# Electronic Supplementary Information (ESI)

## $CoO_x(OH)_y$/C nanocomposites *in situ* derived from $Na_4Co_3(PO_4)_2P_2O_7$ as sustainable electrocatalysts for water splitting

Ievgen V. Odynets,[a] Nataliia Yu. Strutynska,[b] Junzhi Li,[a] Wei Han,[a,c] Igor V. Zatovsky*[a] and N.I. Klyui*[a,d]

[a] Jilin Supercapacitor Engineering Laboratory, College of Physics, Jilin University, 2699 Qianjin str., 130012 Changchun, P.R. China.

[b] Taras Shevchenko National University, 64/13 Volodymyrska str., 01601 Kyiv, Ukraine

[c] International Center of Future Science, Jilin University, Changchun City 130012, PR China

[d] V. Lashkaryov Institute of Semiconductor Physics, NAS of Ukraine, 41 pr. Nauki, 03028 Kyiv, Ukraine

E-mail: klyuini@ukr.net (N.I. Klyui*); zvigo@yndex.ru (Igor. V. Zatovsky*)

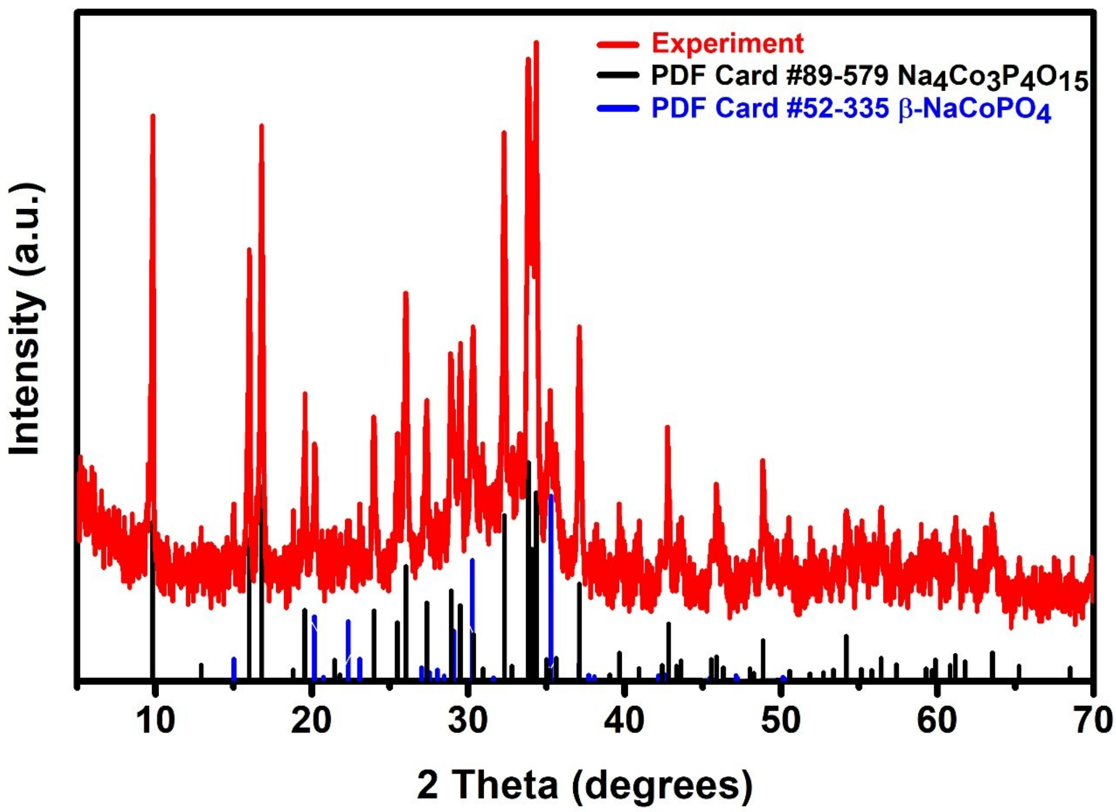


**Fig. S1**. Powder XRD pattern of **GC** at 600 $^{o}$C heated during 3 hours.

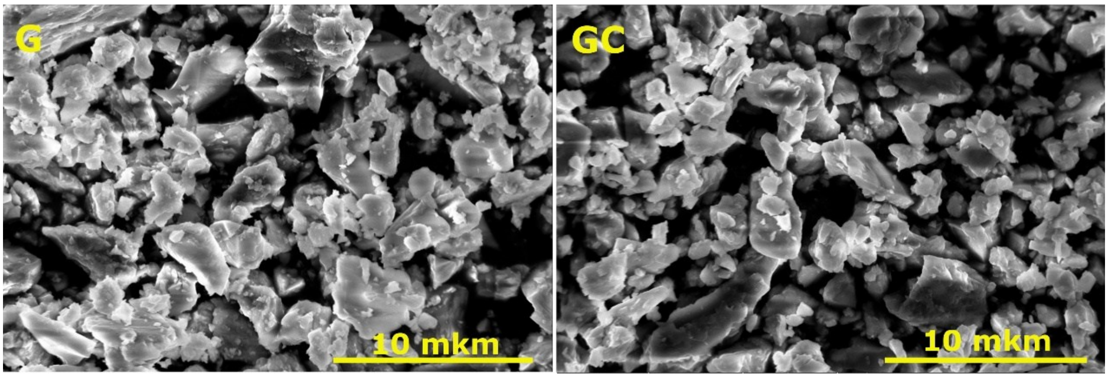


**Fig. S2**. SEM image of **G** and **GC** after milling.

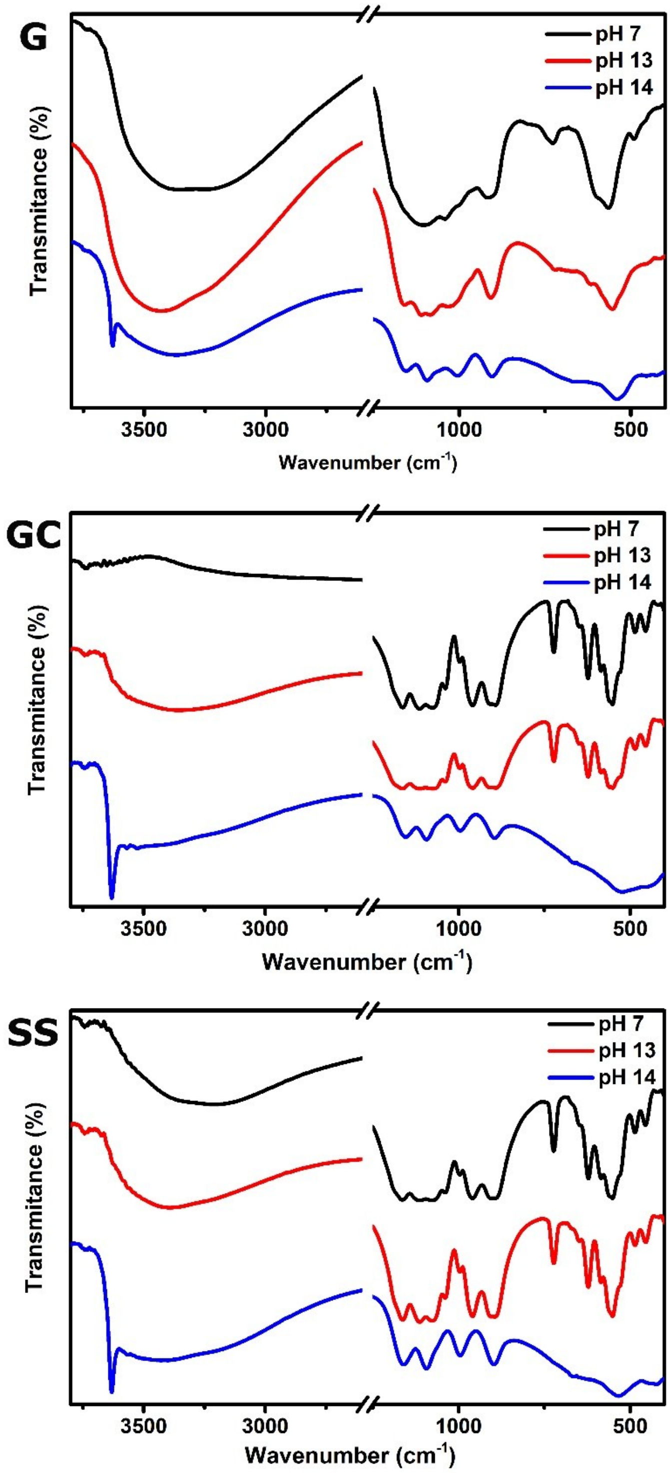


**Fig. S3**. FTIR spectra of **G**, **GC** and **SS** after chemical treatment in different solution (pH 7, 13, 14).

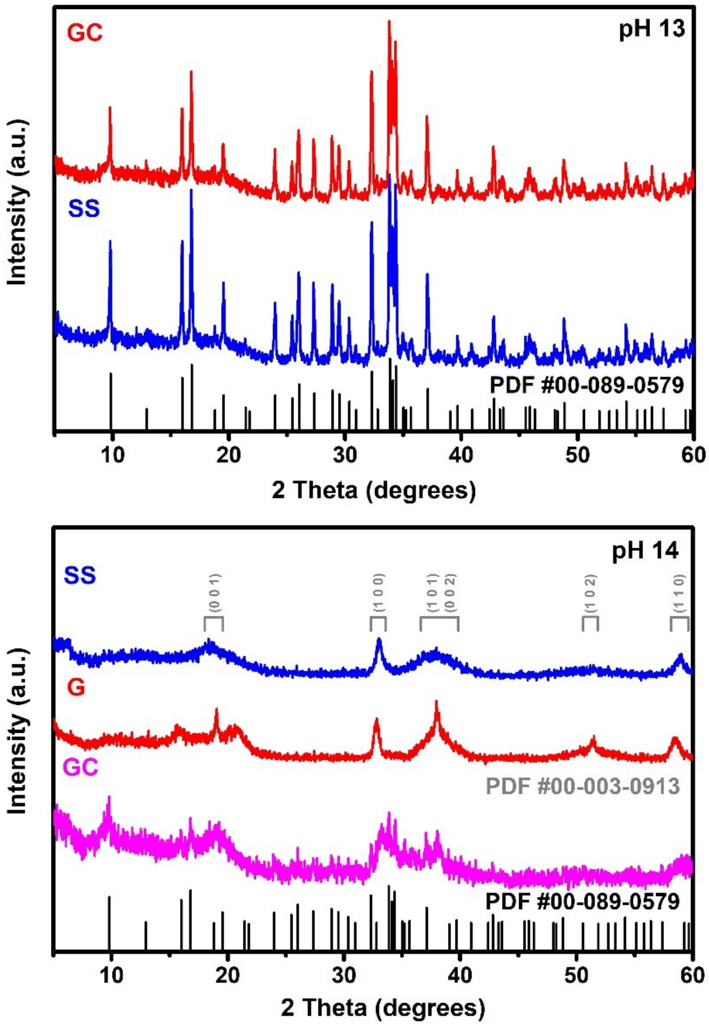


**Fig. S4**. Powder XRD pattern of **G**, **GC** and **SS** after chemical treatment in different solution (pH 13 and 14). PDF #00-089-0579 – $Na_4Co_3P_4O_{15}$; PDF #00-003-0913 -β-$Co(OH)_2$.


**Fig. S5**. Photo of the **G**, **GC** and **SS** powders after chemical treatment in different solution (pH 7, 13, 14).

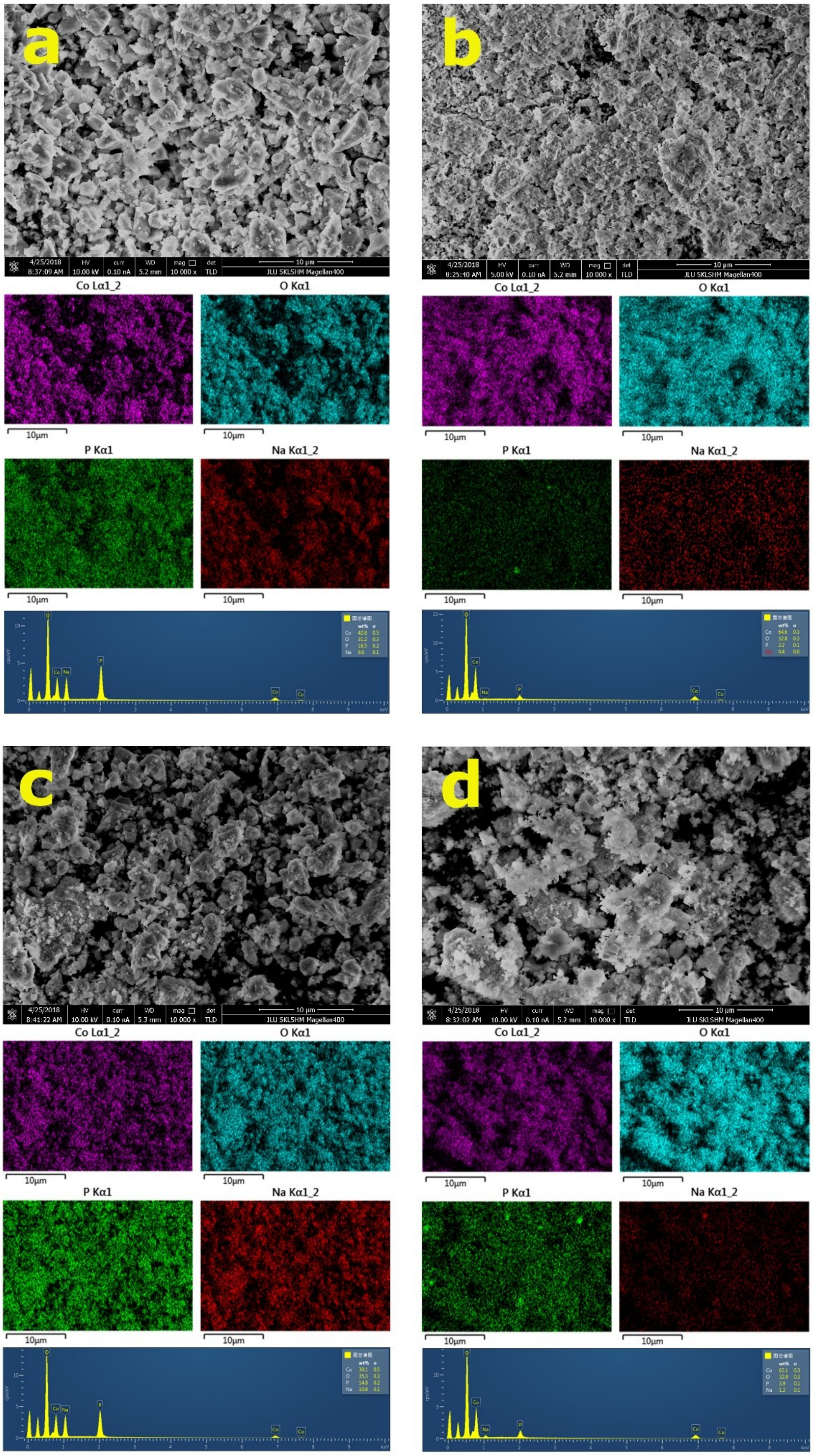


**Fig. S6.** SEM image, EDS and elemental mapping of composite with polycrystalline sample (**SS**) after chemical treatment in base solution pH 13 (a) and 14 (b), SEM image, EDS and elemental mapping of composite with polycrystalline sample (**GC**) after chemical treatment in base solution pH 13 (c) and 14 (d).

**Table S1.** XPS data of $Na_4Co_3P_4O_{15}$ (sample **SS)**: as-prepared, after OER and HER test.

| Sample | $Co^{2+}$ | | $Co^{3+}$ | | $O^{2-}$ | $P^{5+}$ | $Na^{+}$ | $C^{4+}$ |
|---|---|---|---|---|---|---|---|---|
| | 2p $_{3/2}$ | 2p $_{1/2}$ | 2p $_{3/2}$ | 2p $_{1/2}$ | 1s | 2p | 1s | 1s |
| As-prepared | 781.9 eV<br>(785.2 eV<br>satellite) | 797.9 eV<br>(803.0 eV<br>satellite) | - | - | 530.9 eV<br>531.8 eV<br>535.7 eV | 133.3 eV | 1071.9<br>eV | 284.8 eV |
| After OER | 780.7 eV<br>(790.3 eV<br>satellite) | 796.5 eV<br>(805.2 eV<br>satellite) | 779.9 eV | 794.9 eV | 529.5 eV<br>531.0 eV<br>531.9 eV | - | 1071.0<br>eV | 284.6 eV<br>284.9 eV<br>287.9 eV<br>290.9 eV |
| After HER | 780.9 eV<br>(790.2 eV<br>satellite) | 795.6 eV<br>(804.3 eV<br>satellite) | 779.9 eV | 794.9 | 529.7 eV<br>531.0 eV<br>532.3 eV | - | 1070.5<br>eV | 283.0 eV<br>284.5 eV<br>285.2 eV<br>288.2 eV<br>290.4 eV |

(a)

(b)

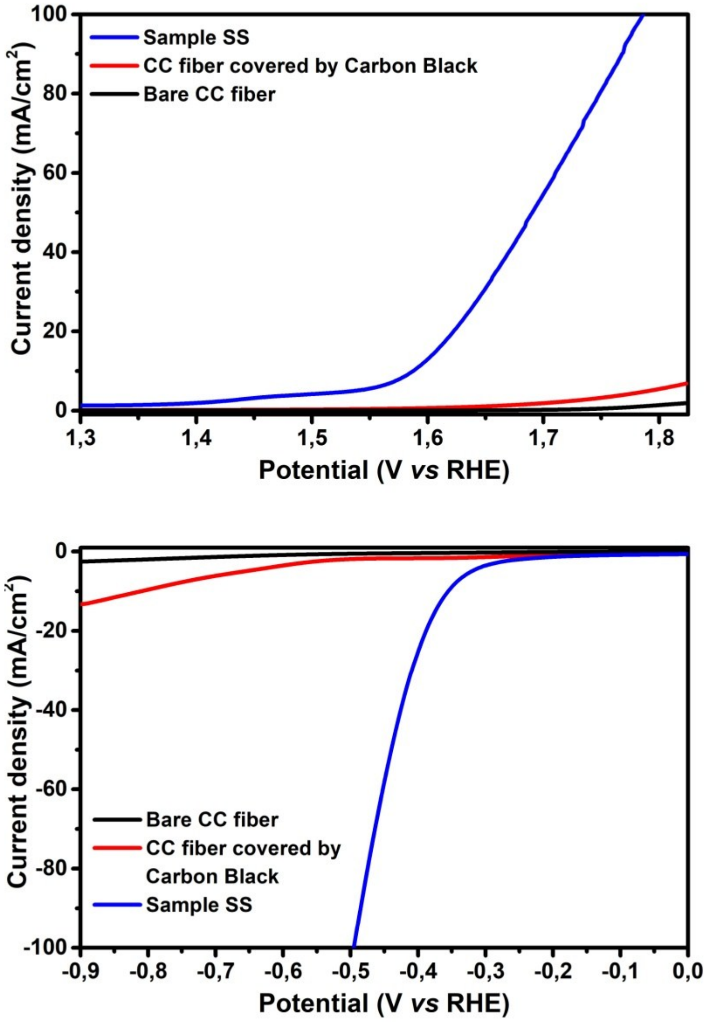


**Fig. S7**. LSV curves for carbon fiber, carbon fiber with carbon black and **SS** at a scan rate of 1 $mV \cdot s^{-1}$ in a 1M NaOH solution: (a) for OER process; (b) for HER process.

| Parameters | Pristine | Before chronopotentiometry | After chronopotentiometry |
|---|---|---|---|
| L x$10^{-6}$ (H·cm$^{-2}$) | 1.491 | 1.56 | 4.26x$10^{-16}$ |
| $R_s$ (Ω·cm$^{-2}$) | 1.503 | 1.535 | 1.649 |
| $Y_o$ (S·sec$^n$·cm$^{-2}$) | 0.006781 | 0.2372 | 5.147x$10^{20}$ |
| Freq power, n (0<n<1) | 0.8827 | 0.5875 | 0.542 |
| CPE x$10^3$ (F·cm$^{-2}$) | 5.917 | 18.44 | 3994x$10^5$ |
| $R_{ct}$ (Ω·cm$^{-2}$) | 0.1289 | 3.201 | 7.024x$10^{10}$ |

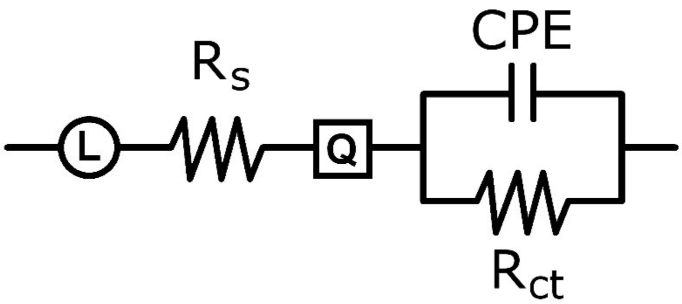


**Fig. S8**. The equivalent circuit for fitting the AC impedance results after OER.

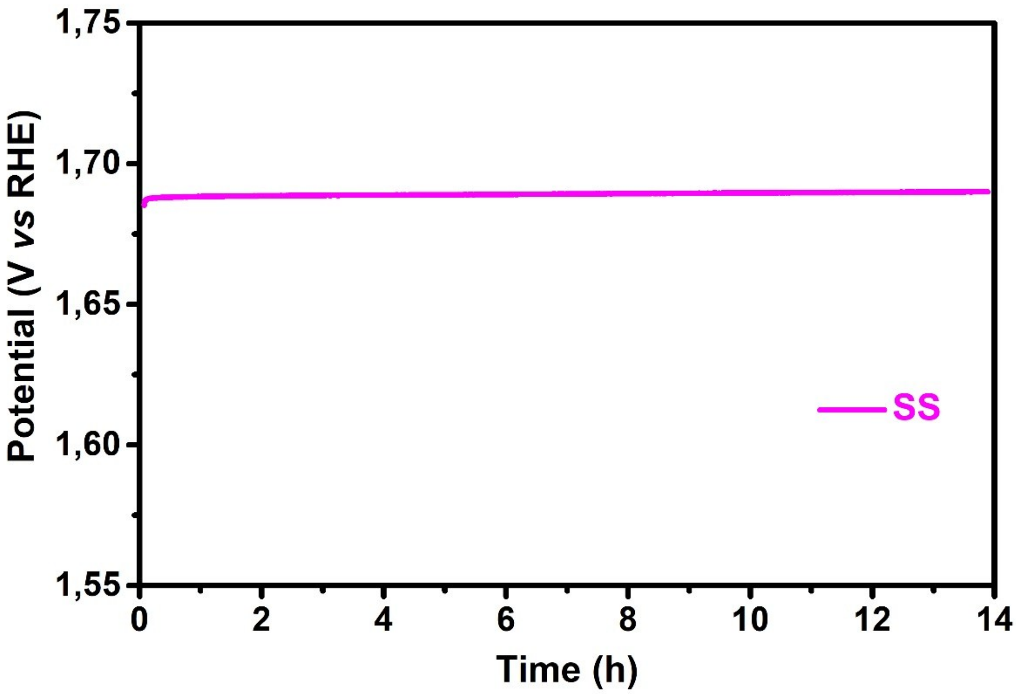


**Fig. S9**. Time dependencies of potential under a constant current density of 20 mA·cm$^{-2}$ for **SS**, second measurement, OER test.

| Parameters | Before chronopotentiometry | After chronopotentiometry |
|---|---|---|
| $R_s$ ($\Omega\cdot cm^{-2}$) | 2.915 | 2.849 |
| CPE $x10^3$ ($F\cdot cm^{-2}$) | 2.729 | 3.817 |
| $R_{ct}$ ($\Omega\cdot cm^{-2}$) | 36.11 | 1606 |
| $Y_o$ $x10^3$ ($\Omega^{-1}\cdot cm^{-2}\cdot S^{0.5}$) | 33.44 | 2.459 |

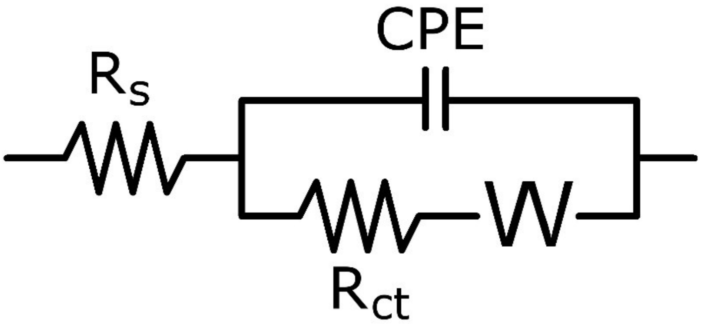


**Fig S10**. The equivalent circuit for fitting the AC impedance results after HER.

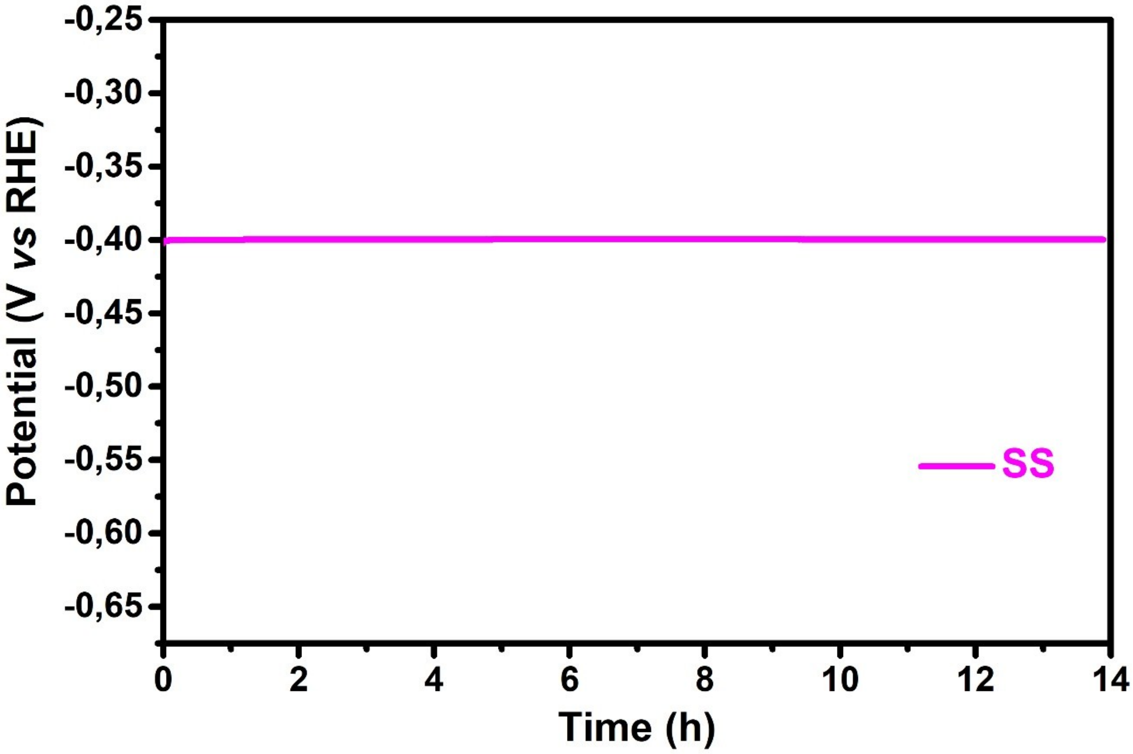


**Fig. S11**. Time dependencies of potential under a constant current density of 20 mA·$cm^{-2}$ for **SS**, second measurement, HER test.