

## **Electronic Supplementary Information**

### **A simple electrodeposition to synthesize NiFeS<sub>x</sub>-modified Ti-Fe<sub>2</sub>O<sub>3</sub> photoanode: an effective strategy to improve photoelectrochemical water oxidation reaction**

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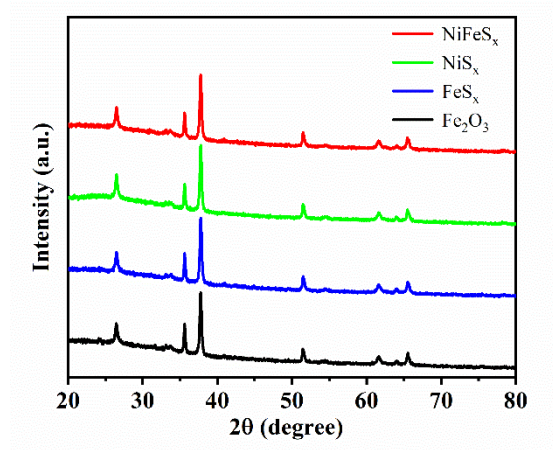


Figure S1 XRD patterns of Ti-Fe<sub>2</sub>O<sub>3</sub>/NiFeS<sub>x</sub>, Ti-Fe<sub>2</sub>O<sub>3</sub>/NiS<sub>x</sub>, Ti-Fe<sub>2</sub>O<sub>3</sub>/FeS<sub>x</sub> and Ti-Fe<sub>2</sub>O<sub>3</sub>.

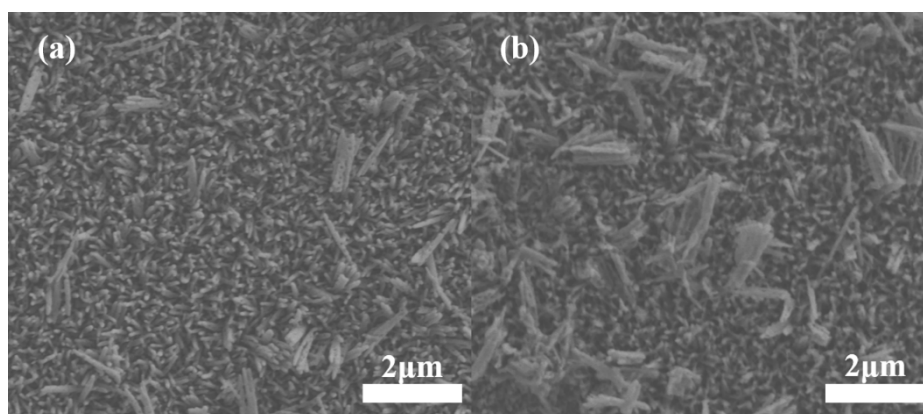


Figure S2 FE-SEM images of Ti-Fe<sub>2</sub>O<sub>3</sub> (a) and Ti-Fe<sub>2</sub>O<sub>3</sub>/NiFeS<sub>x</sub> (b).

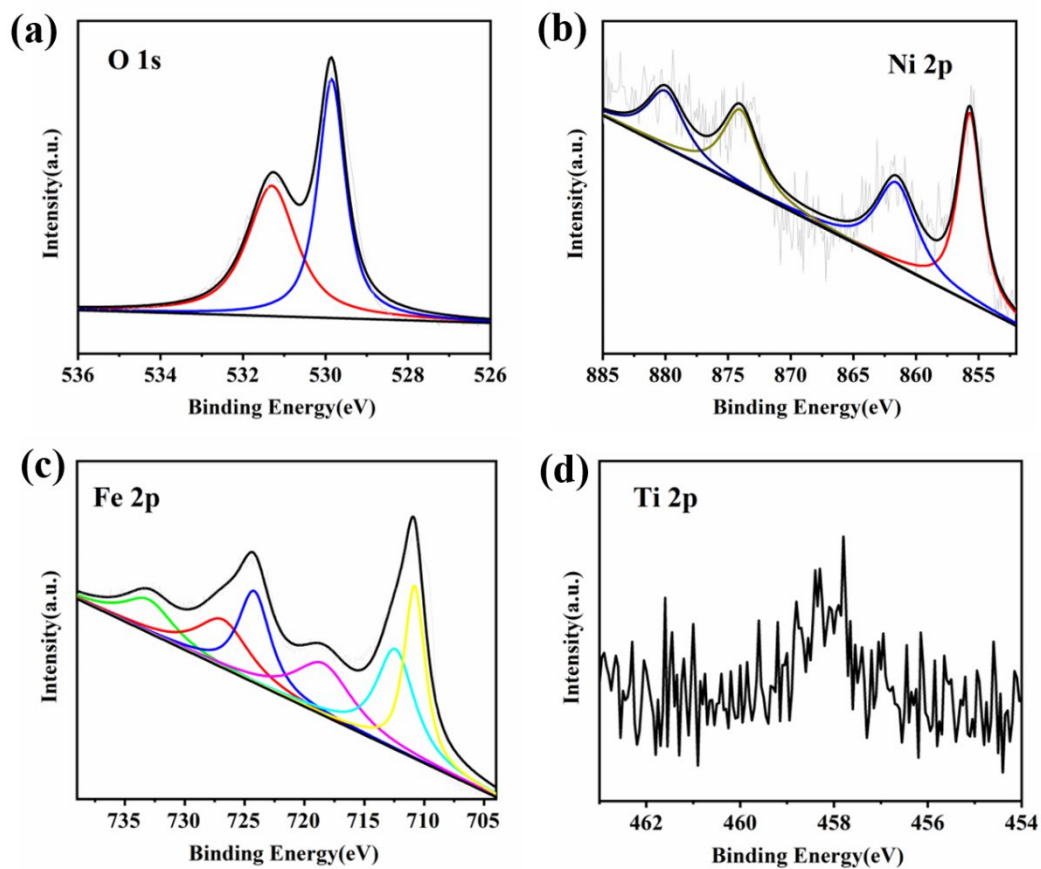


Figure S3 XPS spectrum of O 1s (a), Ni (2p), Fe (2p) and Ti (2p) for Ti-Fe<sub>2</sub>O<sub>3</sub>/NiFeS<sub>x</sub>.

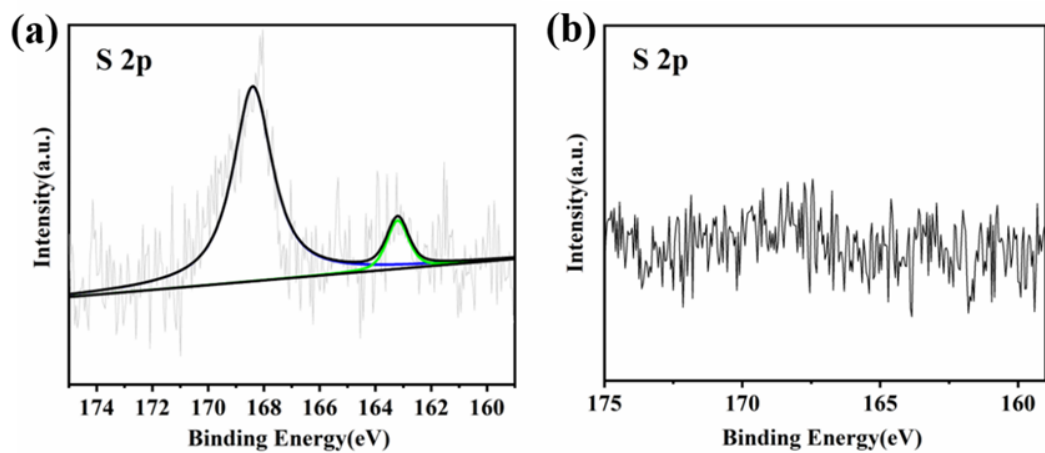


Figure S4 XPS spectrum of S 2p for Ti-Fe<sub>2</sub>O<sub>3</sub>/NiFeS<sub>x</sub>, before reaction (a), after reaction (b).

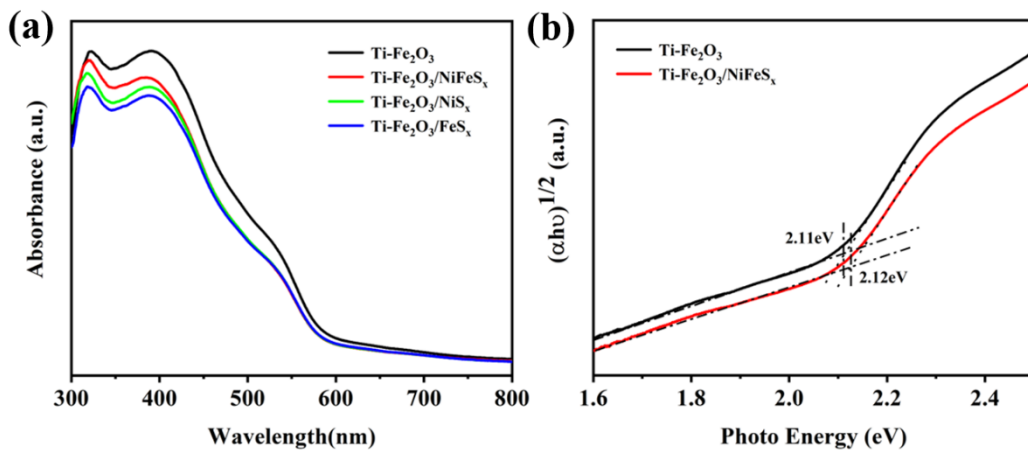


Figure S5 UV-vis absorption spectra (a) and the corresponding Tauc's plots (b) of Ti-Fe<sub>2</sub>O<sub>3</sub> and Ti-Fe<sub>2</sub>O<sub>3</sub>/NiFeS<sub>x</sub>.

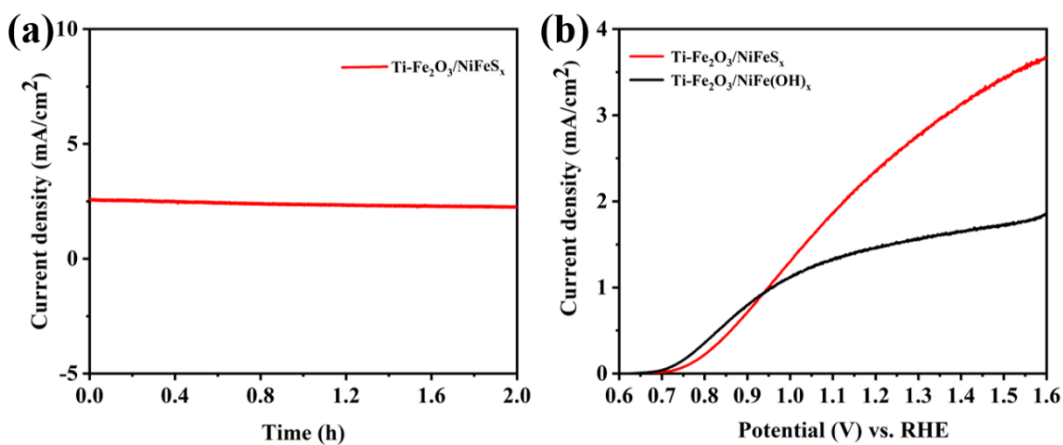


Figure S6 Photostability measurement of Ti-Fe<sub>2</sub>O<sub>3</sub>/NiFeS<sub>x</sub> at 1.23 V vs. RHE in 1 M KOH with one drop of Triton X-400 (a) and the photocurrent of Ti-Fe<sub>2</sub>O<sub>3</sub>/NiFeS<sub>x</sub> and Ti-Fe<sub>2</sub>O<sub>3</sub>/NiFe(OH)<sub>x</sub> (b).

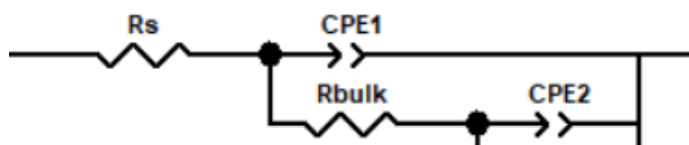


Figure S7 The equivalent circuit model for fitting Nyquist plots of photoanodes.

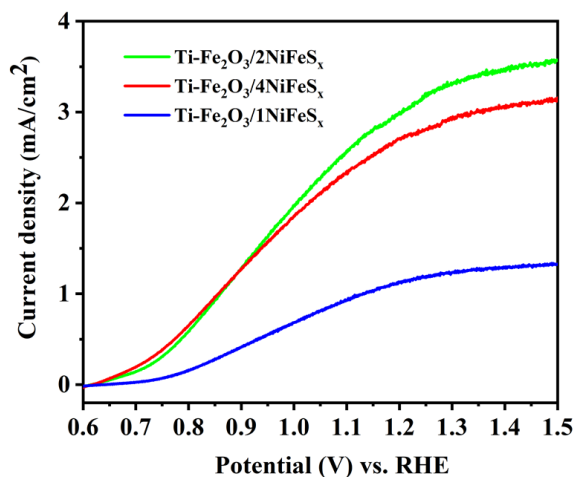


Figure S8 The photocurrent of Ti-Fe<sub>2</sub>O<sub>3</sub>/2NiFeS<sub>x</sub>, Ti-Fe<sub>2</sub>O<sub>3</sub>/4NiFeS<sub>x</sub> and Ti-Fe<sub>2</sub>O<sub>3</sub>/1NiFeS<sub>x</sub>.

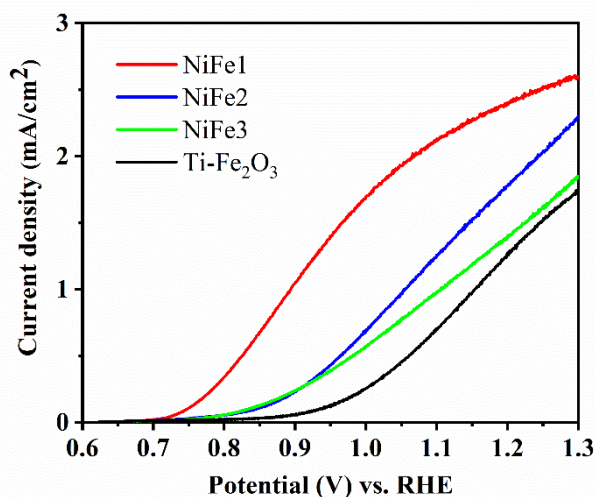


Figure S9 The photocurrent of NiFe1, NiFe2, NiFe3 and Ti-Fe<sub>2</sub>O<sub>3</sub>.

**Table S1** The fitted results of Nyquist plots for Ti-Fe<sub>2</sub>O<sub>3</sub> and Ti-Fe<sub>2</sub>O<sub>3</sub>/NiFeS<sub>x</sub>.

| Photoanode  | R <sub>Bulk</sub> (Ω) | CPE1 (Fcm <sup>-2</sup> ) | R <sub>ct</sub> (Ω) | CPE2 (Fcm <sup>-2</sup> ) |
|---|-----------------------|---------------------------|---------------------|---------------------------|
| Ti-Fe <sub>2</sub> O <sub>3</sub> /NiFeS <sub>x</sub> | 96.86                 | 1.51×10 <sup>-5</sup>     | 446.9               | 3.18×10 <sup>-4</sup>     |
| Ti-Fe <sub>2</sub> O <sub>3</sub>                     | 156.9                 | 3.78×10 <sup>-5</sup>     | 1636                | 3.32×10 <sup>-4</sup>     |

**Table S2** Comparison of the photocurrent density of Fe<sub>2</sub>O<sub>3</sub> in literature with our result under AM 1.5 G illumination

| Composite   | Photocurrent density at 1.23V vs. RHE | Electrolyte | Ref |
|---|---------------------------------------|-------------|-----|
| Fe <sub>2</sub> O <sub>3</sub> /C <sub>3</sub> N <sub>4</sub> /CoO <sub>x</sub> | 1.50 mA/cm <sup>2</sup>               | 1 M NaOH    | [1] |
| Ti-Fe <sub>2</sub> O <sub>3</sub> /FeP  | 3.9 mA/cm <sup>2</sup>                | 1 M KOH     | [2] |

|  |                               |                   |                             |
|--|-------------------------------|-------------------|-----------------------------|
| <b>Fe<sub>2</sub>O<sub>3</sub>/NiOOH</b>                                 | <b>1.64 mA/cm<sup>2</sup></b> | <b>1 M NaOH</b>   | <b>[3]</b>                  |
| <b>Fe<sub>2</sub>O<sub>3</sub>/FeB/CoPi</b>                              | <b>1.9 mA/cm<sup>2</sup></b>  | <b>1 M NaOH</b>   | <b>[4]</b>                  |
| <b>Fe<sub>2</sub>O<sub>3</sub>/Vo/CoPi</b>                               | <b>3 mA/cm<sup>2</sup></b>    | <b>1 M NaOH</b>   | <b>[5]</b>                  |
| <b>NiCoAl-LDH/ Fe<sub>2</sub>O<sub>3</sub></b>                           | <b>2.56 mA/cm<sup>2</sup></b> | <b>0.5 M K-Pi</b> | <b>[6]</b>                  |
| <b>SiO<sub>x</sub>/np-Fe<sub>2</sub>O<sub>3</sub></b>                    | <b>2.44 mA/cm<sup>2</sup></b> | <b>1 M NaOH</b>   | <b>[7]</b>                  |
| <b>Ti-Fe<sub>2</sub>O<sub>3</sub>-FeOOH</b>                              | <b>2.31 mA/cm<sup>2</sup></b> | <b>1 M KOH</b>    | <b>[8]</b>                  |
| <b>Ti-Fe<sub>2</sub>O<sub>3</sub>/Ni(OH)<sub>2</sub>/IrO<sub>2</sub></b> | <b>2.2 mA/cm<sup>2</sup></b>  | <b>1 M NaOH</b>   | <b>[9]</b>                  |
| <b>Ti-Fe<sub>2</sub>O<sub>3</sub>/NiFeS<sub>x</sub></b>                  | <b>3mA/cm<sup>2</sup></b>     | <b>1 M KOH</b>    | <b>In<br/>this<br/>work</b> |

**Table S3** Photocurrent of 10NiFeS<sub>x</sub>/Ti-Fe<sub>2</sub>O<sub>3</sub> under AM 1.5 G illumination

| <b>Composite</b>  | <b>Photocurrent density at 1.23V vs. RHE</b> |
|---|--|
| 1NiFeS <sub>x</sub> /Ti-Fe <sub>2</sub> O <sub>3</sub>  | 3.03 mA/cm <sup>2</sup>                      |
| 2NiFeS <sub>x</sub> /Ti-Fe <sub>2</sub> O <sub>3</sub>  | 3.00 mA/cm <sup>2</sup>                      |
| 3NiFeS <sub>x</sub> /Ti-Fe <sub>2</sub> O <sub>3</sub>  | 2.99 mA/cm <sup>2</sup>                      |
| 4NiFeS <sub>x</sub> /Ti-Fe <sub>2</sub> O <sub>3</sub>  | 3.02 mA/cm <sup>2</sup>                      |
| 5NiFeS <sub>x</sub> /Ti-Fe <sub>2</sub> O <sub>3</sub>  | 2.96 mA/cm <sup>2</sup>                      |
| 6NiFeS <sub>x</sub> /Ti-Fe <sub>2</sub> O <sub>3</sub>  | 2.93 mA/cm <sup>2</sup>                      |
| 7NiFeS <sub>x</sub> /Ti-Fe <sub>2</sub> O <sub>3</sub>  | 2.91 mA/cm <sup>2</sup>                      |
| 8NiFeS <sub>x</sub> /Ti-Fe <sub>2</sub> O <sub>3</sub>  | 2.89 mA/cm <sup>2</sup>                      |
| 9NiFeS <sub>x</sub> /Ti-Fe <sub>2</sub> O <sub>3</sub>  | 2.86mA/cm <sup>2</sup>                       |
| 10NiFeS <sub>x</sub> /Ti-Fe <sub>2</sub> O <sub>3</sub> | 2.98 mA/cm <sup>2</sup>                      |

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