

## Supplementary information

# Unified effects of lanthanoid elements and magnetic fields on the electrocatalytic CO<sub>2</sub> reduction reaction

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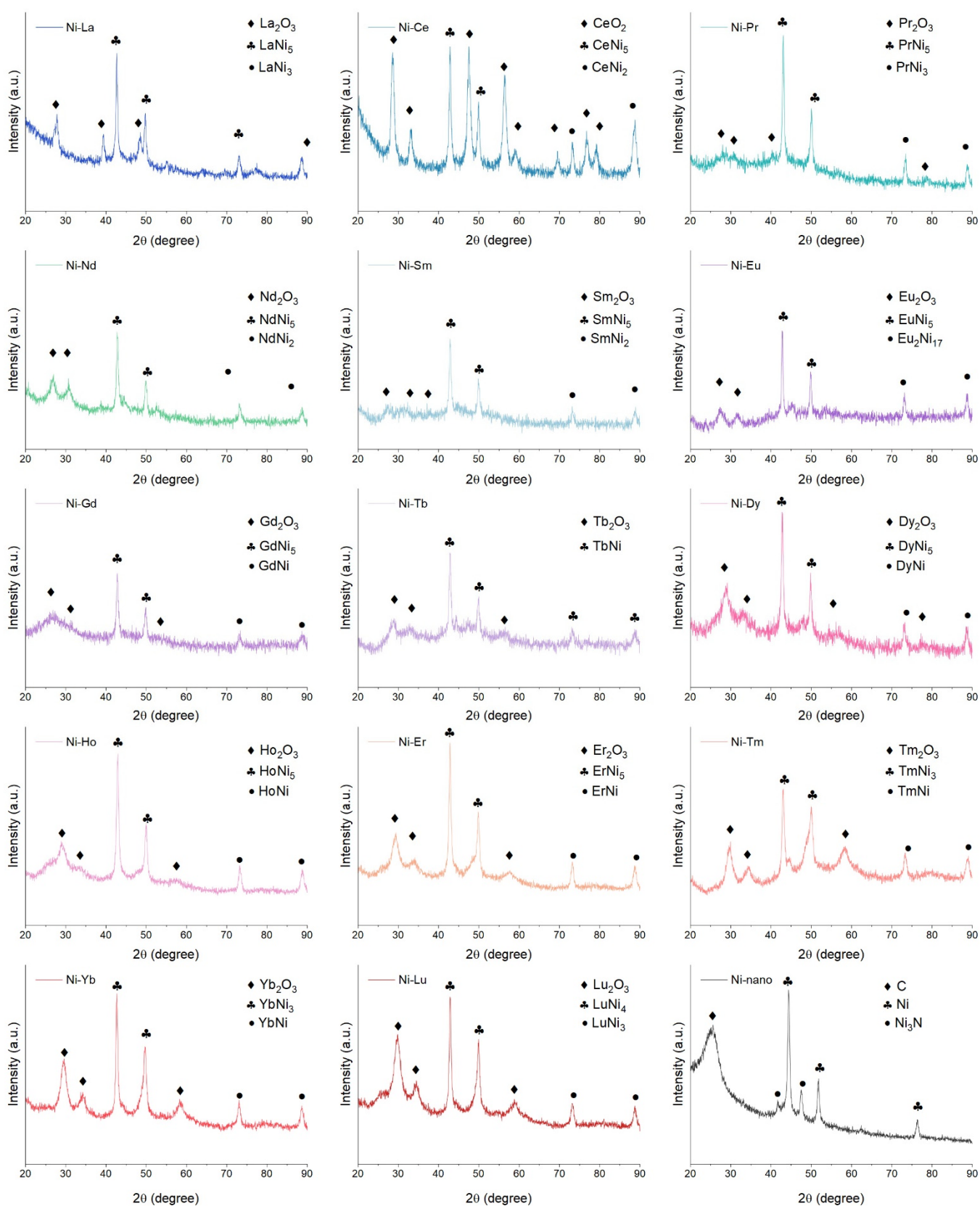
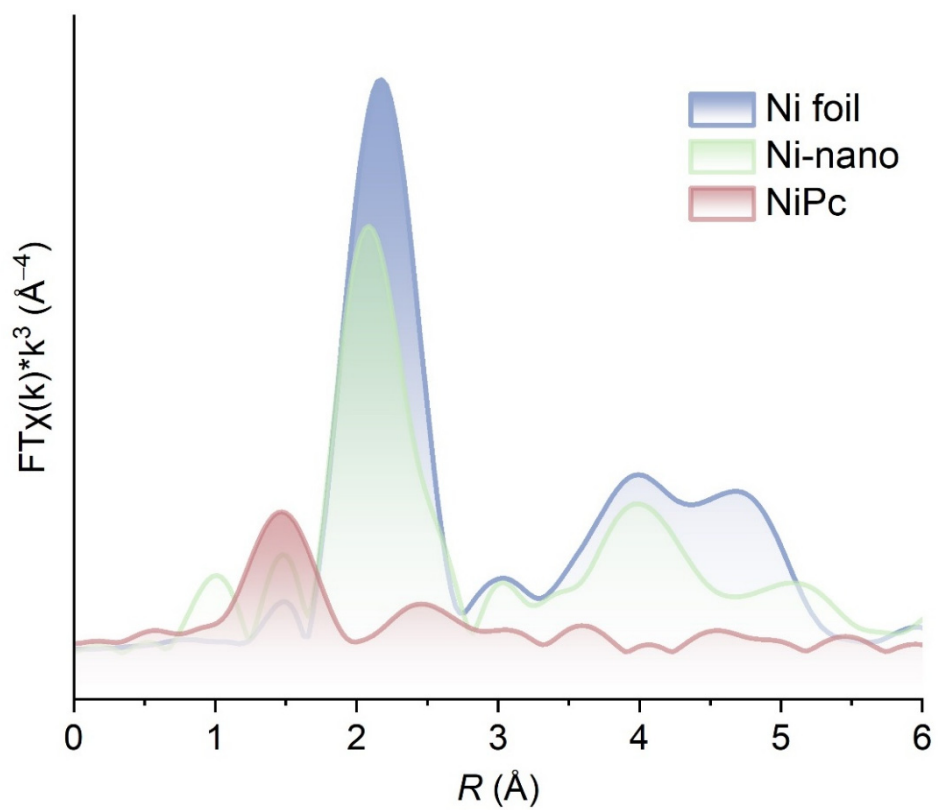
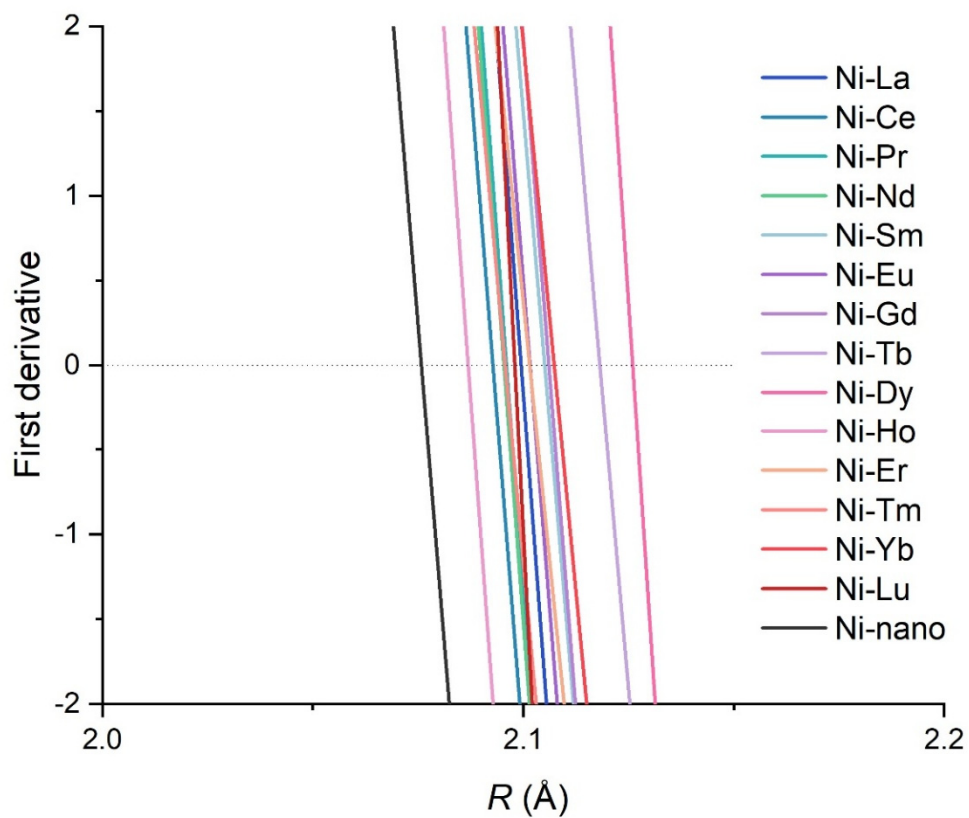


Fig. S1 XRD patterns of Ni-Ln and Ni-nano catalysts.



**Fig. S2** Fourier-transformed Ni K-edge EXAFS spectra of Ni foil, NiPc, and Ni-nano in R-space.



**Fig. S3** First derivative of the R-space EXAFS spectra shown in Fig. 3a.

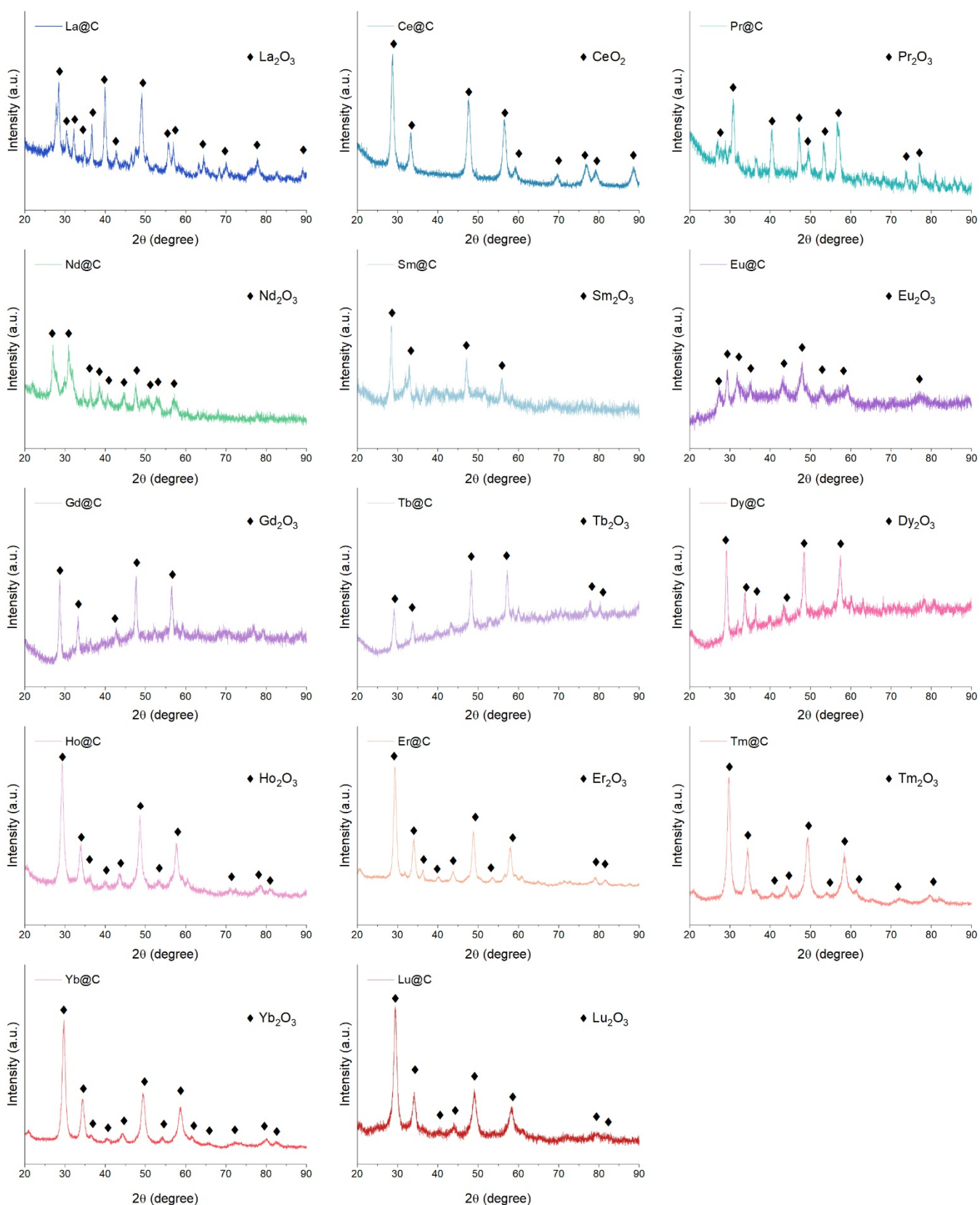
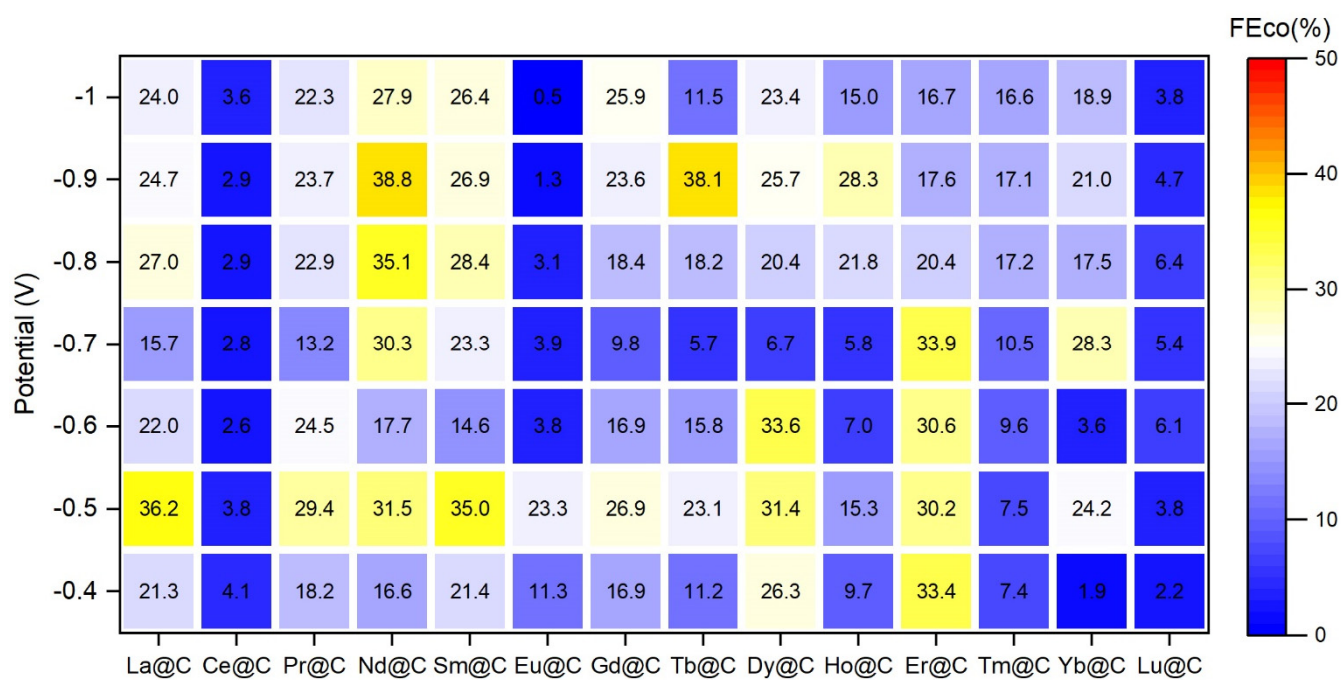
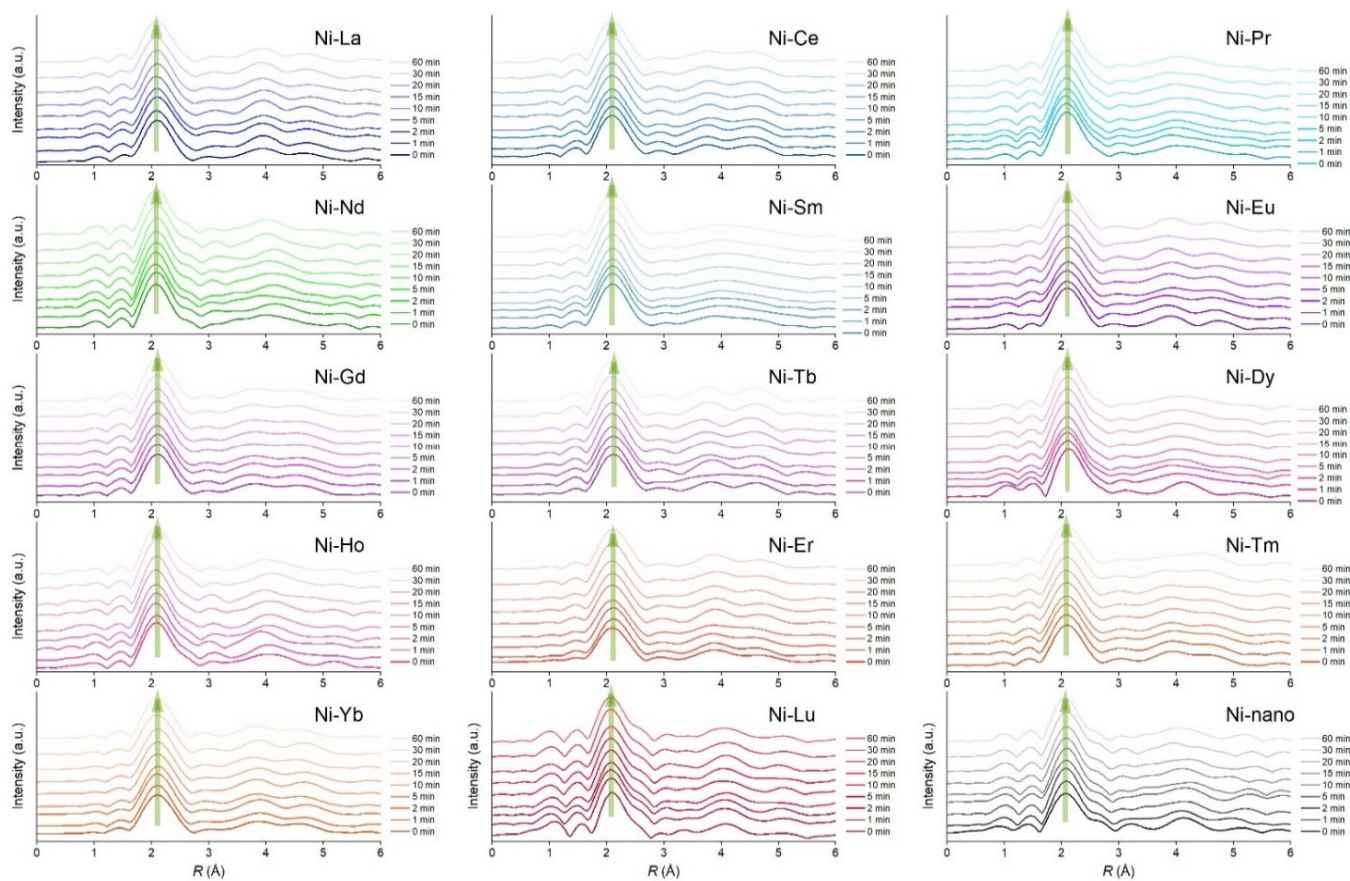


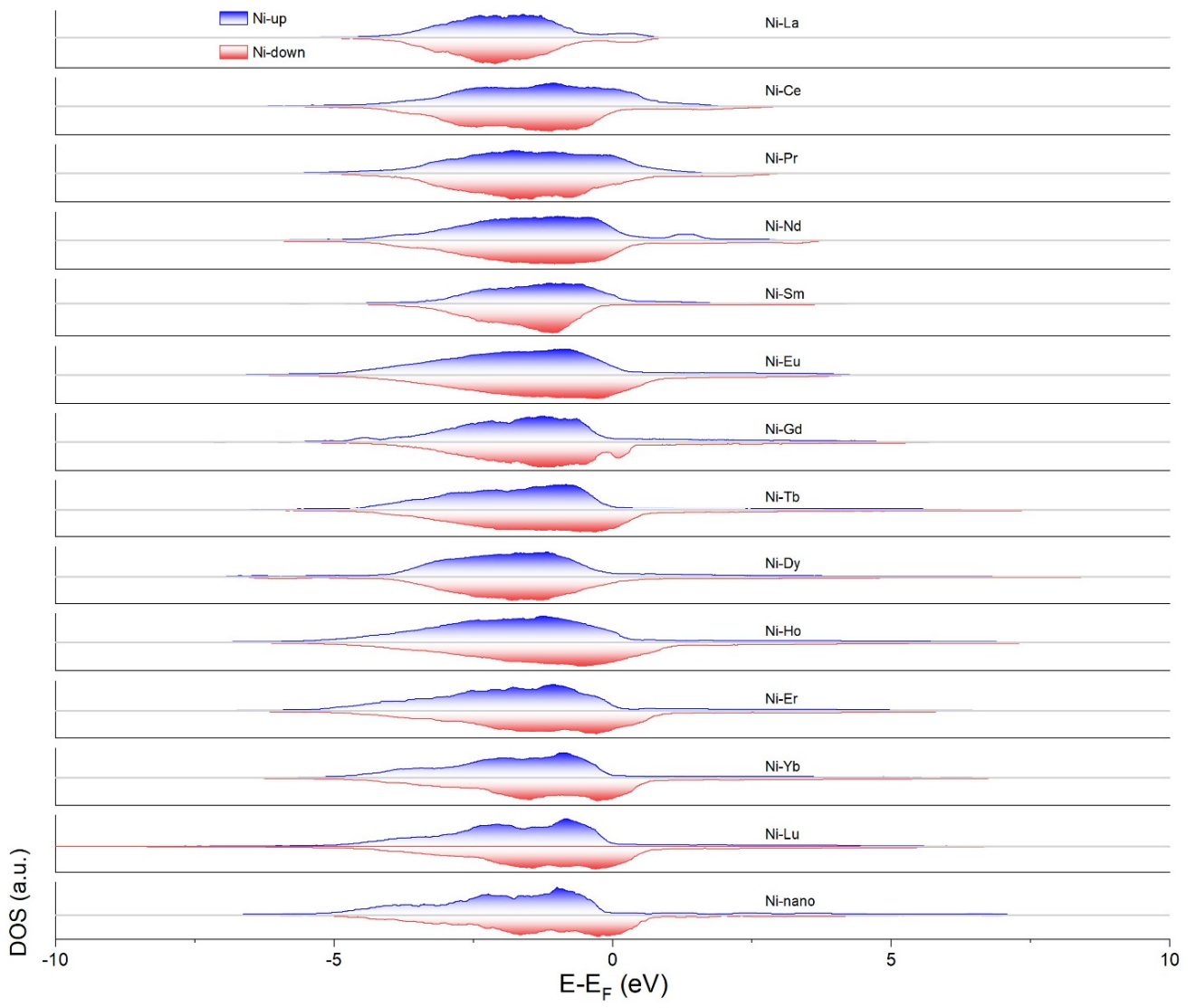
Fig. S4 XRD patterns of Ln@C control samples.



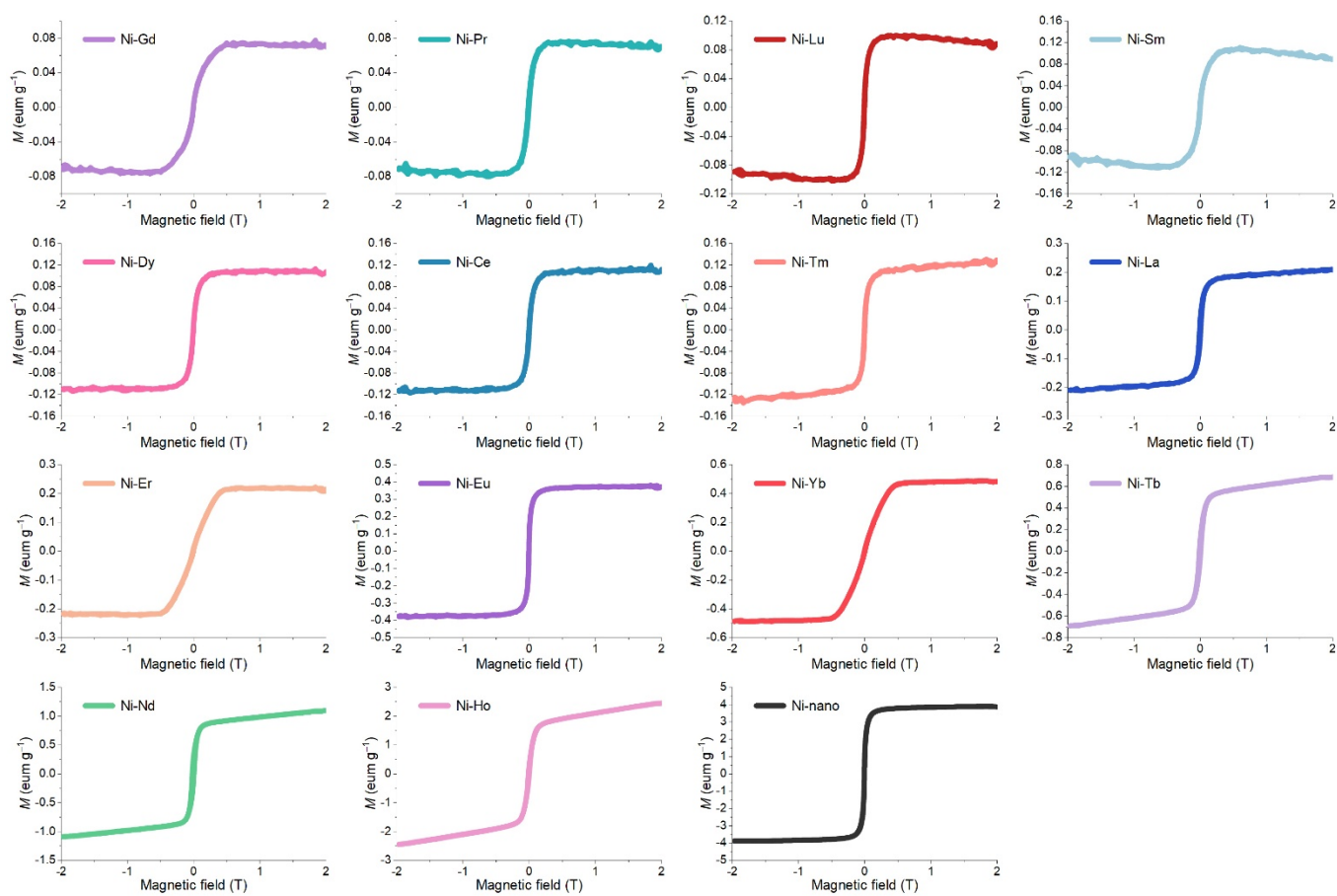
**Fig. S5** FE<sub>CO</sub> of Ln@C control samples at different applied potentials.



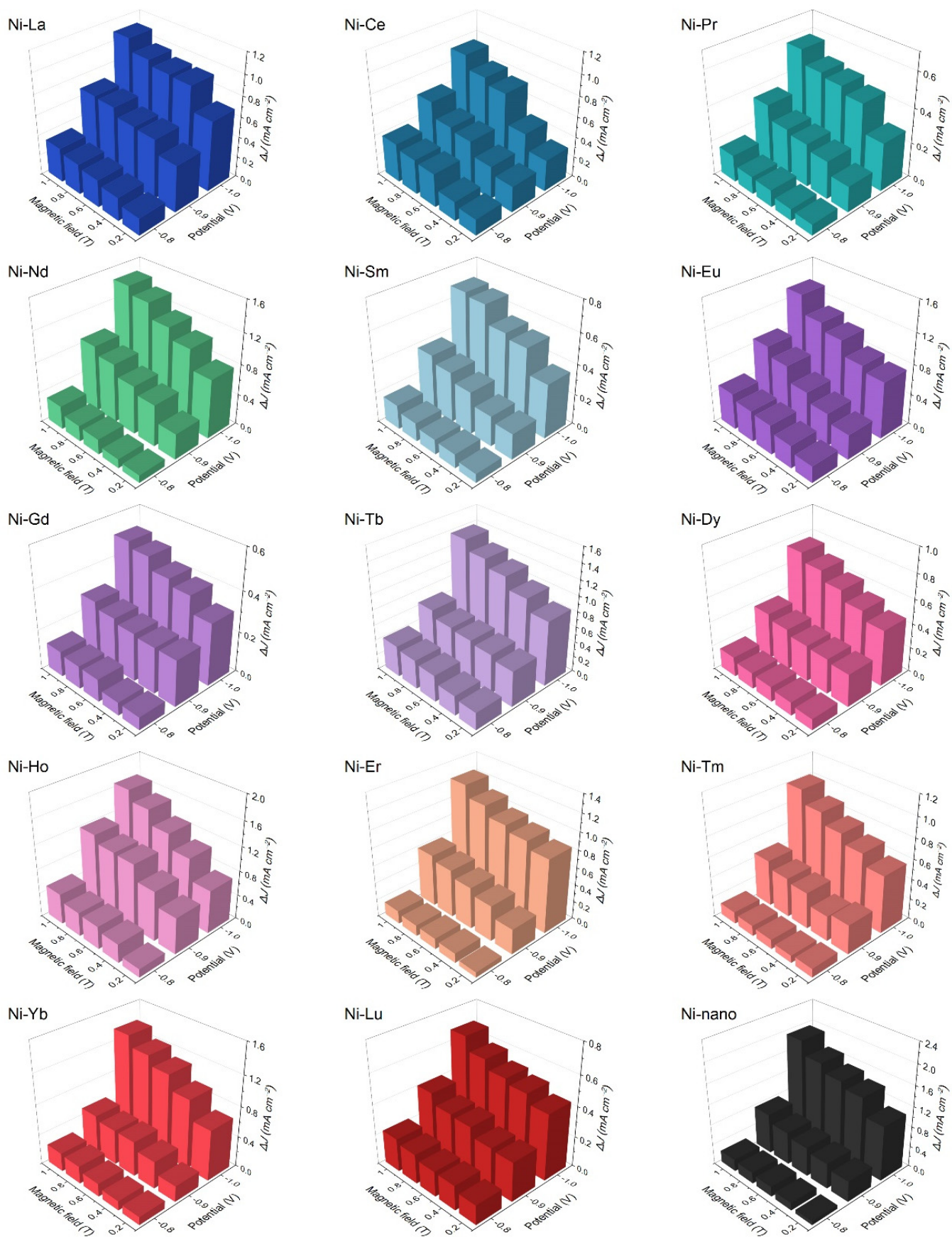
**Fig. S6** Fourier-transformed Ni K-edge EXAFS spectra of Ni-Ln and Ni-nano in R-space, measured in situ at  $-0.8$  V vs. RHE during the eCO<sub>2</sub>RR.



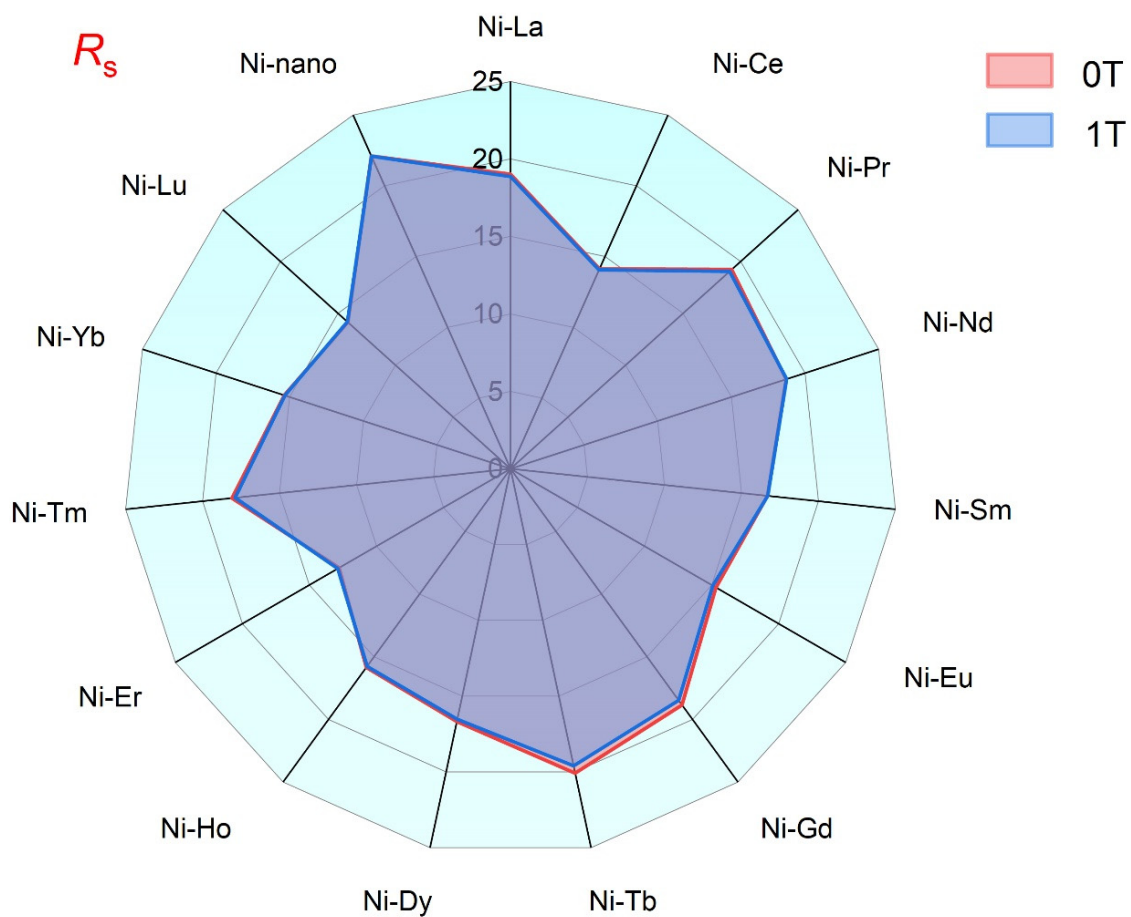
**Fig. S7** DOS of Ni atoms in Ni-Ln and Ni-nano.



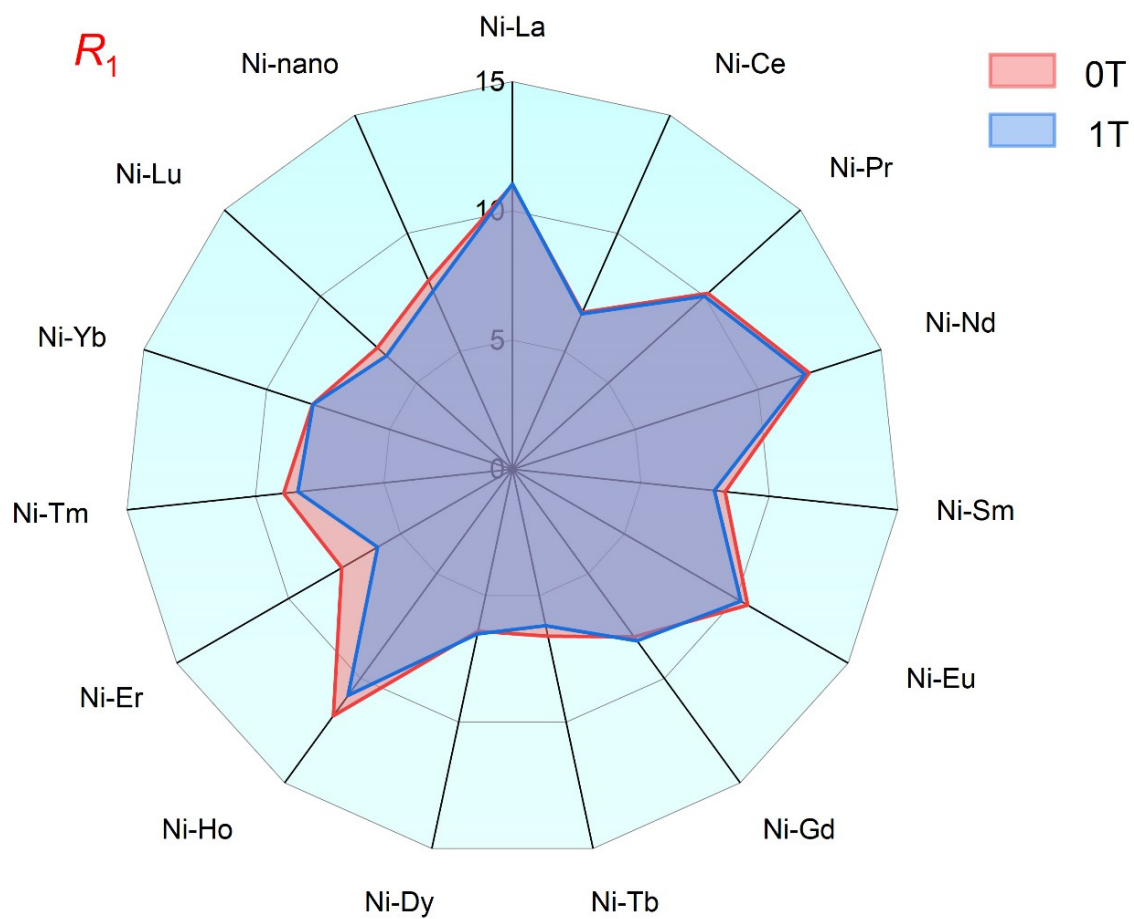
**Fig. S8** Complete magnetic hysteresis loops of Ni-Ln and Ni-nano.



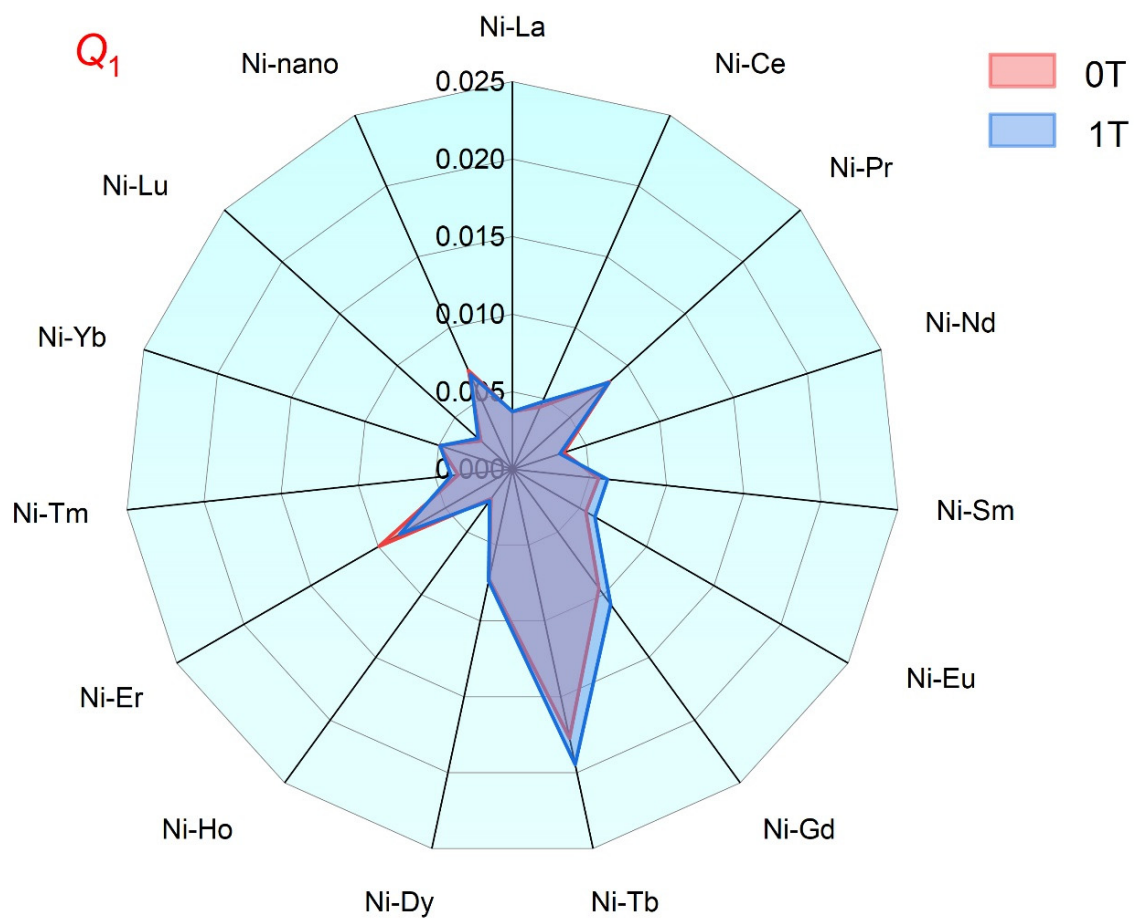
**Fig. S9**  $\Delta J$  of all Ni-Ln catalysts and Ni-nano under all combinations of applied potential and magnetic field strength tested in this study.



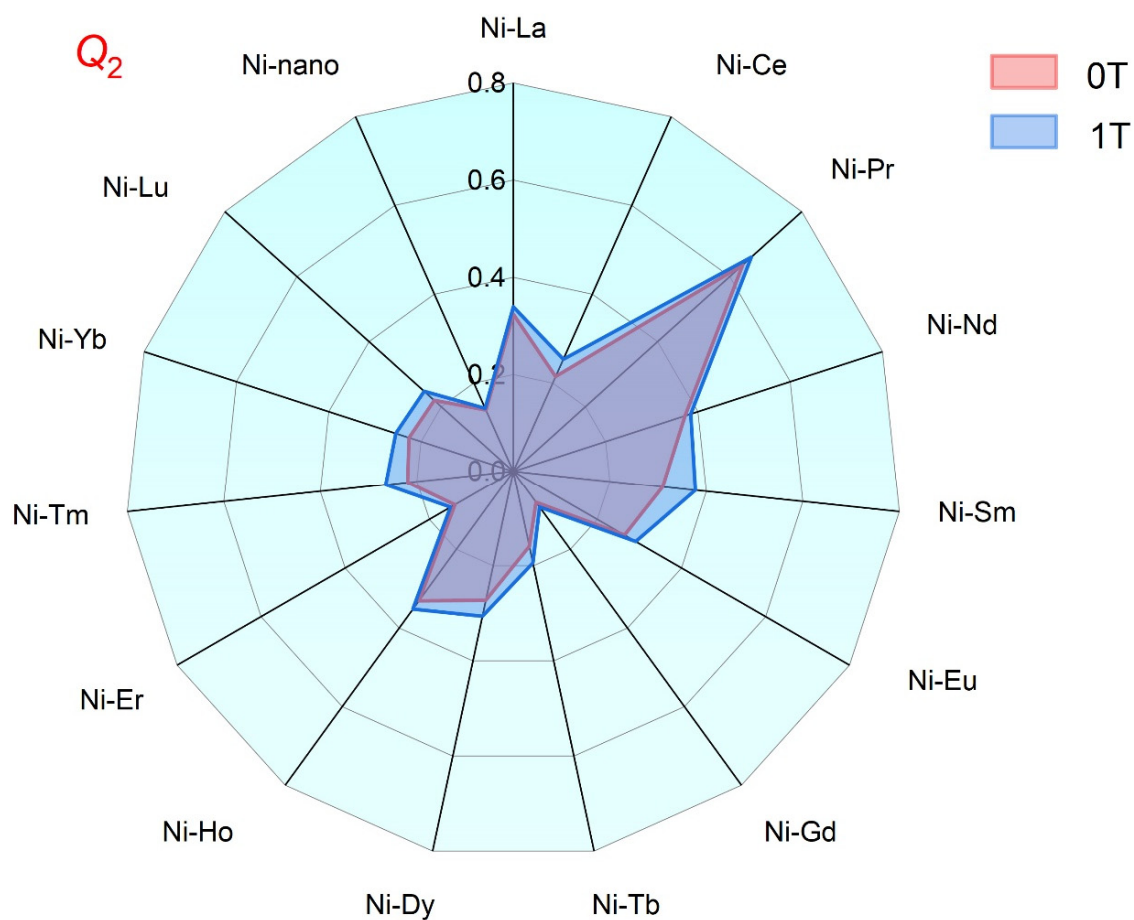
**Fig. S10** Fitted values of electrolyte resistance ( $R_s$ ) at 0 T and 1 T magnetic fields for Ni-Ln and Ni-nano. All  $R_s$  values are given in  $\Omega$ .



**Fig. S11** Fitted values of catalyst-film resistance ( $R_1$ ) at 0 T and 1 T magnetic fields for Ni-Ln and Ni-nano. All  $R_1$  values are given in  $\Omega$ .



**Fig. S12** Fitted values of the constant phase element  $Q_1$ , representing the catalyst-layer capacitance, at 0 T and 1 T magnetic fields for Ni-Ln and Ni-nano. All  $Q_1$  values are given in  $\Omega^{-1} \text{ s}^n$ .



**Fig. S13** Fitted values of the constant phase element  $Q_2$ , representing the double-layer capacitance, at 0 T and 1 T magnetic fields for Ni-Ln and Ni-nano. All  $Q_2$  values are given in  $\Omega^{-1} s^n$ .

**Table S1.** Absorption edge energy difference ( $\Delta E$ ) between the Ni K-edge XANES spectra of Ni-Ln and Ni-nano.

Sample	$\Delta E$ (eV) <sup>[a]</sup>
Ni-La	0.80
Ni-Ce	0.71
Ni-Pr	0.77
Ni-Nd	1.20
Ni-Sm	0.50
Ni-Eu	0.33
Ni-Gd	1.00
Ni-Tb	0.51
Ni-Dy	1.06
Ni-Ho	0.65
Ni-Er	1.73
Ni-Tm	0.26
Ni-Yb	0.36
Ni-Lu	1.94

[a]  $\Delta E = E(\text{Ni-Ln}) - E(\text{Ni-nano})$ .

**Table S2.** CO<sub>2</sub> adsorption energies ( $E_{\text{ads}}$ ) of Ni-Ln and Ni-nano.

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<b>Sample</b>	<b><math>E_{\text{ads}}</math> (eV)</b>
Ni-La	-1.16
Ni-Ce	-1.26
Ni-Pr	-1.23
Ni-Nd	-1.33
Ni-Sm	-0.85
Ni-Eu	-1.08
Ni-Gd	-1.10
Ni-Tb	-1.34
Ni-Dy	-0.77
Ni-Ho	-0.49
Ni-Er	-1.13
Ni-Tm	-0.76
Ni-Yb	-0.85
Ni-Lu	-0.93
Ni-nano	0.14

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**Table S3.** Optimal potential, peak CO faradaic efficiency (FE<sub>CO</sub>), and free energy barriers ( $\Delta G_1$  and  $\Delta G_2$ ) for Ni-Ln and Ni-nano.

Sample	Optimal potential (V)	Peak FE <sub>CO</sub> (%)	$\Delta G_1$ (eV)	$\Delta G_2$ (eV)
Ni-La	-0.6	96.6	-0.34	0.00
Ni-Ce	-0.6	98.2	-0.38	-0.19
Ni-Pr	-0.5	93.3	-0.43	0.13
Ni-Nd	-0.6	93.0	-0.65	0.09
Ni-Sm	-0.6	97.4	-0.15	-0.36
Ni-Eu	-0.6	93.9	-0.32	0.17
Ni-Gd	-0.6	97.8	-0.24	-0.10
Ni-Tb	-0.6	94.7	-0.45	0.10
Ni-Dy	-0.5	94.3	0.09	-0.43
Ni-Ho	-0.6	97.5	-0.10	-0.28
Ni-Er	-0.7	98.4	0.02	-0.07
Ni-Tm	-0.7	98.4	-0.02	-0.18
Ni-Yb	-0.7	95.9	0.02	-0.35
Ni-Lu	-0.6	97.8	-0.19	-0.10

**Table S4.** Saturation magnetization ( $M$ ) of Ni-Ln and Ni-nano.

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<b>Sample</b>	<b><math>M</math> (emu g<sup>-1</sup>)</b>
Ni-La	0.187
Ni-Ce	0.110
Ni-Pr	0.076
Ni-Nd	0.920
Ni-Sm	0.108
Ni-Eu	0.360
Ni-Gd	0.074
Ni-Tb	0.570
Ni-Dy	0.108
Ni-Ho	1.900
Ni-Er	0.210
Ni-Tm	0.111
Ni-Yb	0.460
Ni-Lu	0.099
Ni-nano	3.780

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**Table S5.** Charge-transfer resistance ( $R_{ct}$ ) of Ni-Ln and Ni-nano in the absence of a magnetic field (0 T).

Sample	$R_{ct}$ ( $\Omega$ )	$\Delta R_{ct}$ (%) <sup>[a]</sup>
Ni-nano	24.6	0
Ni-La	12.1	-50.8
Ni-Ce	10.4	-57.7
Ni-Pr	12.4	-49.6
Ni-Nd	13.5	-45.1
Ni-Sm	11.8	-52.0
Ni-Eu	12.6	-48.8
Ni-Gd	19.0	-22.8
Ni-Tb	16.0	-35.0
Ni-Dy	10.3	-58.1
Ni-Ho	11.2	-54.5
Ni-Er	16.2	-34.1
Ni-Tm	13.2	-46.3
Ni-Yb	11.5	-53.3
Ni-Lu	11.4	-53.7

[a] Percentage change in  $R_{ct}$  for each Ni-Ln catalyst relative to Ni-nano:  $\Delta R_{ct} = (R_{ct} - 24.6) / 24.6 \times 100\%$ .

**Table S6.** Charge-transfer resistance ( $R_{ct}$ ) of Ni-Ln and Ni-nano at 0 T and 1 T magnetic fields.

Sample	$R_{ct}$ ( $\Omega$ ) <sup>[a]</sup>	$R_{ct-magnet}$ ( $\Omega$ ) <sup>[b]</sup>	$\Delta R_{ct-magnet}$ (%) <sup>[c]</sup>
Ni-nano	24.6	19.9	-19.1
Ni-La	12.1	10.9	-9.9
Ni-Ce	10.4	7.9	-24.0
Ni-Pr	12.4	10.1	-18.5
Ni-Nd	13.5	11.1	-17.8
Ni-Sm	11.8	8.5	-28.0
Ni-Eu	12.6	10.7	-15.1
Ni-Gd	19.0	15.6	-17.9
Ni-Tb	16.0	13.1	-18.1
Ni-Dy	10.3	7.7	-25.2
Ni-Ho	11.2	8.7	-22.3
Ni-Er	16.2	12.6	-22.2
Ni-Tm	13.2	9.7	-26.5
Ni-Yb	11.5	9.9	-13.9
Ni-Lu	11.4	8.6	-24.6

[a]  $R_{ct}$  measured in the absence of a magnetic field (0 T). [b]  $R_{ct}$  measured under a 1 T magnetic field. [c]

Percentage change in  $R_{ct}$  induced by the magnetic field:  $\Delta R_{ct-magnet} = (R_{ct-magnet} - R_{ct}) / R_{ct} \times 100\%$ .