Electronic Supplementary Information

Enhanced visible photocatalytic activity of nanocrystalline $\alpha$-Fe$_2$O$_3$

by coupling phosphate-functionalized graphene

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**ESI-Figures:**

**ESI-Figure 1** XRD patterns (A) and Raman spectra (B) of graphenes (a: un-pretreated, b: pretreated as G, and c-e: phosphate-functionalized with 0.5 M, 1.0 M and 1.5 M phosphoric acid as PG).

**ESI-Figure 2** P2p XPS spectra of G, 0.5PG, 1.0PG and 1.5PG, in XPG X means the concentration of used phosphoric acid solution.
**ESI-Figure 3** XRD patterns. A: F, 1G-F, 3G-F and 5G-F, in XG-F X represents the mass ratio of used G to F in the resulting composite, and B: 3G-F, 0.5PG-F, 1.0PG-F and 1.5PG-F, in XPG-F X is the concentration of used phosphoric acid solution in the 3G-F composite, and the same elsewhere unless stated.

**ESI-Figure 4** Uv-vis DRS spectra of different samples.
ESI-Figure 5 SS-SPS responses. A: F, 3G-F and 1.0PG-F in different atmosphere, B: F, 1G-F, 3G-F, and 5G-F in air, and C: 3G-F, 0.5PG-F, 1.0PG-F and 1.5PG-F in air.
**ESI-Figure 6** Photocatalytic degradation. A: gas-phase acetaldehyde on F, 1G-F, 3G-F and 5G-F, B: gas-phase acetaldehyde on 3G-F, 0.5PG-F, 1.0PG-F and 1.5PG-F. (Initial concentration of aldehyde: 810 ppm, irradiation time: 1h).

**ESI-Figure 7** Electrochemical reduction of O$_2$ in the dark on F, 1G-F, 3G-F and 5G-F films (A) and on 3G-F, 0.5PG-F, 1.0PG-F and 1.5PG-F films (B) measured in an oxygen-bubbled 1.0M NaOH solution.