am. Chem.*  *Soc.***2014**,136,  14385 |
| P-doped ZIF8-  derived carbons | 0.1 | 0.9 | 0.71 | 0.77 | 4.0 | *J.Am. Chem.*  *Soc.***2014**,136,  14385 |
| ZIF-derived  porouscarbons | 0.1 | 0.83 | N/A | 0.68 | 3.3 | *J.Am. Chem.*  *Soc.***2014**,136,  6790 |
| P-doped ordered  mesoporous carbon | 0.3 | 0.92 | 0.82 | 0.72 | 3.5 | *Angew. Chem.*  *Int.Ed.***2015**,  54,9230 |
| N,P-codoped  ordered  mesoporous  carbon | 0.3 | 0.95 | 0.82 | 0.73 | 3.7 | *Angew. Chem.*  *Int.Ed.***2015**,  54,9230 |
| N/Co-doped  PCP//NRGO | 0.714 | 0.97 | 0.86 | 0.82 | 3.9 | *Adv.Funct. Mater.*  **2015***,25,*872 |
| N/Co-doped PCP-  RGO | 0.714 | 0.94 | N/A | 0.80 | 3.3 | *Adv.Funct. Mater.***2015***,25,*872 |
| Co/N-carbon  fibres | 0.306 | 0.95 | N/A | 0.85 | 3.9 | *Chem. Eur. J.*  **2015***,21,*2165 |
| N-Carbon  nanotube  frameworks | 0.2 | 0.97 | 0.87 | 0.87 | 3.97 | *Nature energy,****2016,*** *1,1.* |

***SupplementaryTable 2.*** Comparison of the OER electrocatalytic activity of Co3(PO4)2-NC with some newly reported electrocatalysts.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Catalysts** | **Loading**  **(mgcm-2)** | **Potential (V)**  **@1mAcm-2** | **Potential (V)**  **@10mAcm-2** | **References** |
| Co3(PO4)2-NC | **0. 2** | **-** | **1.61 V** | **This work** |
| Mn3O4/CoSe2  hybrids | 0.2 | 1.56 | 1.68V | *J.Am. Chem.Soc.*  **2012**,134,2930 |
| N-doped carbon/NiOx | 0.2 | 1.52 | 1.61V | *Nat.Commun.*  **2013**,4,2390 |
| [NiCo2S4@N](mailto:NiCo2S4@N)/S- rGO | .283 |  | 1.70 | *ACS Appl.Mater.*  *Inter.* **2013**, 5, 5002 |
| Crumpled graphene/CoO | 0.36 | N/A | 1.65V | *Energy Environ.*  *Sci.***2014**, 7, 609 |
| CaMn4Ox | 0.6 | N/A | 1.77 V | *J.Am. Chem.Soc.***2010**,132,13612 |
| MnxOy/NC | 0.21 | N/A | 1.66 V | *Angew. Chem. Int.Ed.***2014**,53,8508 |
| NixOy/NC | 0.21 | N/A | 1.64 V | *Angew. Chem. Int.Ed.***2014**,53,8508 |
| MnxOy/NC | 0.21 | N/A | 1.68 V | *Angew. Chem. Int.Ed.***2014**,53,8508 |
| N/Co-doped MOF derived carbon /NRGO | 0.36 | N/A | 1.66 | *Adv.Funct. Mater.***2015**,25, 872 |