Supporting Information

$NiSe_2$ Pyramids Deposited on N-doped Graphene Encapsulated Ni Foam for High-Performance Water Oxidation

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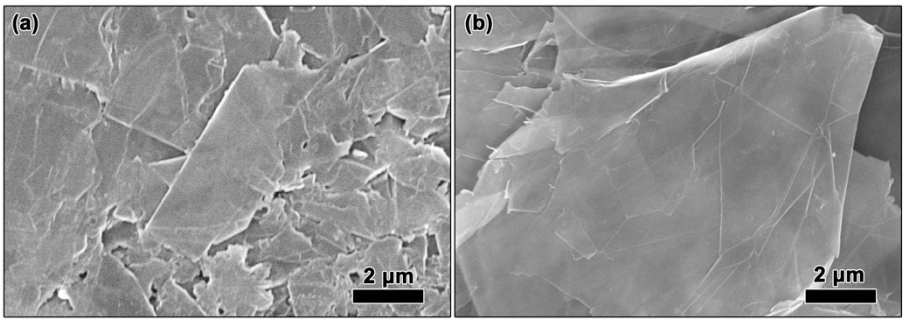

Fig. S1 SEM images of initial graphite (a) and exfoliated graphene (b).

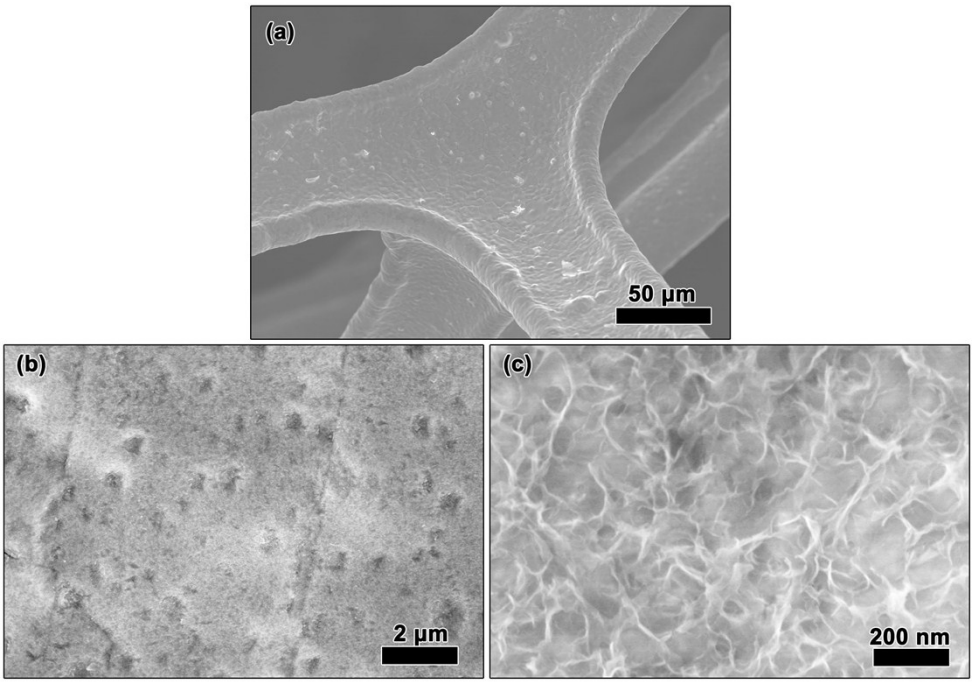

Fig. S2 SEM images of N-doped graphene encapsulated Ni foam.

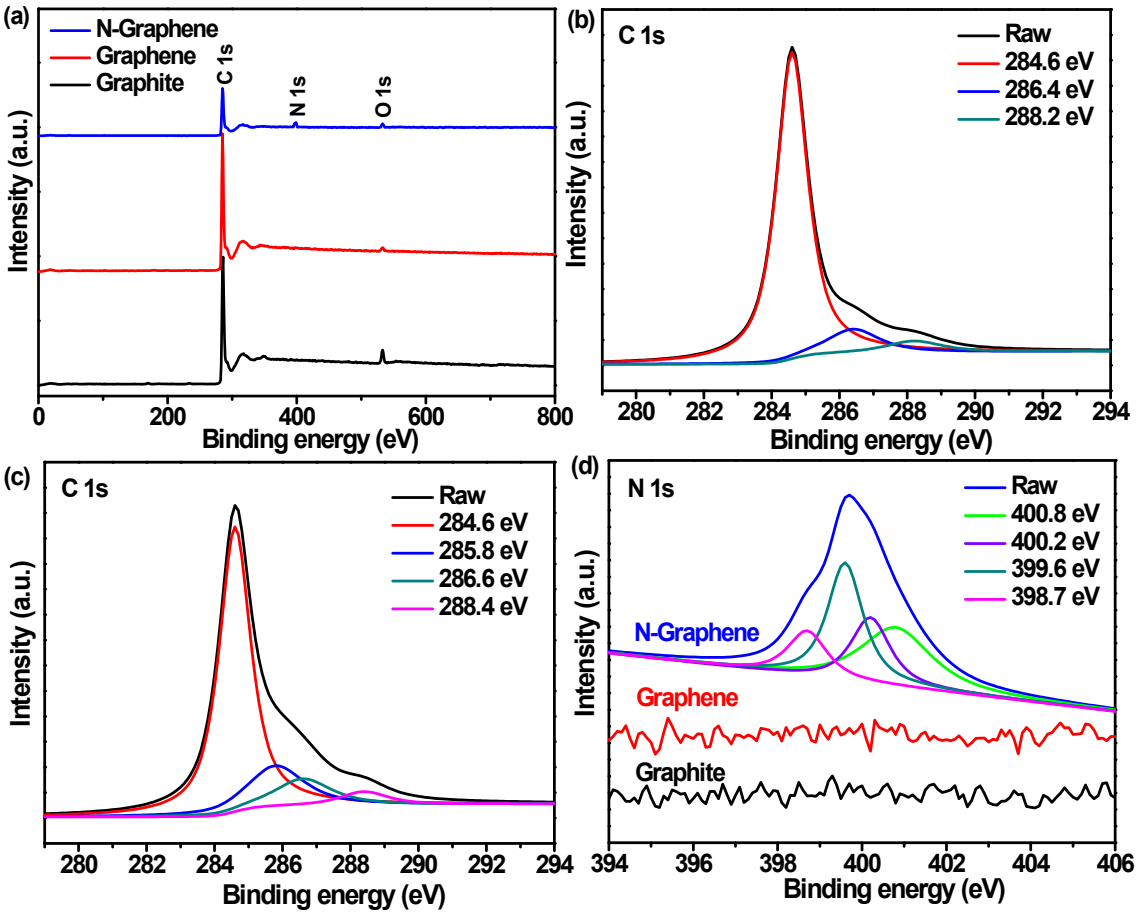

Fig. S3 (a) XPS survey spectra of natural graphite, exfoliated graphene and N doped graphene. (b) C 1s of exfoliated graphene, (c) C 1s of N doped graphene, (d) N 1s of N doped graphene.

The high-resolution C 1s spectra of graphene N doped graphene are compared in Fig. S3b and c. The three peaks at 284.6, 286.4 and 288.2 eV can be ascribed to sp^2 hybridized C atoms, C–O and C=O configurations, respectively. The emerging peak at 285.8 in N doped graphene reveals the appearance of new C–N bond. The survey spectra in Fig. S3a clearly prove the presence of N 1s in N-graphene. Furthermore, the N 1s spectrum can be fitted to four peaks, including pyridinic N (398.7 eV), C-N-C (399.6 eV), pyrrolic N (400.2 eV), and graphitic N (400.8 eV). The results suggest the successful introducation of N element into graphene.

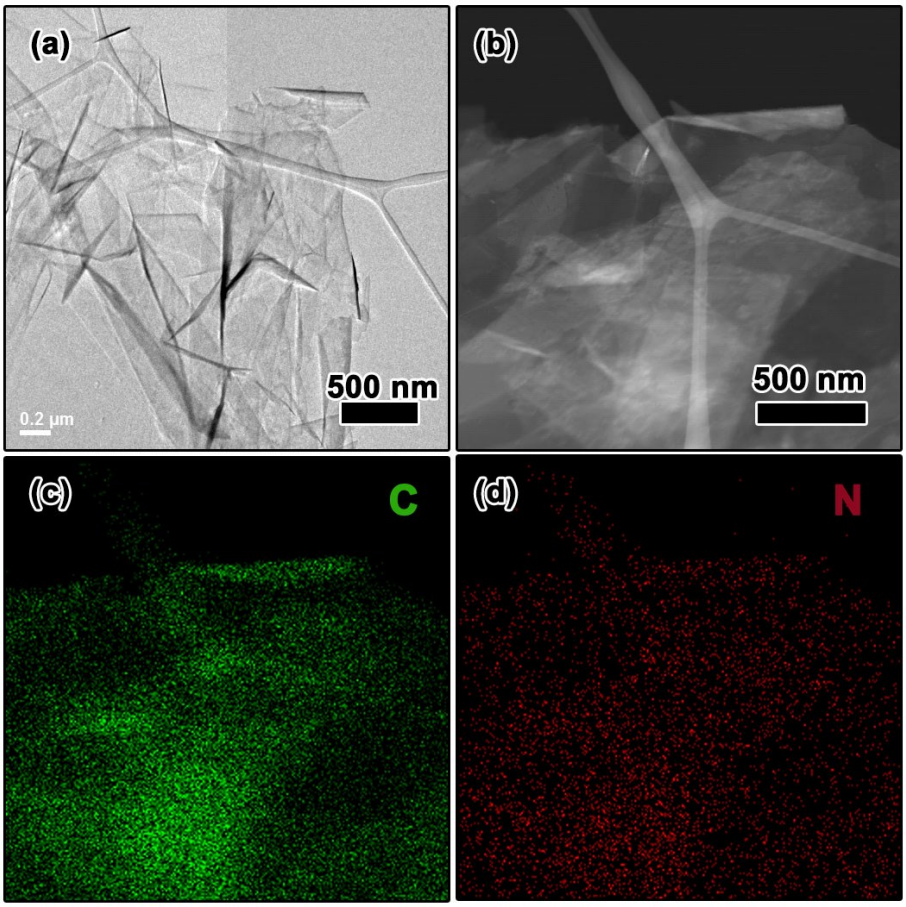

Fig. S4 TEM image (a), STEM image (b) and EDX mappings of N doped graphene (c, d).

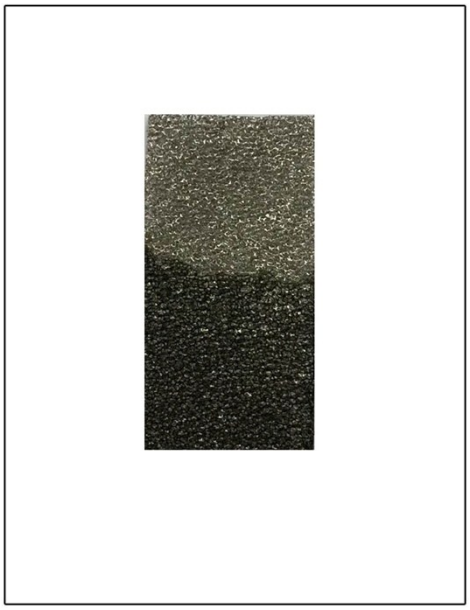

Fig. S5 Optical photograph of the deposited NG/$NiSe_2$/NF electrode on the surface of N-doped graphene encapsulated Ni foam.

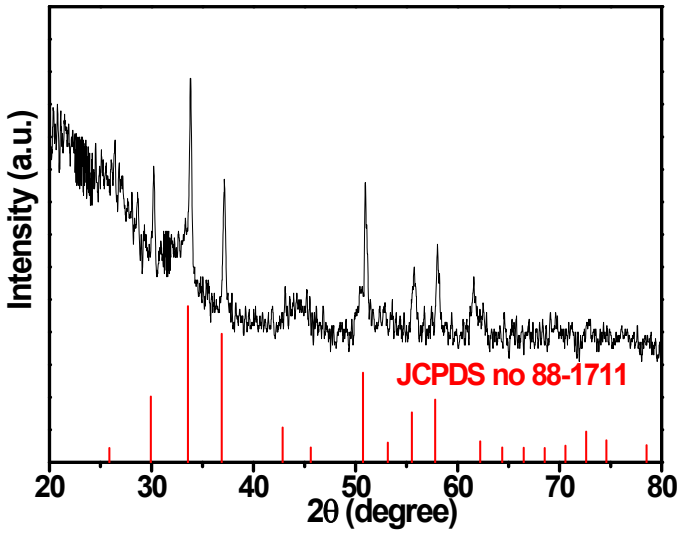

Fig. S6 XRD pattern of $NiSe_2$ powder scraped from NG/$NiSe_2$/NF electrode.

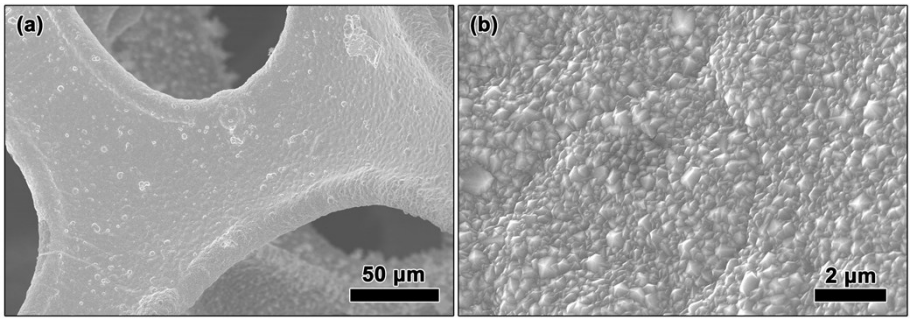

Fig. S7 Low-magnification SEM images of NG/$NiSe_2$/NF.

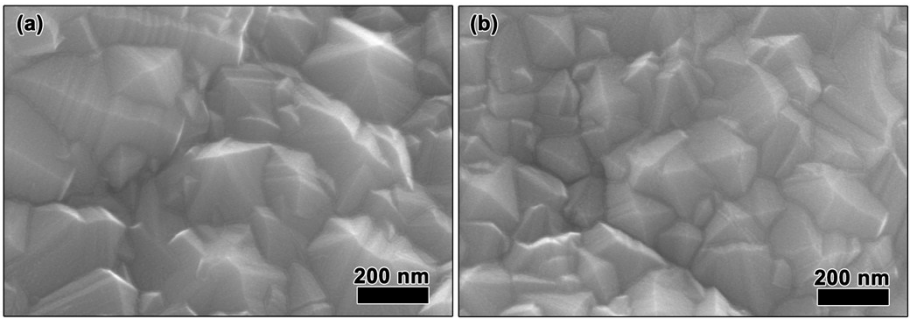

Fig. S8 SEM images of $NiSe_2$/NF (a) and G/$NiSe_2$/NF (b).

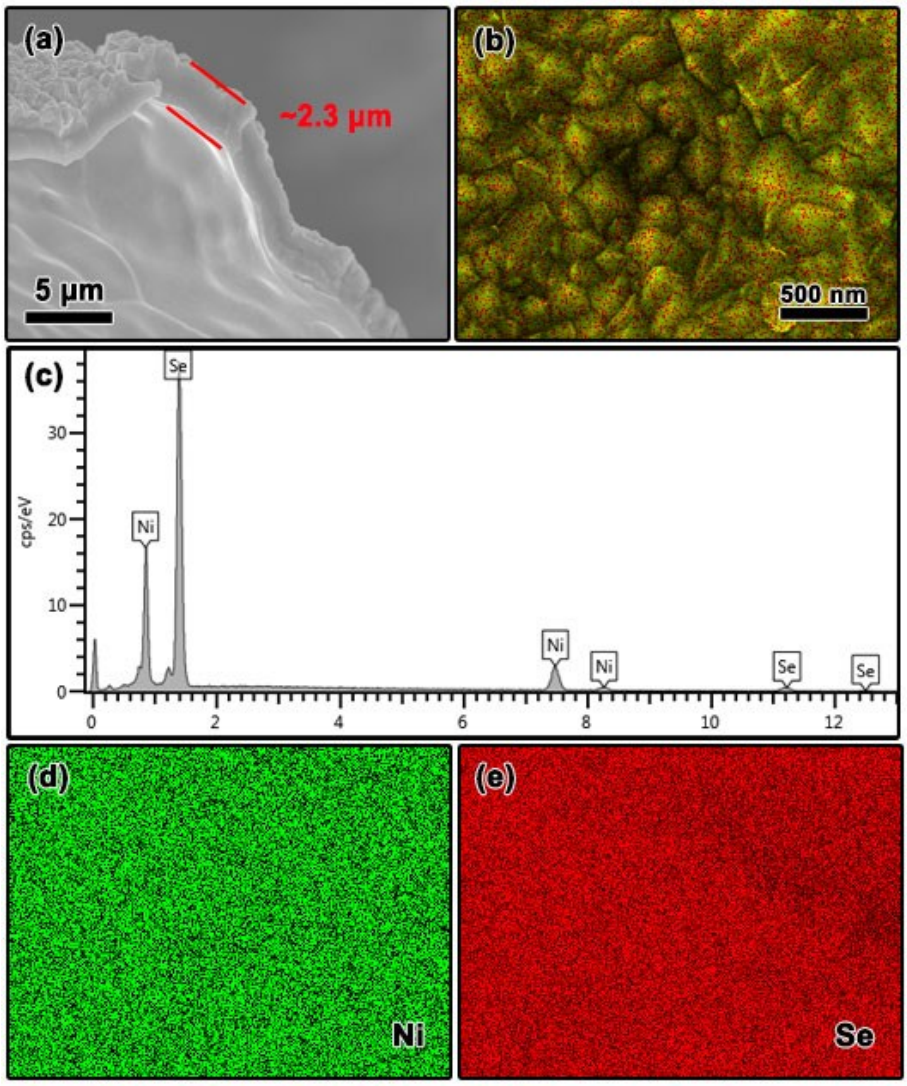

Fig. S9 (a) Cross-section SEM image, (b) SEM image, (c) EDS and (d,e) EDS elemental mappings of NG/$NiSe_2$/NF.

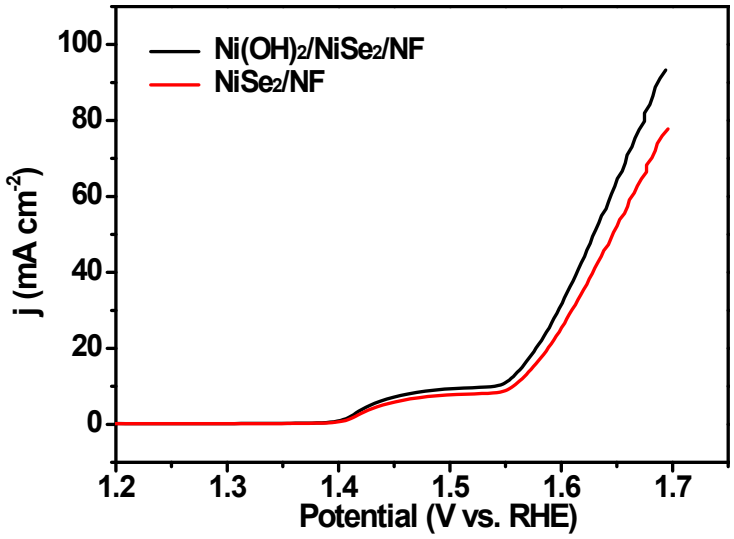

Fig. S10 LSV curves of $NiSe_2$ grown on cleaned Ni foam and hydrothermal treatment Ni foam. The latter presented enhanced OER activity, indicating the synergistic effect between $NiSe_2$ and oxidized Ni substrate.

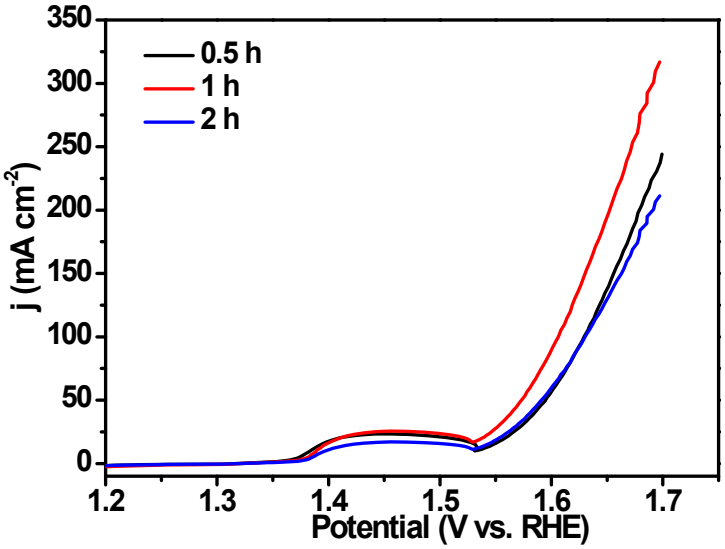

Fig. S11 LSV curves of deposited NG/$NiSe_2$/NF films with different deposition time. Increasing catalyst loading with longer deposition time will lead to the increase of active sites to accelerate the electrocatalytic process. Meanwhile, excess deposition (longer than 1 hour deposition) will lead to overgrowth and even multilayers which will block surface active sites and the electron transfer.

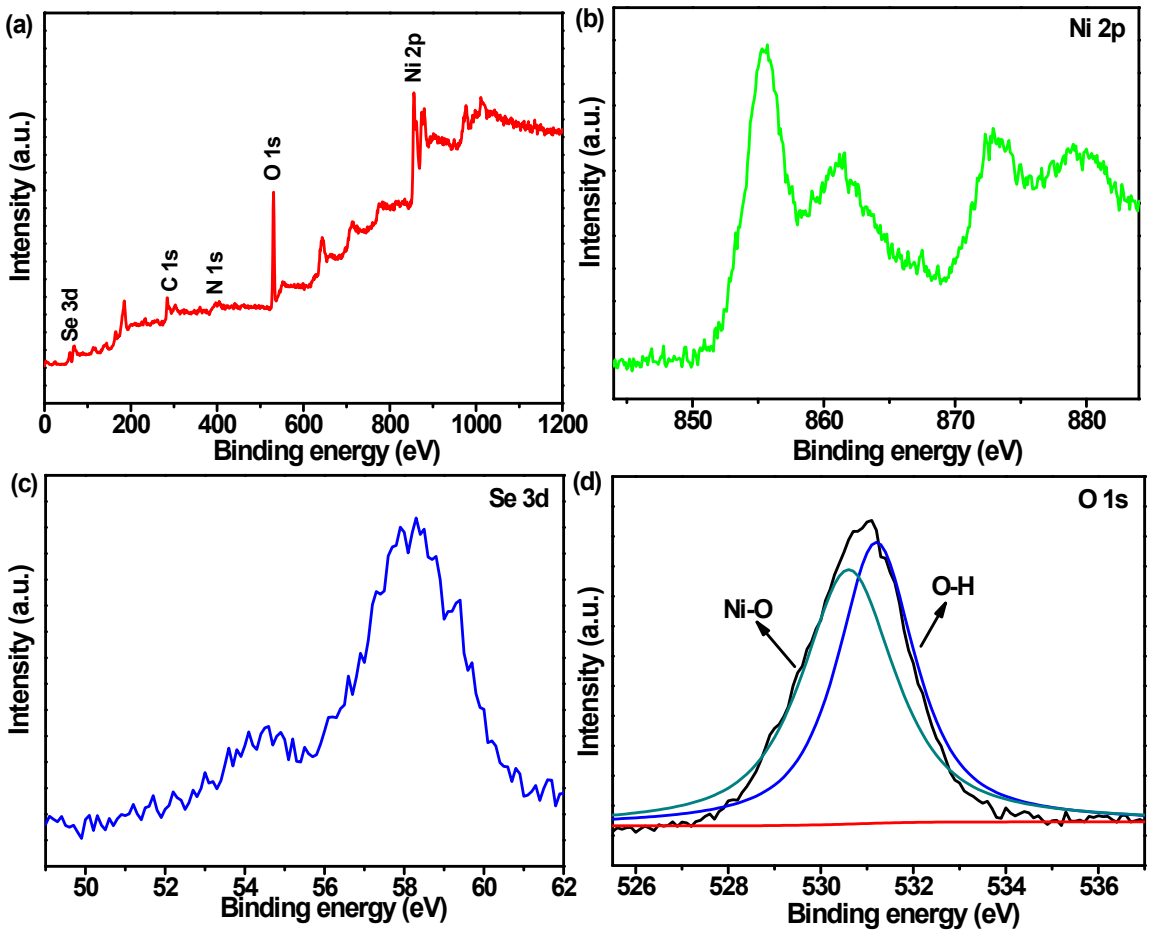

Fig. S12 XPS analysis of NG/$NiSe_2$/NF after OER test. (a) survey, (b-d) High-resolution XPS of Ni 2p, Se 3d and O 1s, respectively.

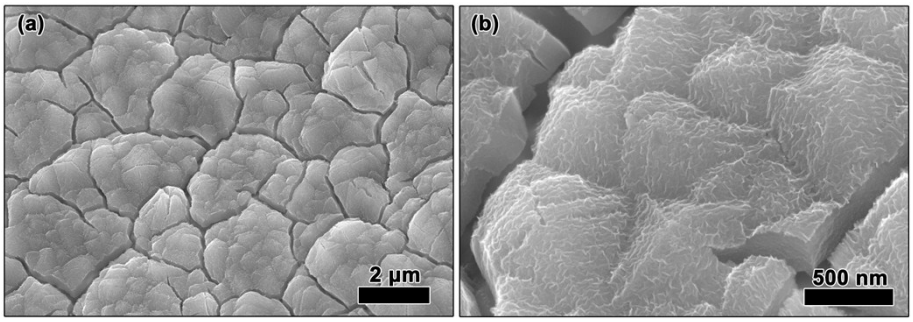

Fig. S13 SEM images of NG/$NiSe_2$/NF after OER in 0.1 M KOH.

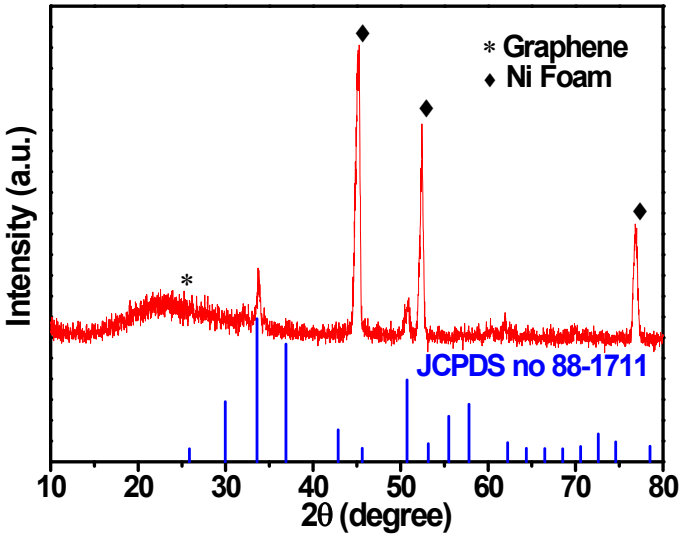

Fig. S14 XRD pattern of NG/$NiSe_2$/NF after OER in 0.1 M KOH

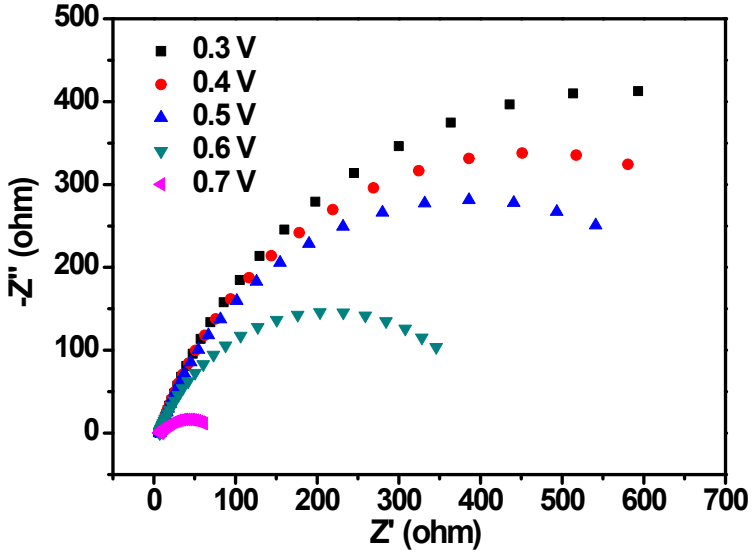

Fig. S15 Nyquist plots of NG/$NiSe_2$/NF at different potentials (vs. RHE). The tremendously reduced R_{ct} values upon increasing overpotentials suggest the accelerated charge transfer kinetics.

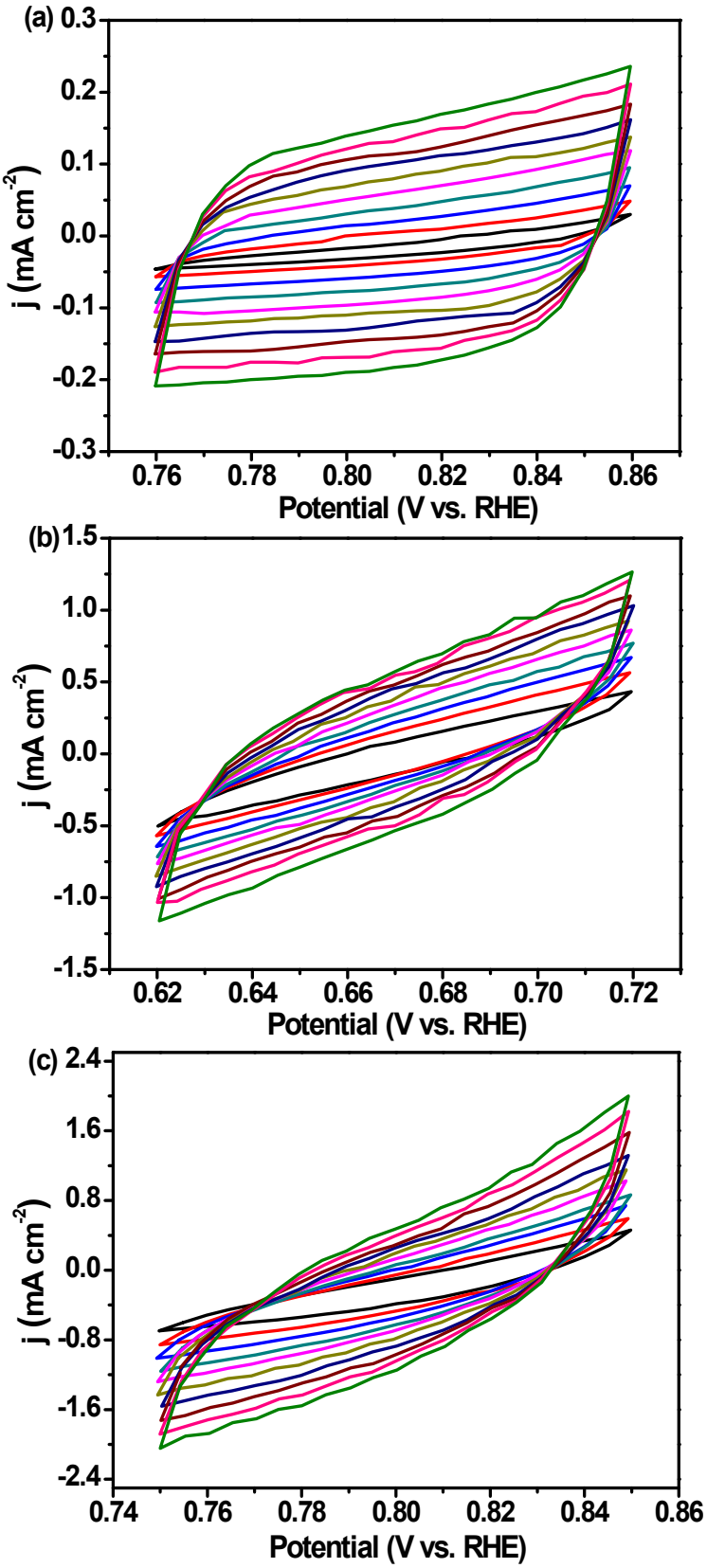

Fig. S16 Electrochemical CV curves of different electrodes at different scanning rates from 20 mV/s to 200 mV/s with an interval point of 20 mV/s in 0.1 M KOH. (a) $NiSe_2$/NF, (b) G/$NiSe_2$/NF, (c) NG/$NiSe_2$/NF.

Supplementary Tables

Table S1. Comparison of OER activity of some non-noble catalysts.

Catalyst	electrolyte	J (mA cm^{-2})	η (mV)	Ref.
NG/$NiSe_2$/NF	0.1 M KOH	20	307	This work
NG/$NiSe_2$/NF	1 M KOH	100	330	This work
NF-Ni_3Se_2/Ni	1 M KOH	100	353	*Nano Energy,* 2016, **24**, 103.
$Co_{0.13}Ni_{0.87}Se_2$/Ti	1 M KOH	100	320	*Nanoscale,* 2016, **8**, 3911.
Ni_3Se_2/CF	1 M KOH	50	340	*Catal. Sci. Technol.,* 2015, **5**, 4954
NiSe nanowire/Ni	1 M KOH	35	400	*Angew. Chem., Int. Ed.,* 2016, **55**, 1710.
NiSe/NF	1 M KOH	20	270	*Angew.Chem.,* 2015, **127**, 9483.
CoO_x-CoSe	1 M KOH	100	300	*J. Mater. Chem. A,* 2016, **4**, 10933.
$NiCo_2O_4$	1 M KOH	100	~470	*Adv. Energy Mater.,* 2015, **5**, 1402031.
$(Ni, Co)_{0.85}Se$	1 M KOH	122	360	*Adv. Mater.,* 2016, **28**, 77.
NiCo LDH	1 M KOH	10	367	*Nano Lett.,* 2015, **15**, 1421.
$NiSe_2$	0.1 M KOH	10	410	*ACS Appl. Mater. Interfaces*, 2016, **8**, 5327.
$CoSe_2$/N-Graphene	0.1 M KOH	10	366	*ACS Nano,* 2014, **8**, 3970.
Ni_3Se_2	0.3 M KOH	10	310	*Energy Environ. Sci.,* 2016, **9**, 1771.
N-Co_9S_8/G	0.1 M KOH	10	409	*Energy Environ. Sci.,* 2016, **9**, 1320.
$CoSe_2$	0.1 M KOH	10	320	*J. Am. Chem. Soc.,* 2014, **136**, 15670.