

Supporting Information

Engineered biochar derived from pyrolyzed waste tea as a carbon support for Fe-N-C electrocatalysts for the oxygen reduction reaction

Stefano Zago¹, Mattia Bartoli^{2,3}, Mohsin Muhyuddin⁴, Giovanni M. Vanacore⁴, Pravin Jagdale²,

Alberto Tagliaferro^{1,3}, Carlo Santoro⁴, Stefania Specchia^{1*}

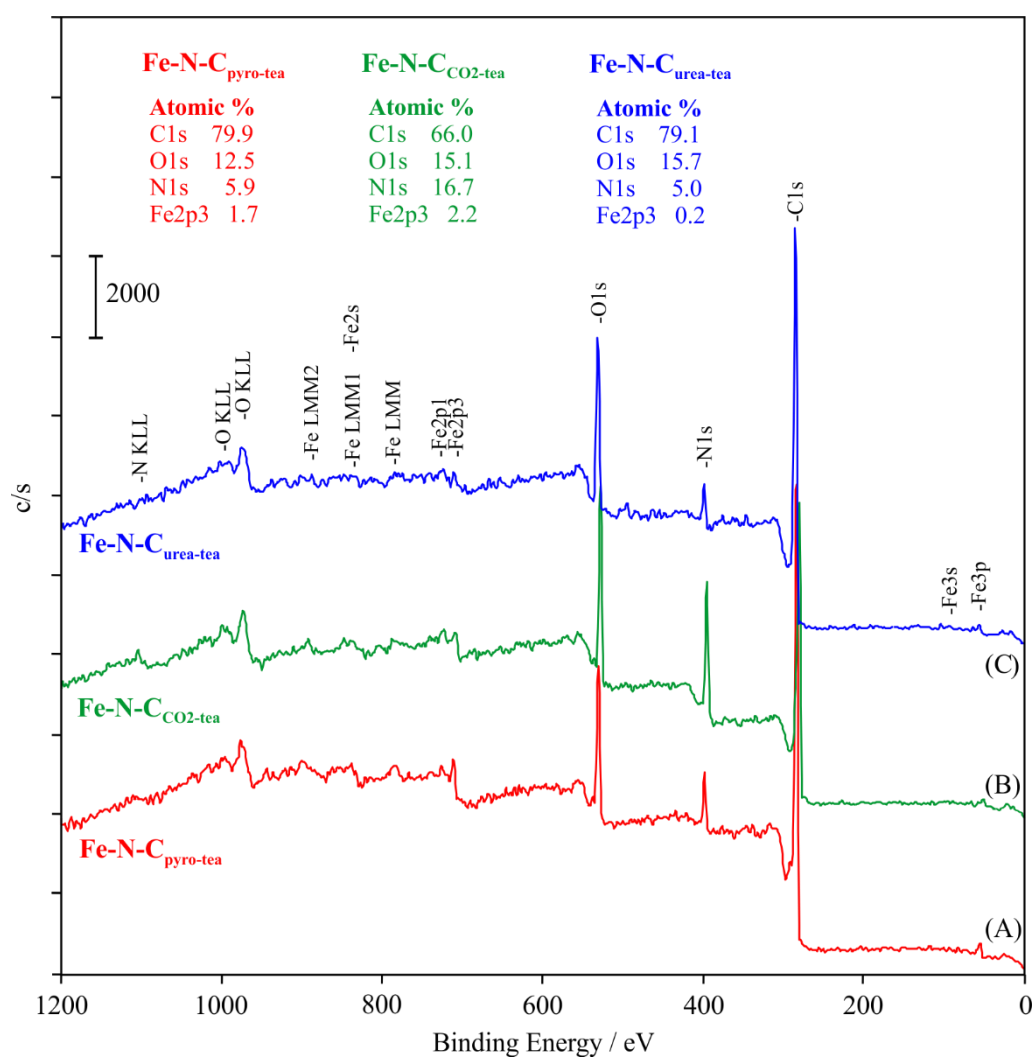


Figure S1. XPS survey spectra of Fe-N-C_{pyro-tea} (a); Fe-N-C_{CO2-tea} (b), and Fe-N-C_{urea-tea} (c).

Table S1. Main elements peak binding energies (b.e.) and relative areas (r.a.) for the three Fe-N-C electrocatalysts synthesized, from the deconvolution of the high-resolution peaks from XPS analysis (N1: pyridinic-N; N2: pyrrolic-N; n.d.: not determined).

		Fe-N-C_{pyro-tea}		Fe-N-C_{CO2-tea}		Fe-N-C_{urea-tea}	
		b.e. [eV]	r.a. [%]	b.e. [eV]	r.a. [%]	b.e. [eV]	r.a. [%]
C 1s	C-sp ³	284.4	12.0	n.d.	n.d.	284.3	11.2
	C-sp ²	284.9	51.2	284.6	50.2	284.9	45.4
	C-OH	285.4	26.6	285.7	25.6	285.6	33.9
	C=O	288.4	5.5	288.9	21.8	288.7	6.7
	COOH	292.9	3.6	292.7	1.7	292.8	1.8
	π - π^*	295.8	1.1	295.8	0.7	295.5	1.0
N 1s	N1	398.6	40.6	398.5	25.2	398.6	52.4
	N2	400.0	59.4	400.2	74.8	400.0	47.6
O 1s	C-OH	529.9	24.5	530.9	23.6	530.9	31.5
	C=O	531.5	61.1	531.9	67.1	531.9	38.2
	COOH	533.1	14.5	533.6	9.3	533.4	30.3
Fe 2p3	Fe(II)	710.6	55.1	710.6	78.1	710.9	68.1
	Fe(III)	712.5	44.9	712.5	21.9	712.5	31.9

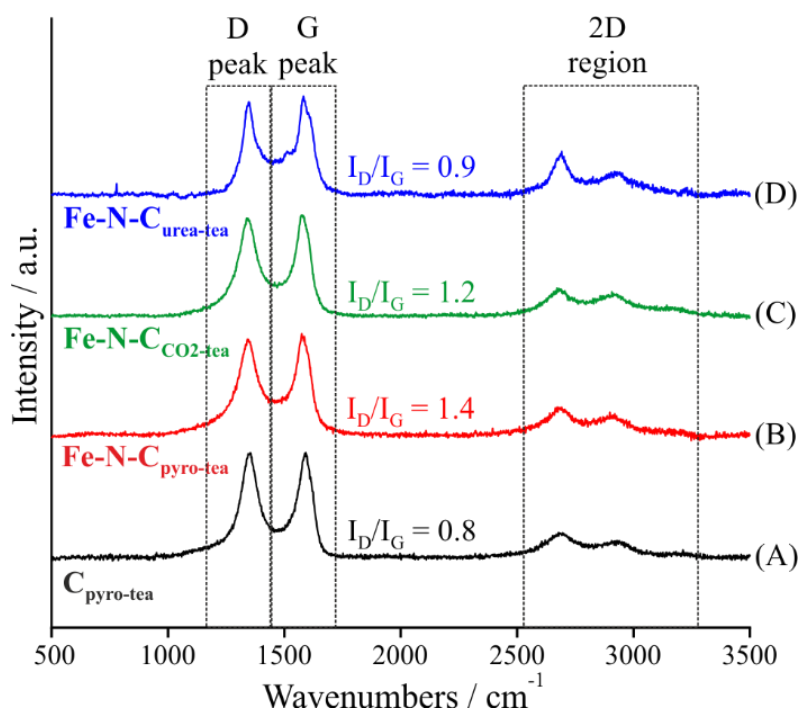


Figure S2. Raman spectra of C_{pyro-tea} (A), Fe-N-C_{pyro-tea} (B), Fe-N-C_{CO₂-tea} (C) and Fe-N-C_{urea-tea} (D).

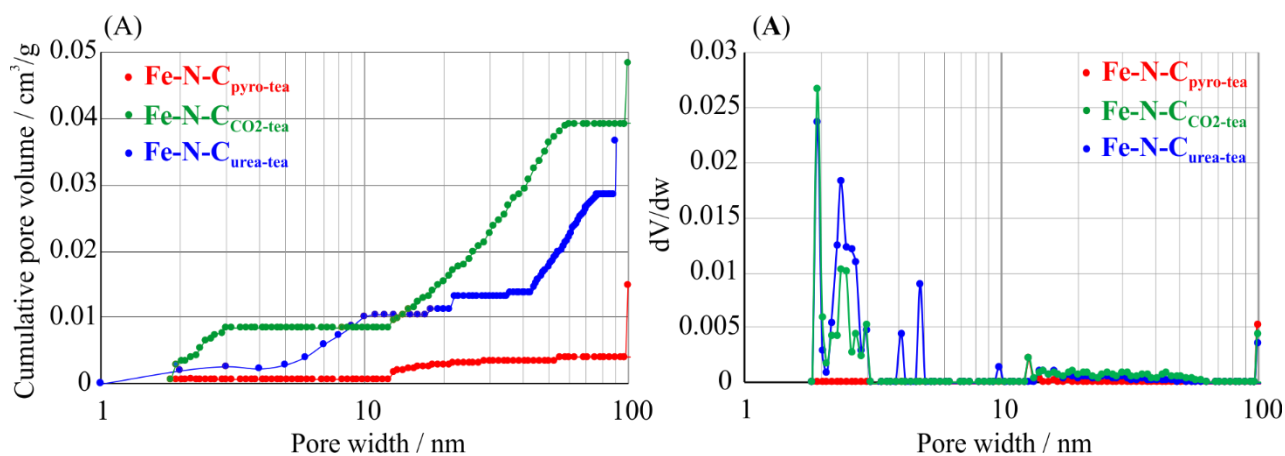


Figure S3. Cumulative pore volume (A) and dV/dw pore volume (B) for the three Fe-N-C electrocatalysts according to the N₂ @ 77 K on Carbon Slit Pores NL-DFT model by Micromeritics software.

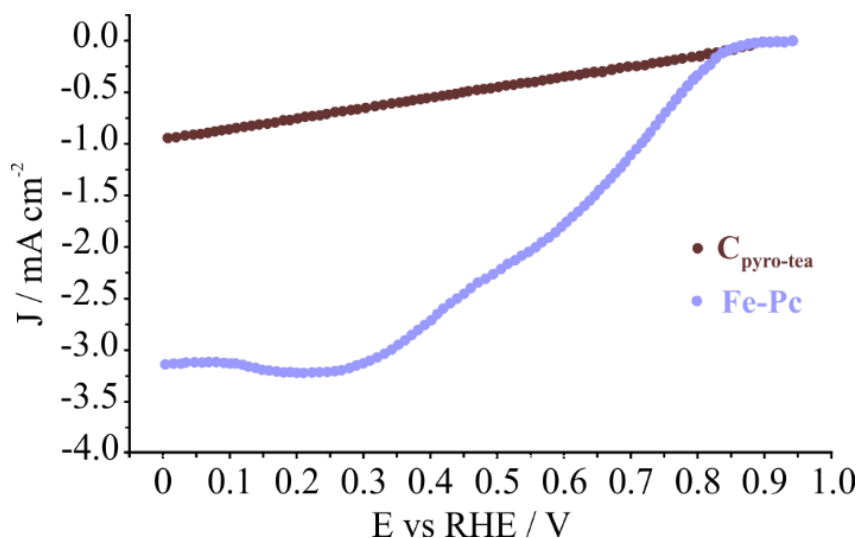


Figure S4. SCV curves of the starting materials: $C_{\text{pyro-tea}}$, (pyrolized tea leaves without further activation treatment) and Fe-Pc recorded in RDE at room temperature, in N_2 -saturated 0.1 M KOH solution, scan rate 10 mV s^{-1} , electrode loading $400 \mu\text{g cm}^{-2}$.

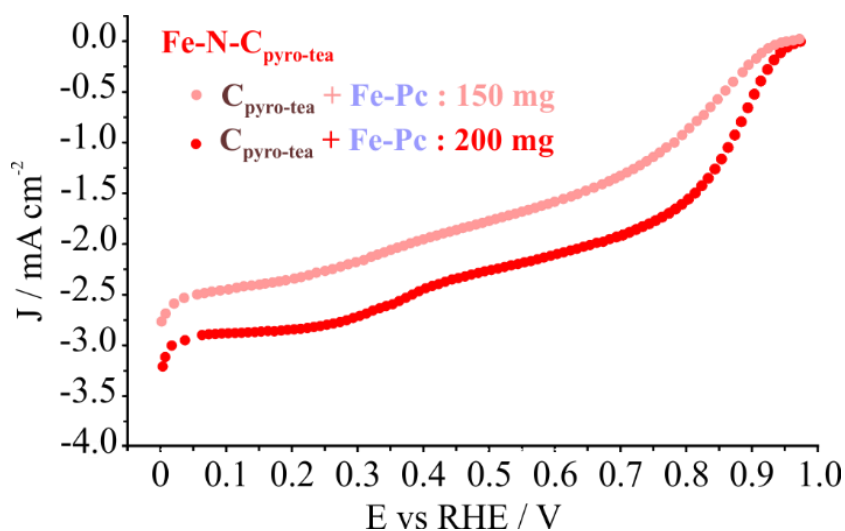


Figure S5. SCV curves of different amounts (150 and 200 mg) of $C_{\text{pyro-tea}}$ and Fe-Pc in the translational mixer for ball milling: recorded in RDE at room temperature, in N_2 -saturated 0.1 M KOH solution, scan rate 10 mV s^{-1} , electrode loading $400 \mu\text{g cm}^{-2}$. $C_{\text{pyro-tea}} : \text{Fe-Pc}$ ratio = 2:1.

Milling time: 99 min.

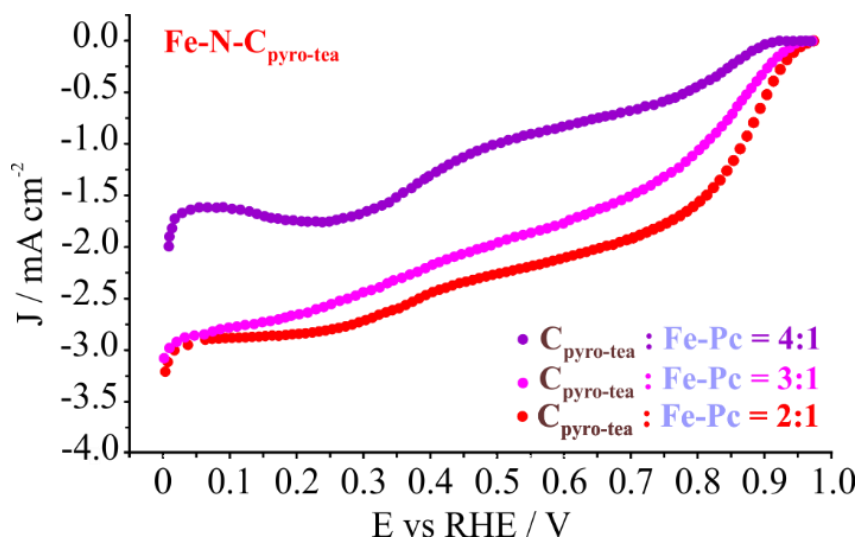


Figure S6. SCV curves of different $\text{C}_{\text{pyro-tea}} : \text{Fe-Pc}$ ratios (2:1 / 3:1 / 4:1) in the translational mixer for ball milling: recorded in RDE at room temperature, in N_2 -saturated 0.1 M KOH solution, scan rate 10 mV s^{-1} , electrode loading $400 \mu\text{g cm}^{-2}$. $\text{C}_{\text{pyro-tea}} + \text{Fe-Pc}$ amount = 200 mg. Milling time: 99 min.

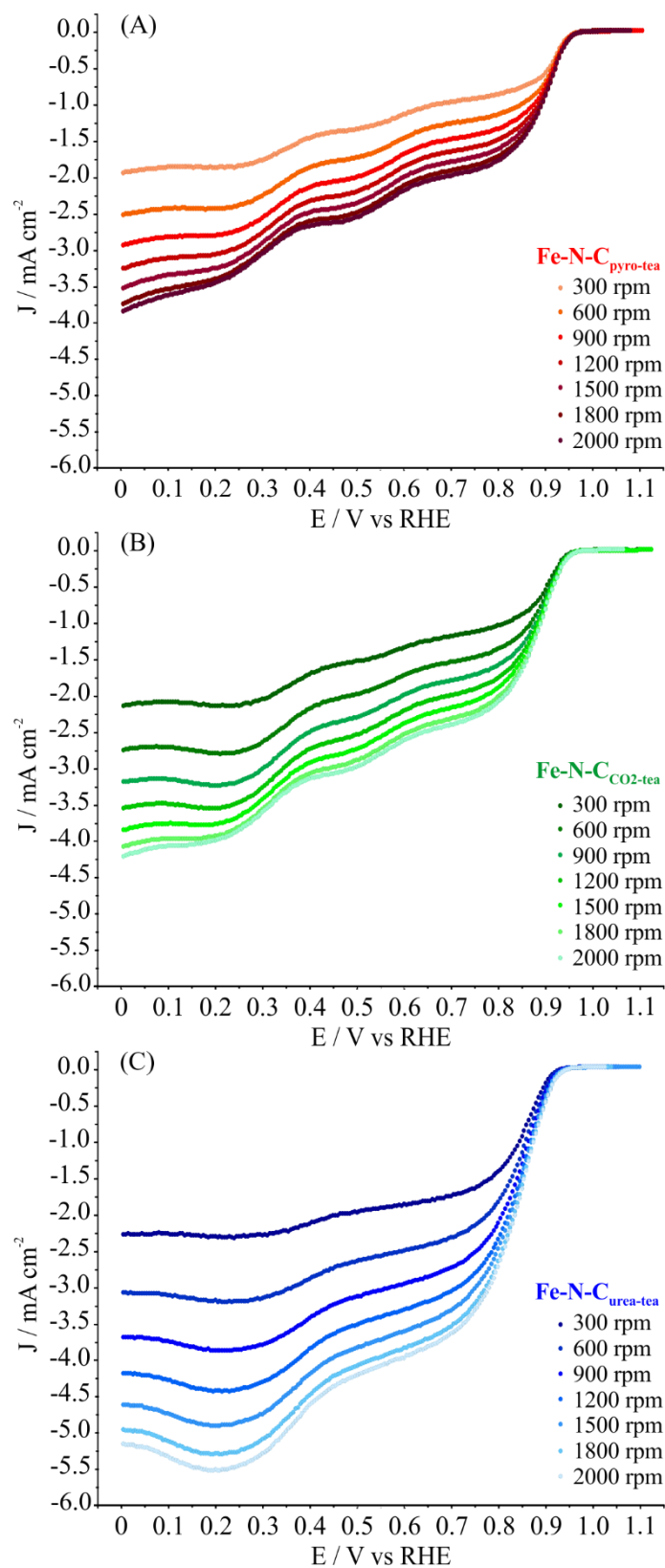


Figure S7. LSV curves of Fe-N-C_{pyro-tea} (A), Fe-N-C_{CO2-tea} (B), and Fe-N-C_{urea-tea} (C) at different rotation speeds of the RDE, recorded at room temperature, in O₂-saturated 0.1 M KOH solution (scan rate 1 mV s⁻¹, electrode loading 400 μg cm⁻²).

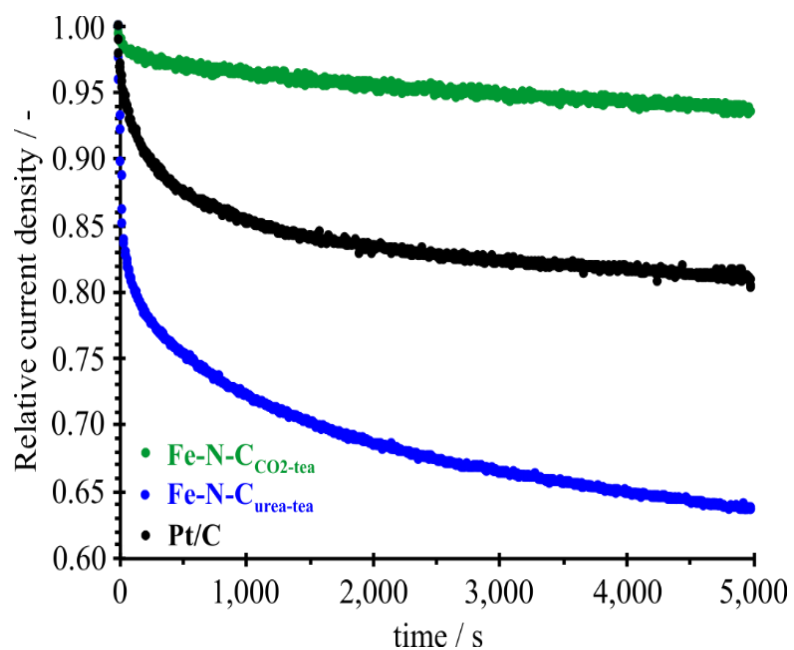


Figure S8. Chronoamperometric curves performed at 0.6 V vs RHE for 5,000 s, on Fe-N-C_{CO2-tea}, Fe-N-C_{urea-tea}, and Pt/C, in 0.1 KOH solution, saturated with O₂, rotation speed 900 rpm (electrode loading 400 $\mu\text{g cm}^{-2}$, 30 $\mu\text{g}_{\text{Pt}} \text{cm}^{-2}$ for Pt/C).

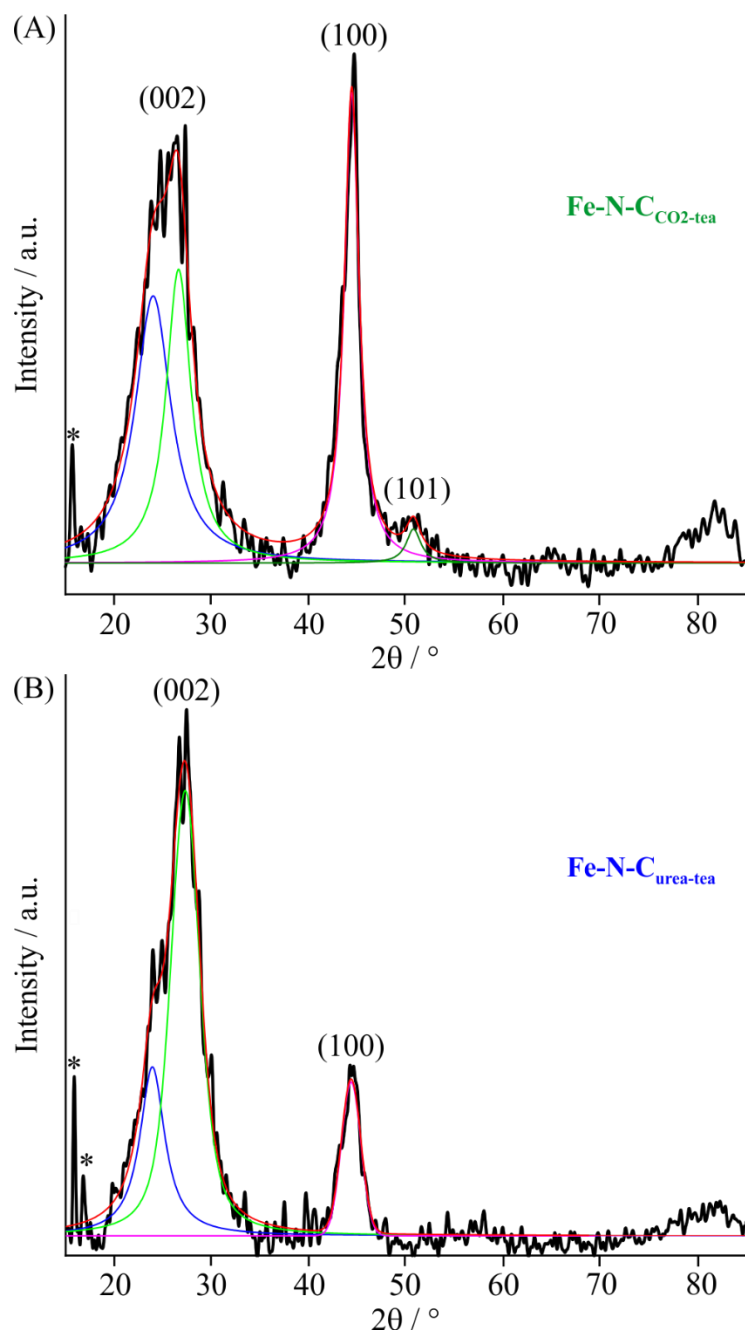


Figure S9. XRD spectra of Fe-N-C_{CO2-tea} (A) and Fe-N-C_{urea-tea} (B) from 15 up to 85 2θ . Peaks attributed to Fe₃O₄ are marked with *.