Supplementary information

Revealing the surface oxidation mechanism and performance evolution of Nd-Fe-B sintered magnets

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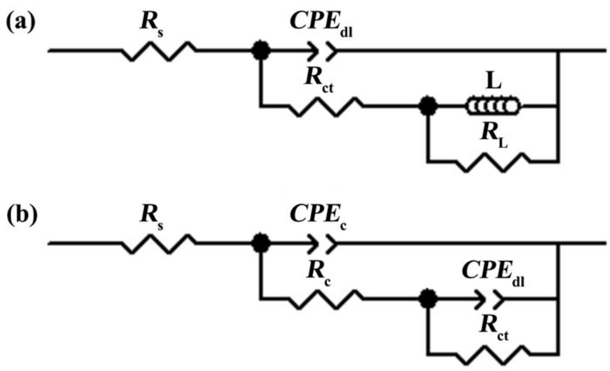

Fig. S1 Electrochemical equivalent circuit in impedance measurement for (a) the original Nd-Fe-B magnet, and (b) the oxidized magnets.

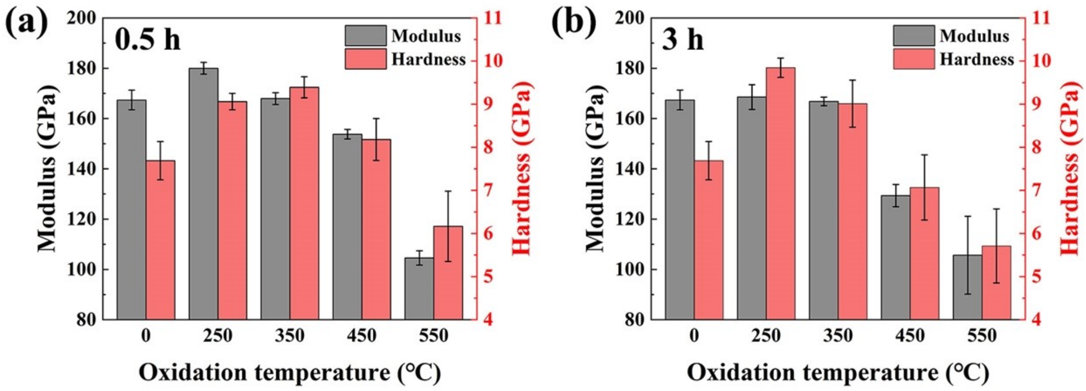

Fig. S2 Mechanical performance of (a) 0.5 h and (b) 3 h oxidized Nd-Fe-B magnets as a function of oxidation temperature, including Modulus and Hardness.

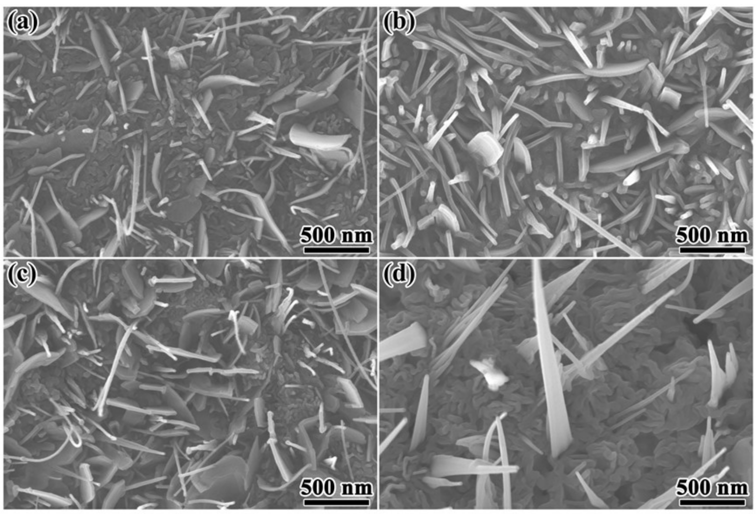

Fig. S3 Surface morphologies of (a) 550 °C-0.5 h, (b) 550 °C-3 h, (c) 650 °C-0.5 h and (d) 650 °C-3 h oxidized Nd-Fe-B magnets.

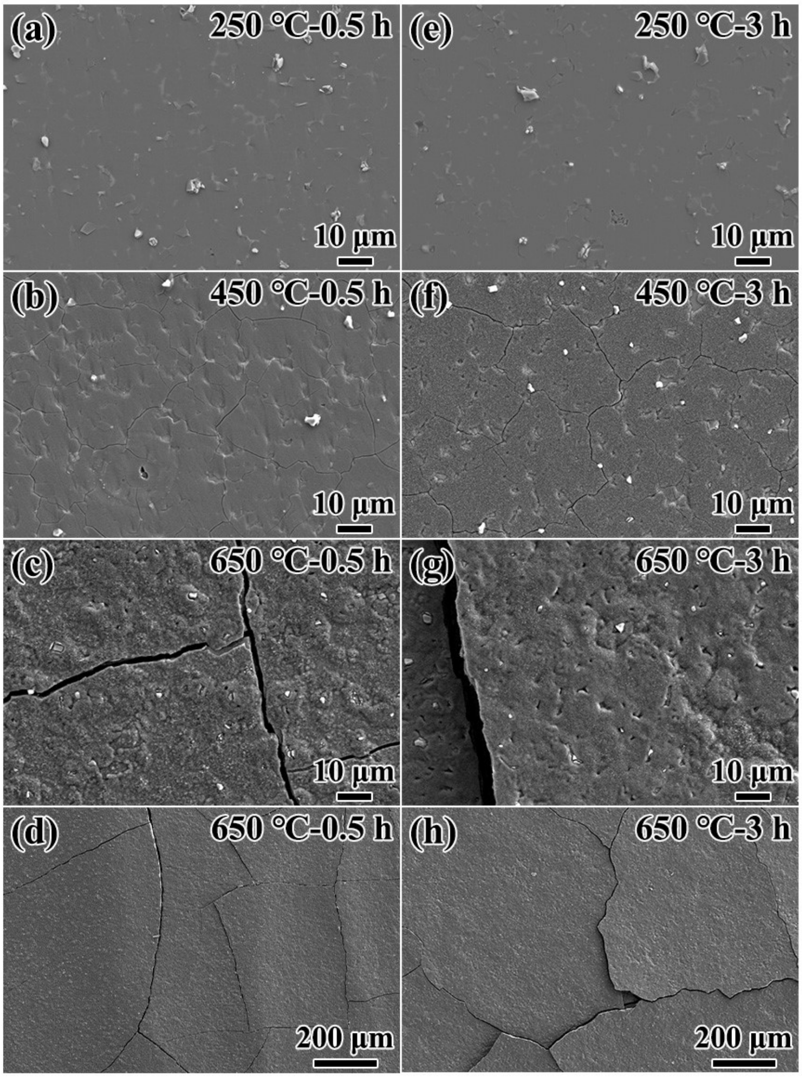

Fig. S4 Low-magnification surface morphologies of (a-d) 0.5 h and (e-f) 3 h oxidized Nd-Fe-B magnets at different temperatures: (a) 250 ℃-0.5 h, (b) 450 ℃-0.5 h, (c, d) 650 ℃-0.5 h, (e) 250 ℃-3 h, (f) 450 ℃-3 h and (g, h) 650 ℃-3 h.

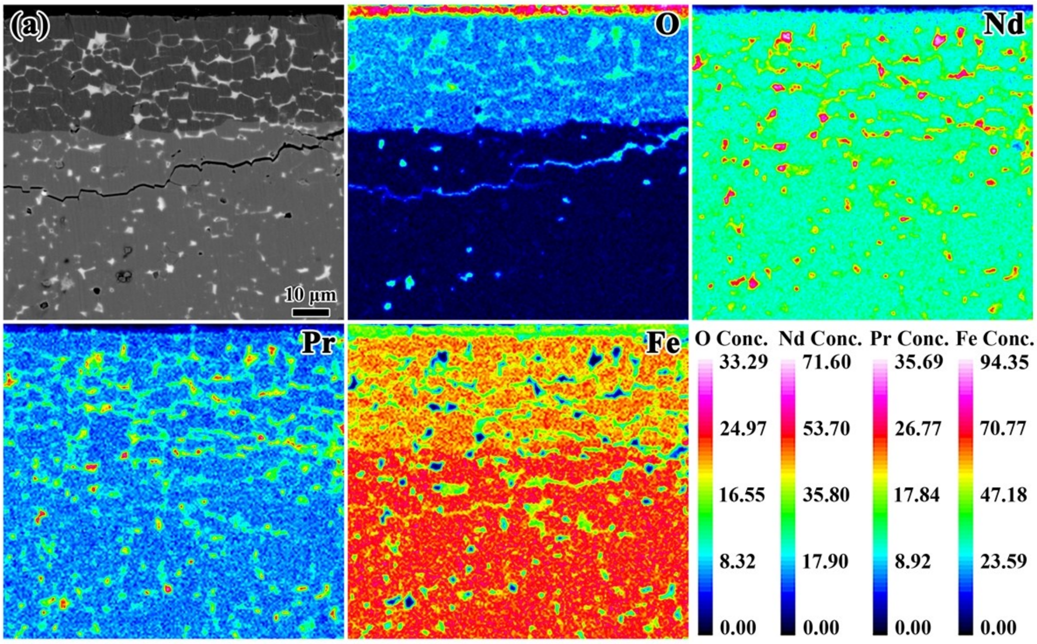

Fig. S5 Cross-sectional BSE SEM image and corresponding EPMA elemental mappings of the 650 ℃-0.5 h oxidized magnet.

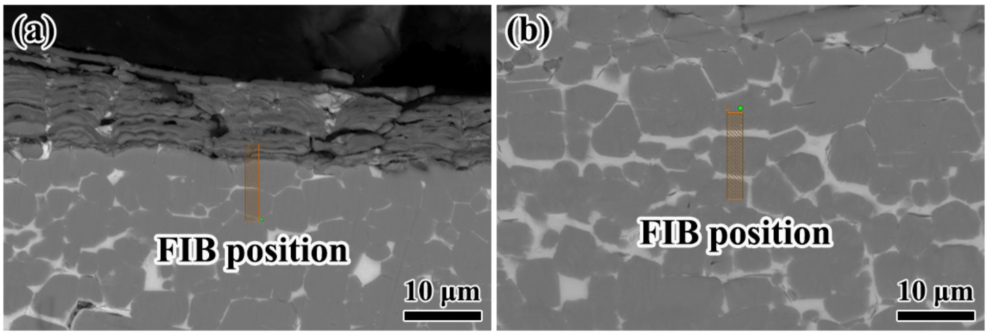

Fig. S6 Focused ion beam-assisted preparation of the TEM sample from the different areas in the 650 ℃-3 h oxidized magnet. (a) Region of interest (ROI 1) from the interface between the outmost surface zone A and the internal oxidation zone B in **Fig. 7**(a). (b) ROI 2 of the continuous and coarse grain boundary in the internal oxidation layer.

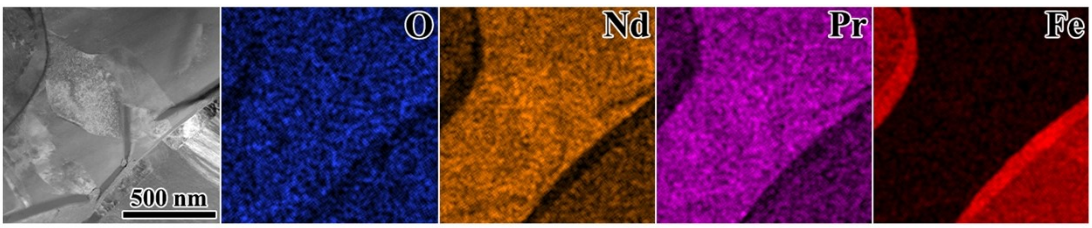

Fig. S7 STEM-EDS mappings for the continuous grain boundary region obtained from **Fig. 9**(a).

Table S1. Electrochemical parameters of the original and 0.5 h oxidized Nd–Fe–B magnets under different oxidation temperatures in 3.5% NaCl solution.

Samples	E_{corr} (V)	I_{corr} ($\mu A\cdot cm^{-2}$)	R_s ($\Omega\cdot cm^2$)	Q_c ($F\cdot cm^{-2}\cdot s^{n-1}$)	n_c	R_c ($\Omega\cdot cm^2$)	Q_{dl} ($F\cdot cm^{-2}\cdot s^{n-1}$)	n_{dl}	R_{ct} ($\Omega\cdot cm^2$)	L ($H\cdot cm^2$)	R_L ($\Omega\cdot cm^2$)
Original	-0.911	31.2	28.6	/	/	/	2.82×10^{-4}	0.710	1450	1558	594
250 ℃	-0.852	10.8	30.7	1.06×10^{-4}	0.773	12.2	6.87×10^{-5}	0.788	2527	/	/
350 ℃	-0.854	7.3	31.6	2.45×10^{-4}	0.812	22.1	4.87×10^{-9}	0.775	4584	/	/
450 ℃	-0.808	9.3	31.9	1.25×10^{-4}	0.770	62.14	1.06×10^{-4}	0.763	3328	/	/
550 ℃	-0.808	10	32.5	1.06×10^{-4}	0.766	277.8	2.26×10^{-4}	0.769	2748	/	/
650 ℃	-0.877	21.4	32.5	1.98×10^{-4}	0.830	543.0	1.37×10^{-4}	0.882	1475		

Table S2. Electrochemical parameters of the original and 3 h oxidized Nd–Fe–B magnets under different oxidation temperatures in 3.5% NaCl solution.

Samples	E_{corr} (V)	I_{corr} ($\mu A\cdot cm^{-2}$)	R_s ($\Omega\cdot cm^2$)	Q_c ($F\cdot cm^{-2}\cdot s^{n-1}$)	n_c	R_c ($\Omega\cdot cm^2$)	Q_{dl} ($F\cdot cm^{-2}\cdot s^{n-1}$)	n_{dl}	R_{ct} ($\Omega\cdot cm^2$)	L ($H\cdot cm^2$)	R_L ($\Omega\cdot cm^2$)
Original	-0.911	31.2	28.6	/	/	/	2.82×10^{-4}	0.710	1450	1558	594
250 ℃	-0.820	7.6	29.1	1.30×10^{-4}	0.797	18.2	8.07×10^{-4}	0.838	3356	/	/
350 ℃	-0.840	7.9	35.5	1.36×10^{-4}	0.742	23.3	3.75×10^{-4}	0.768	3273	/	/
450 ℃	-0.881	26.0	33.5	3.78×10^{-4}	0.787	418.9	2.34×10^{-4}	0.861	1469	/	/
550 ℃	-0.884	29.8	37.8	1.71×10^{-4}	0.718	100.9	9.46×10^{-4}	0.726	1059	/	/
650 ℃	-0.895	38.1	33.6	5.25×10^{-4}	0.764	134.6	1.13×10^{-4}	0.785	547	/	/