Supporting Information

Simultaneous Reduction of Surface, Bulk, and Interface Recombination for Au Nanoparticles Embedded Hematite Nanorod Photoanodes toward Efficient Water Splitting

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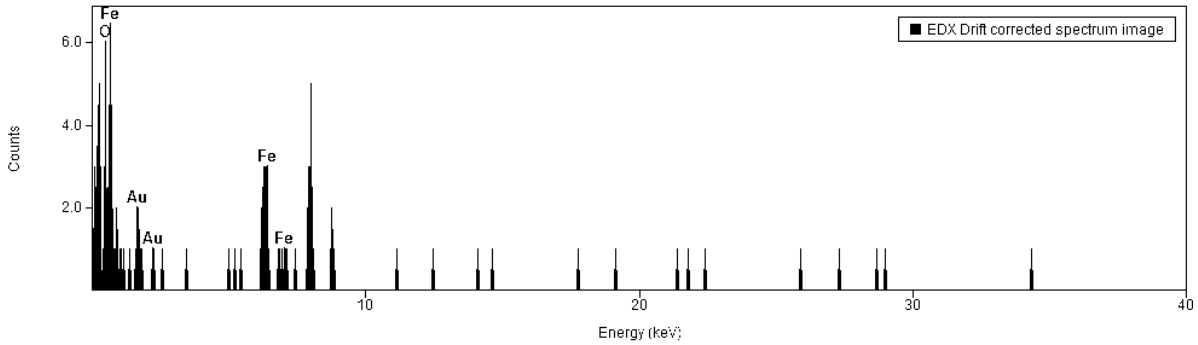

Figure S1. EDX scanning of Au/Fe_2O_3 NRs.

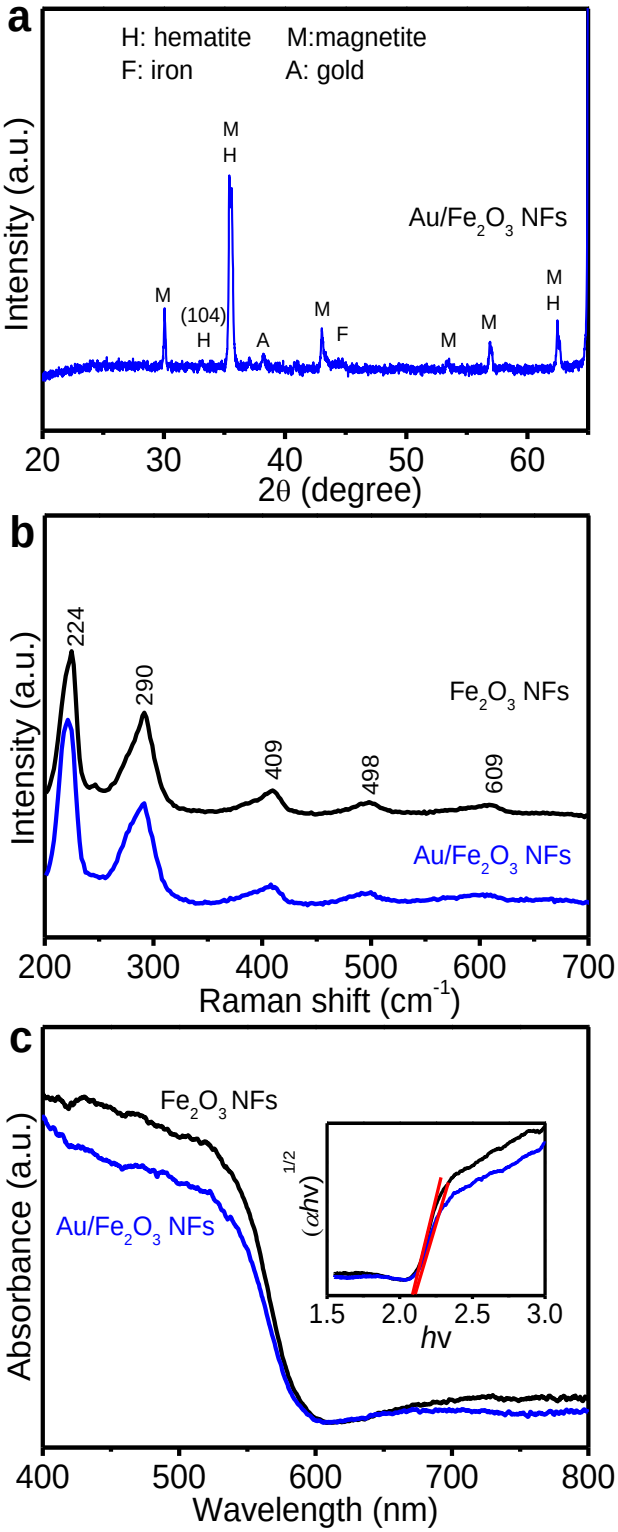

Figure S2. (a) XRD pattern, (b) Raman spectrum, and (c) UV-vis diffuse reflectance spectrum of Au/Fe_2O_3 NFs. The results of Fe_2O_3 NFs were shown for comparison. H: Fe_2O_3; M: Fe_3O_4; F: Fe; A: Au.

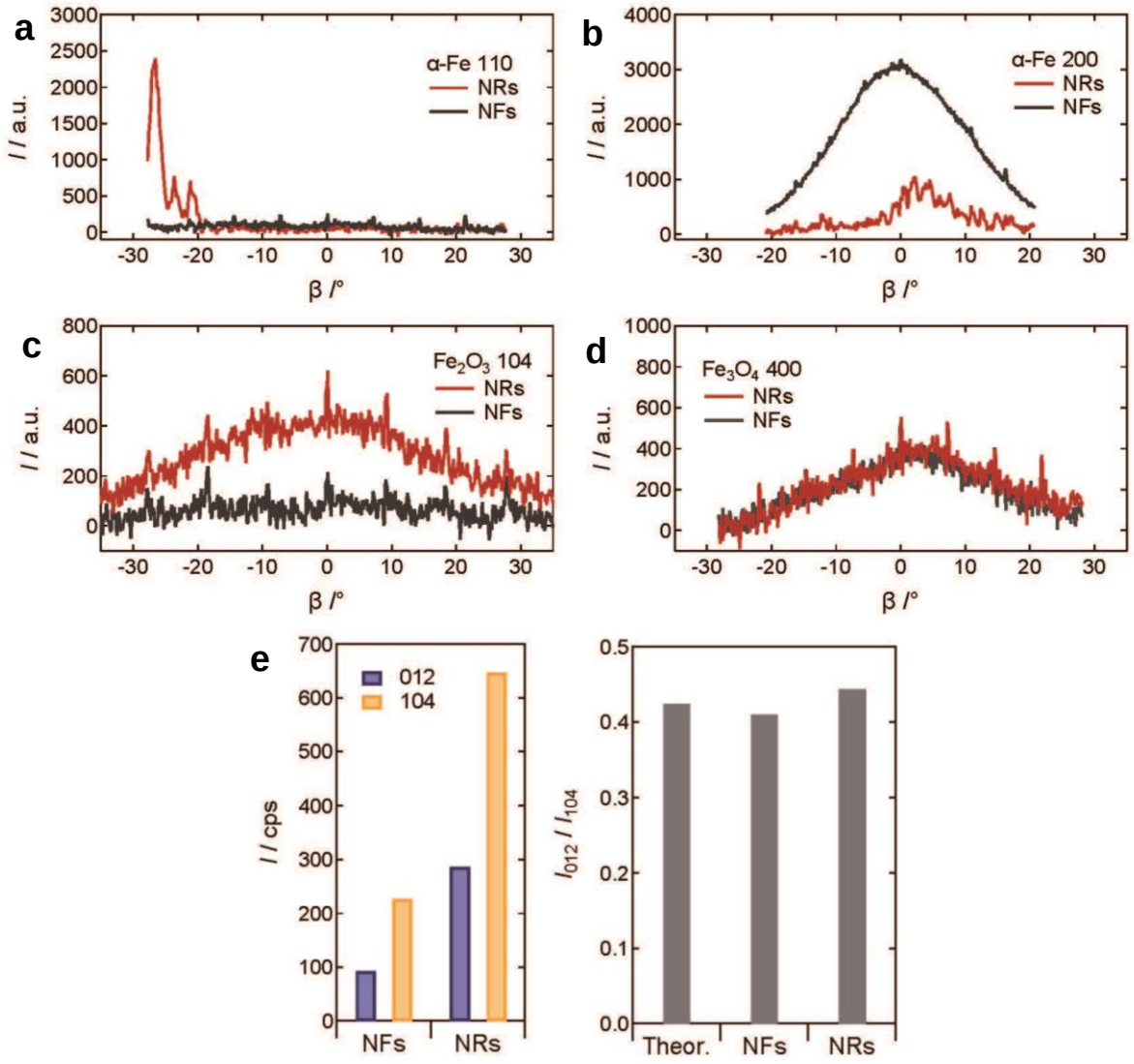

Figure S3. Comparison of 2D XRD patterns of Fe_2O_3 NFs (NFs) and Au/Fe_2O_3 NRs (NRs).

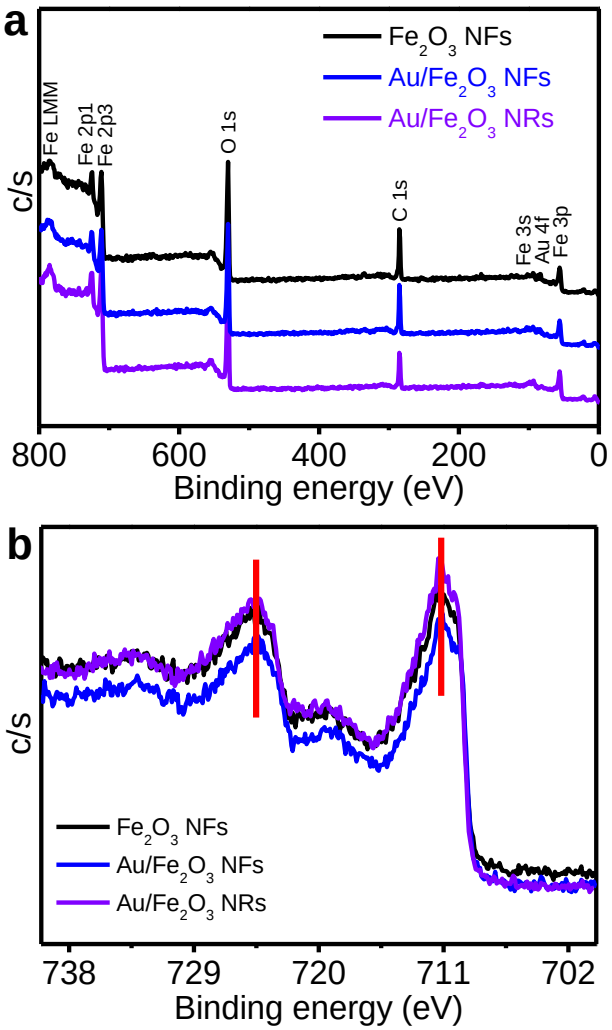

Figure S4. (a) XPS survey spectra, and (b) high resolution Fe 2p of Fe_2O_3 NFs, Au/Fe_2O_3 NFs, and Au/Fe_2O_3 NRs.

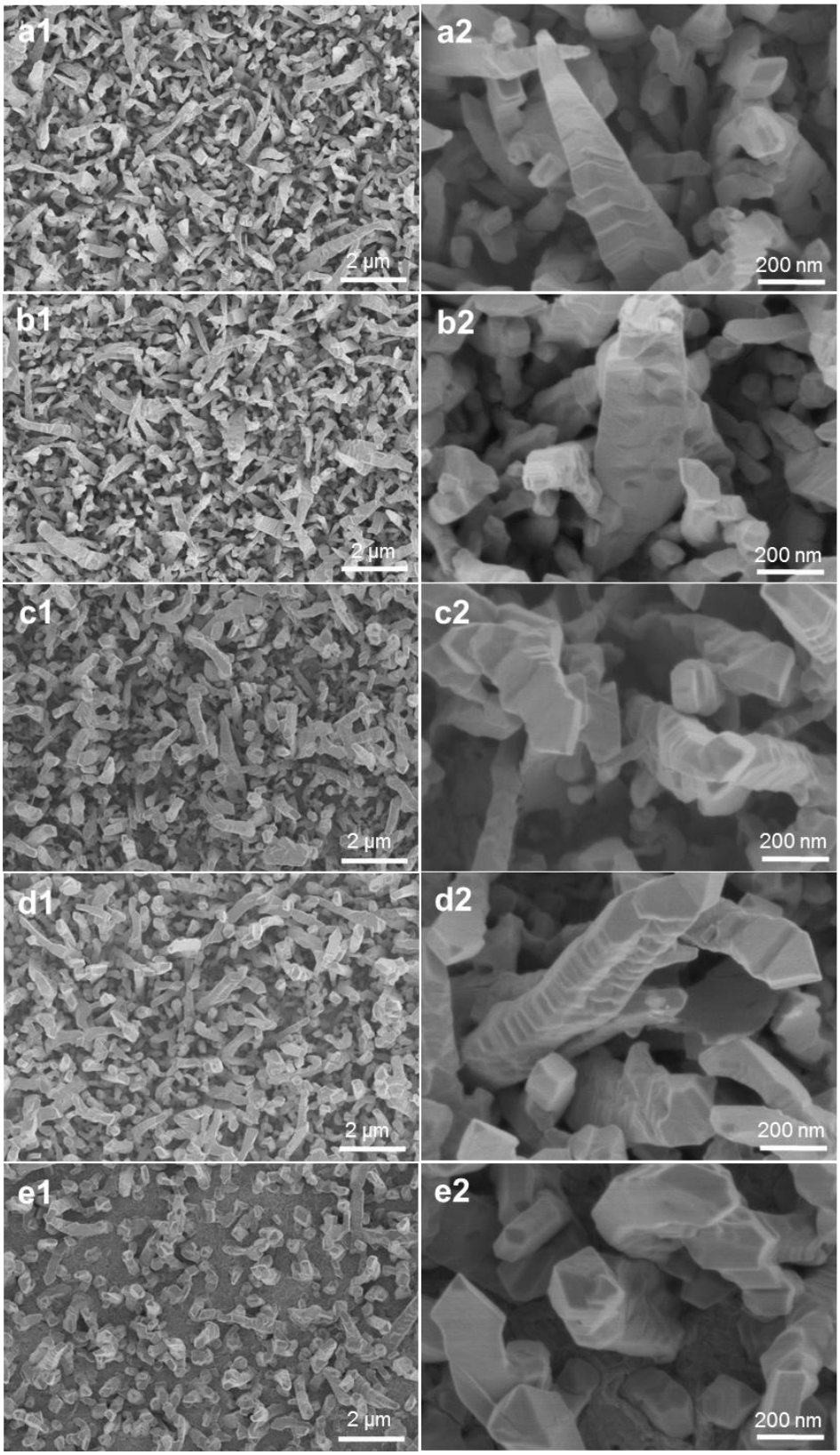

Figure S5. SEM images of Au/Fe_2O_3 NRs. The Au/Fe_2O_3 NFs were annealed in Ar atmosphere at various temperatures. (a) 500 ℃; (b) 550 ℃; (c) 600 ℃; (d) 650 ℃; (e) 700 ℃.

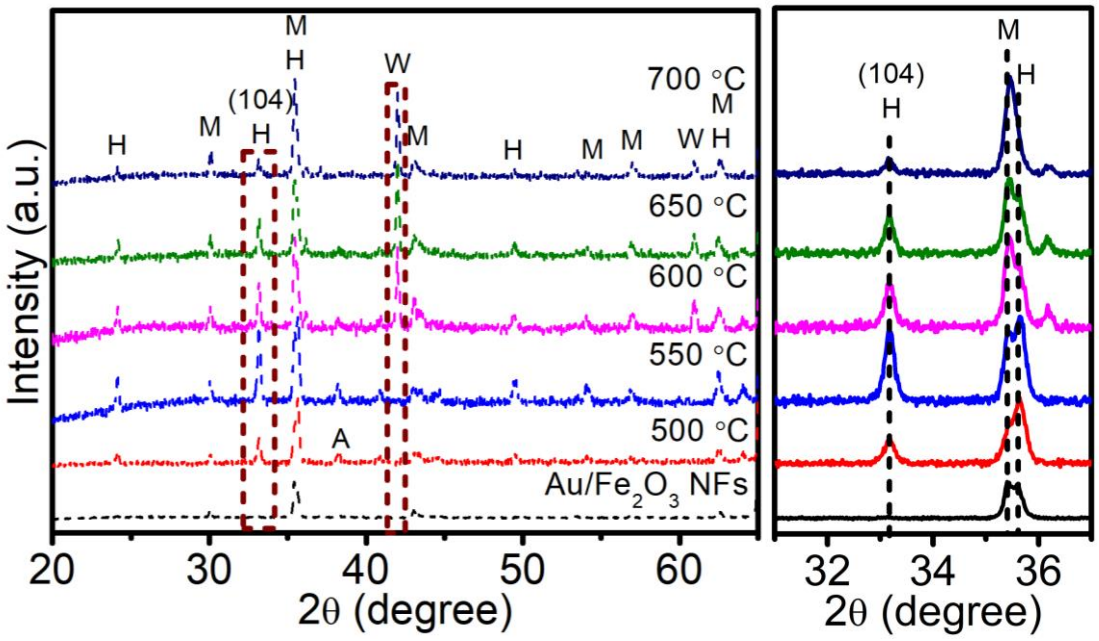

Figure S6. XRD patterns of Au/Fe_2O_3 NRs annealing in Ar atmosphere at various temperatures. H: Fe_2O_3; M: Fe_3O_4; W: FeO; A: Au.

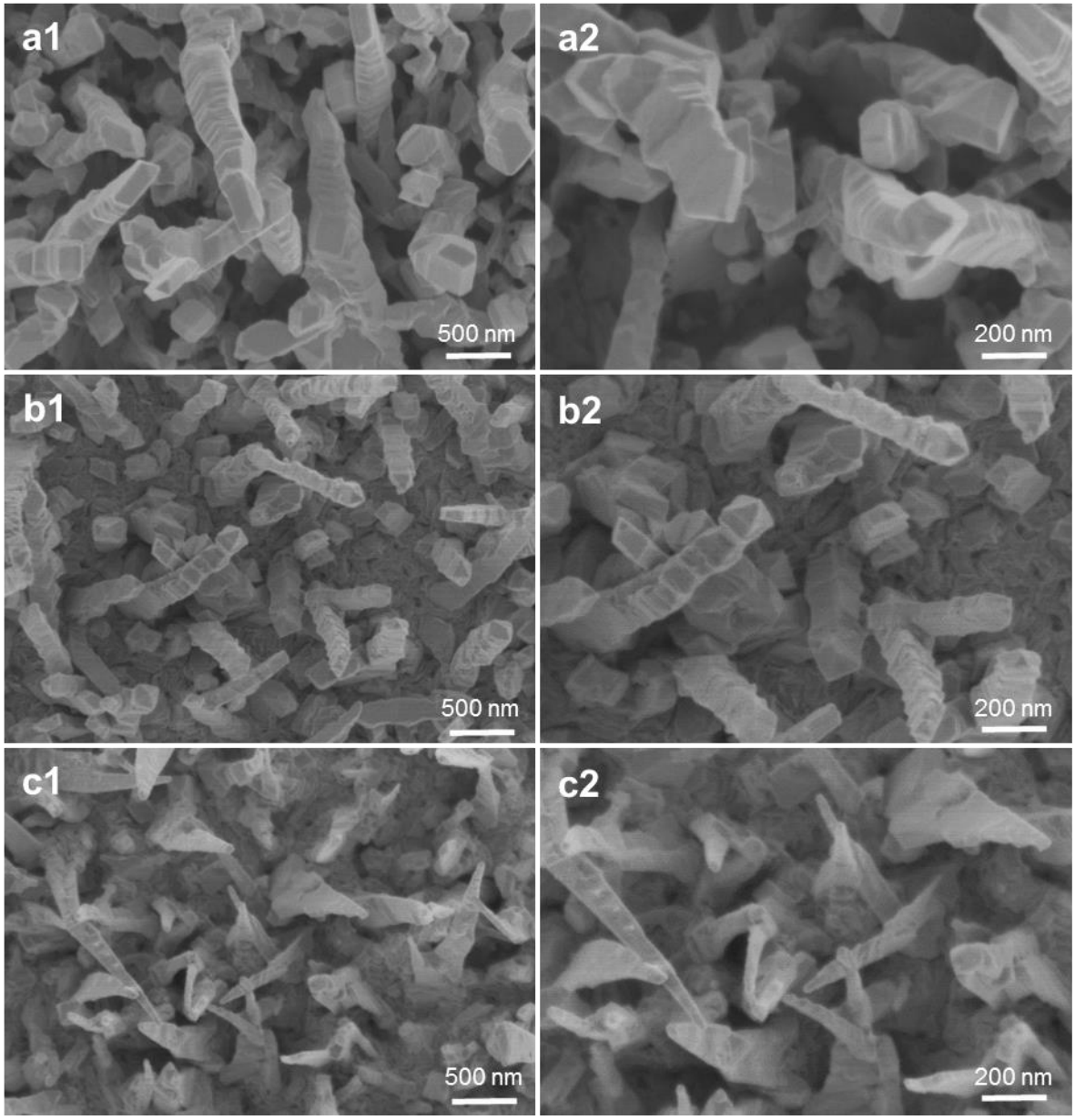

Figure S7. SEM images of (a) Au/Fe_2O_3 NRs, (b) Ti/Fe_2O_3 NRs, and (c) P/Fe_2O_3 NRs.

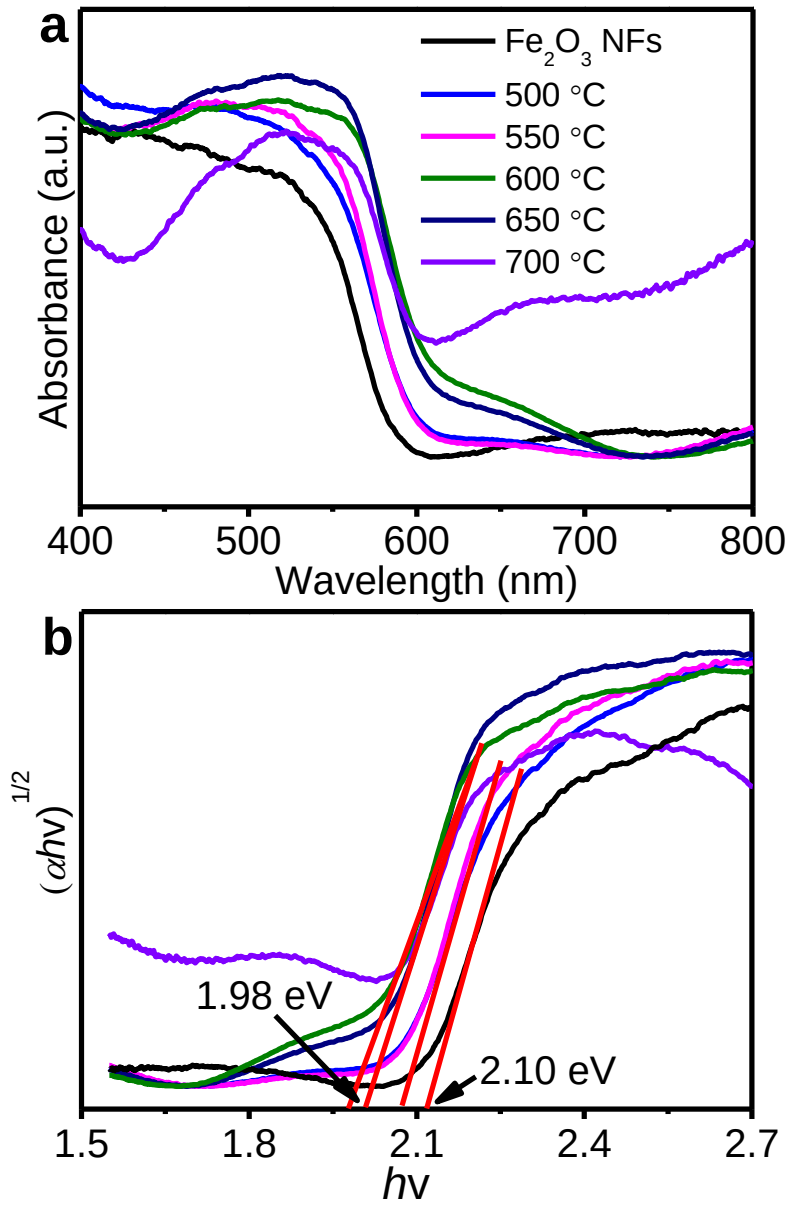

Figure S8. (a) UV-vis diffuse reflectance spectra and (b) calculation of band gaps of Au/Fe_2O_3 NRs. The Au/Fe_2O_3 NFs were annealed in Ar atmosphere at various temperatures.

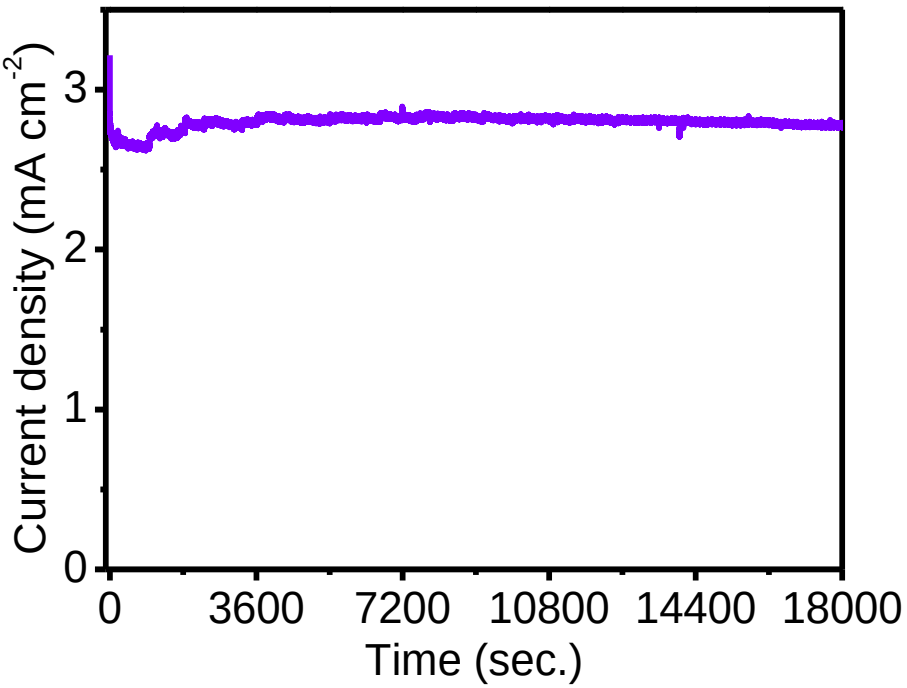

Figure S9. Stability of Au/Fe_2O_3 NRs applied at 1.5 V_{RHE}.

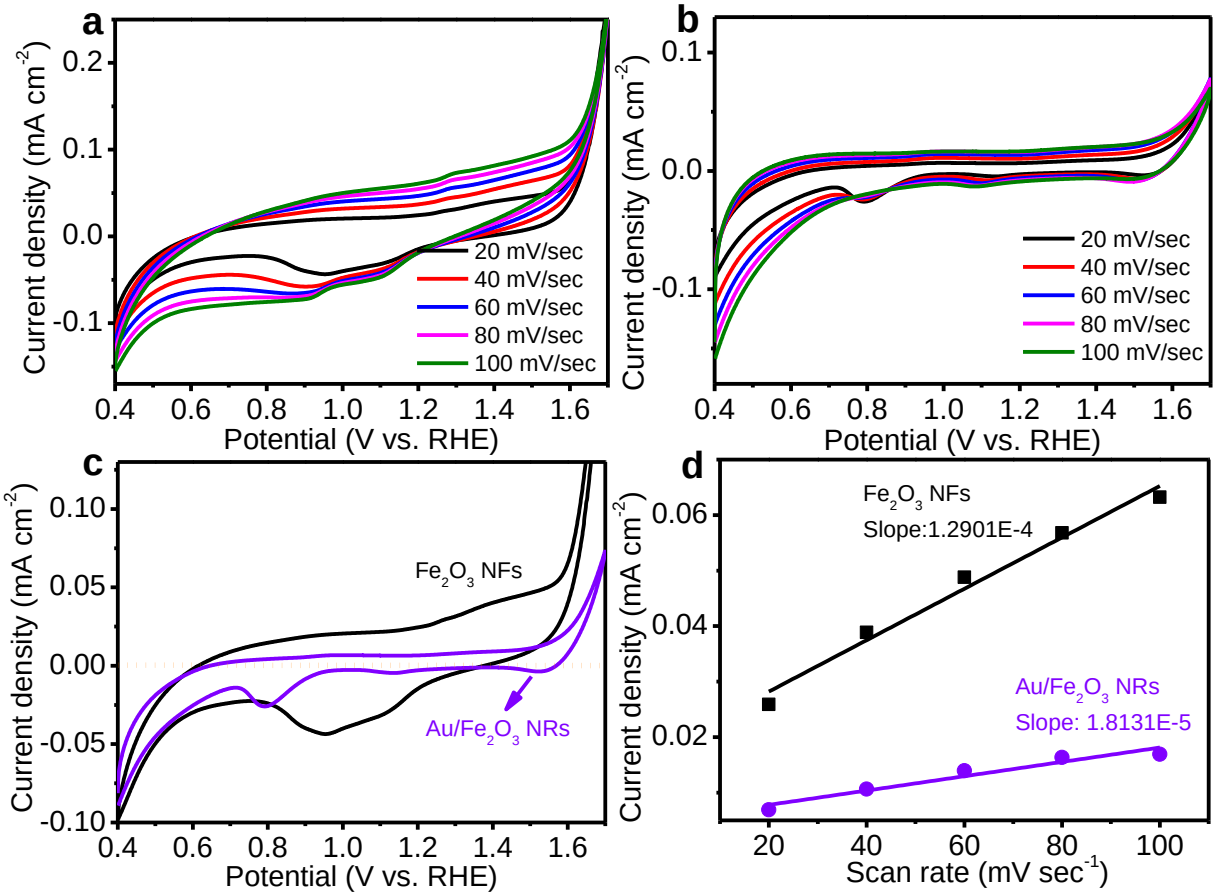

Figure S10. (a-c) Cyclic voltammetry curves and (d) relative electrochemical surface areas of Fe_2O_3 NFs and Au/Fe_2O_3 NRs.

As scan rate increases from 20 to 100 mV sec^{-1}, the current increases while a small positive shift of the oxidation peak potential and a negative shift of the reduction peak potential have been observed with the increased scan rate. It should be related to the reaction capability and the OH^- concentration at the interface between the electrode and electrolyte.

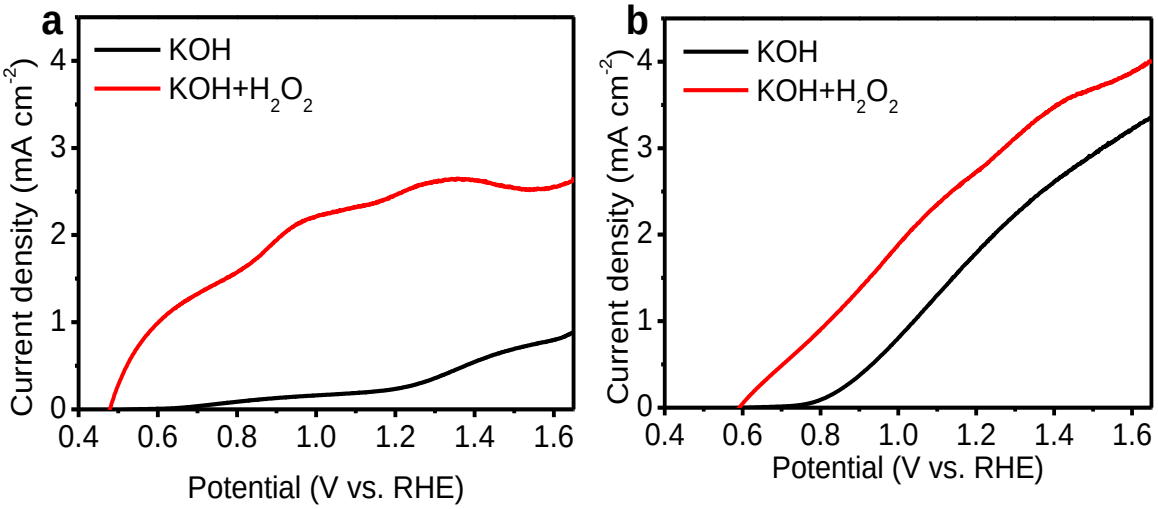

Figure S11. Linear sweep voltammogram (LSV) curves of (a) Fe_2O_3 NFs and (b) Au/Fe_2O_3 NRs in 1 M KOH electrolytes without and with H_2O_2.

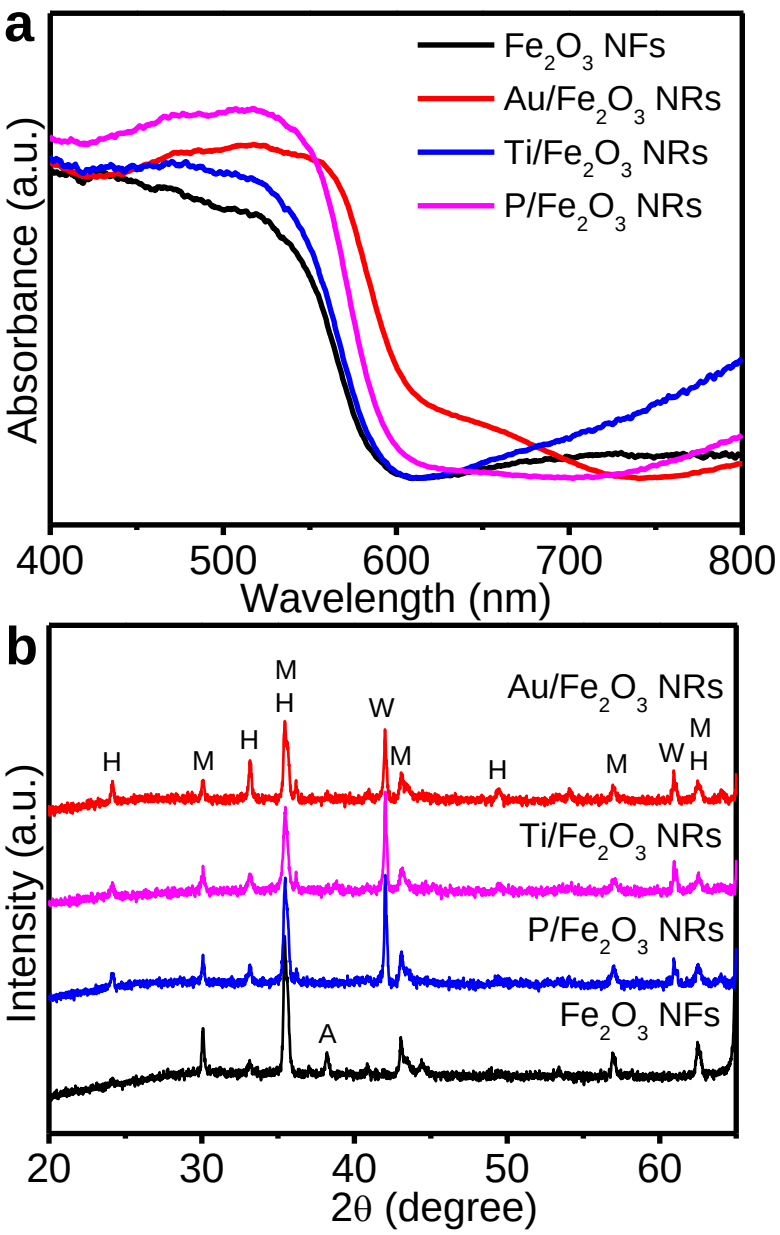

Figure S12. (a) UV-vis diffuse reflectance spectra, and (b) XRD patterns of Au/Fe_2O_3 NRs, Ti/Fe_2O_3 NRs, and P/Fe_2O_3 NRs. H: Fe_2O_3; M: Fe_3O_4; W: FeO; F: Fe; A: Au.

Table S1 Comparison of photoresponses of recent hematite electrodes in solar water splitting under AM 1.5G illumination.[1-6]

Photoanodes	*i* @ 1.23 V_{RHE}	Onset potential	Electrolyte
ITO/Fe_2O_3 nanowires/Fe_2TiO_5/FeNiOOH on FTO [1]	2.2 mA cm^{-2}	~0.95 V_{RHE}	1 M NaOH
Gradient P doped Fe_2O_3 nanobundles on FTO [2]	~1.48 mA cm^{-2}	0.8 V_{RHE}	1 M KOH
$CoFeO_x$/Fe_2O_3 NRs on FTO [3]	1.2 mA cm^{-2}	~0.6 V_{RHE}	1 M NaOH
Zr induced Fe_2O_3 nanotubes on FTO [4]	1.5 mA cm^{-2}	~0.85 V_{RHE}	1 M NaOH
Ti doped Fe_2O_3 NRs on FTO [5]	2.5 mA cm^{-2}	~0.85 V_{RHE}	1 M KOH
Ti doped Fe_2O_3 NRs on FTO [6]	2.4 mA cm^{-2}	~0.95 V_{RHE}	1 M NaOH
Au/Fe_2O_3 on Fe substrate in this work	**2.0 mA cm^{-2}**	**0.6 V_{RHE}**	1 M KOH

Table S1 compared the photocurrent densities for the hematite nanostructures in more recent years. Compared to the hematite nanostructures grown on FTO substrates, the Au/Fe_2O_3 nanorods on iron substrate shows a relatively higher photoresponse, especially for a lower onset potential. A higher temperature annealing (700-800 ℃) is introduced to acivate the Fe_2O_3 on FTO substrates, and Sn doping in the Fe_2O_3 nanostructures.

References

1 P. Tang, H. Xie, C. Ros, L. Han, M. Biset-Peiró, Y. He, W. Kramer, A. P. Rodríguez, E. Saucedo, J. R. Galán-Mascarós, T. Andreu, J. R. Morante and J. Arbiol, *Energy Environ. Sci.*, 2017, **10**, 2124.

2 Z. Luo, C. Li, S. Liu, T. Wang and J. L. Gong, *Chem. Sci.*, 2017, **8**, 91.

3 J. Zhang, R. García-Rodríguez, P. Cameron and S. Eslava, *Energy Environ. Sci.*, 2018, **11**, 2972.

4 C. Li, A. Li, Z. Luo, J. Zhang, X. Chang, Z. Huang, T. Wang and J. L. Gong, *Angew. Chem. Int. Ed.*, 2017, **129**, 4214.

5 Z. Luo, T. Wang, J. Zhang, C. Li, H. Li and J. L. Gong, *Angew. Chem. Int. Ed.*, 2017, **56**, 12878.

6 Z. Wang, X. Mao, P. Chen, M. Xiao, S. A. Monny, S. Wang, M. Konarova, A. Du and L. Wang, *Angew. Chem. Int. Ed.*, 2018,**131**, 1042.