Supporting information

Enhanced oxide ion conductivity in sodium niobate-based ceramics

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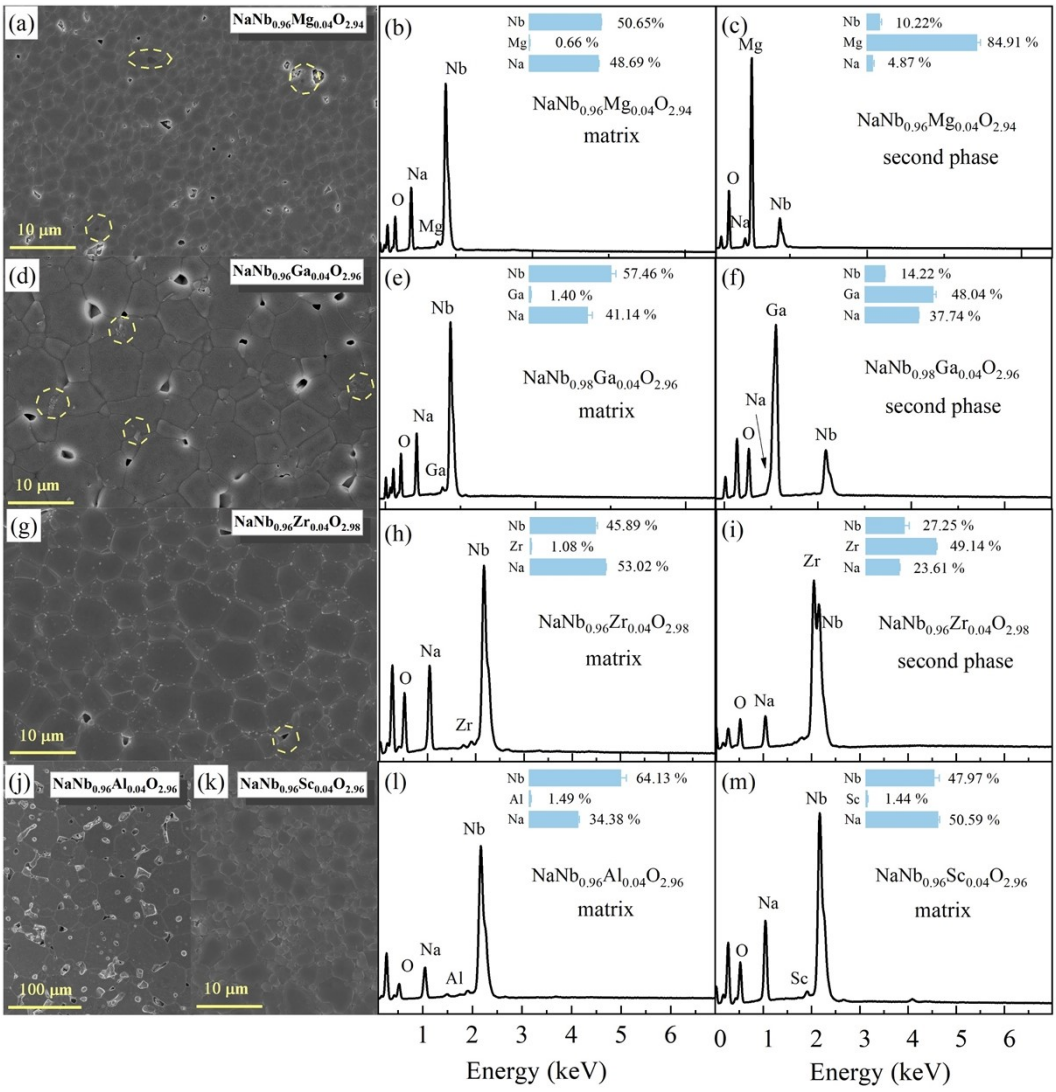

Fig. S1. SEM images and EDS spectra of $NaNb_{0.96}Mg_{0.04}O_{2.94}$, $NaNb_{0.96}Al_{0.04}O_{2.96}$, $NaNb_{0.96}Ga_{0.04}O_{2.96}$, $NaNb_{0.96}Sc_{0.04}O_{2.96}$ and $NaNb_{0.96}Zr_{0.04}O_{2.98}$ ceramics. secondary phase marked with yellow dashed circle.

Table. S1. Relative density of $NaNb_{0.96}Mg_{0.04}O_{2.94}$, $NaNb_{0.96}Al_{0.04}O_{2.96}$, $NaNb_{0.96}Ga_{0.04}O_{2.96}$, $NaNb_{0.96}Sc_{0.04}O_{2.96}$ and $NaNb_{0.96}Zr_{0.04}O_{2.98}$ ceramics. The optimum sintering temperatures are highlighted in color.

Samples	Sintering temperature (°C)	Density (g/cm^3)
$NaNb_{0.96}Mg_{0.04}O_{2.94}$	1025	4.4099
	1050	4.4299
	1075	4.3911

	1275	4.2535
$NaNb_{0.96}Al_{0.04}O_{2.96}$	1300	4.2832
	1325	4.2020
	1100	4.2681
$NaNb_{0.96}Ga_{0.04}O_{2.96}$	1125	4.3770
	1150	4.3256
	1175	4.3533
$NaNb_{0.96}Sc_{0.04}O_{2.96}$	1200	4.4133
	1225	4.3821
	1275	4.4142
$NaNb_{0.96}Zr_{0.04}O_{2.98}$	1300	4.4232
	1325	4.3943

Fig. S2 shows XRD patterns of $NaNb_{1-x}Mg_xO_{3-3x/2}$, $NaNb_{1-y}Ga_yO_{3-y}$ ceramics. No secondary phases are detected for all specimens at the detection threshold of the XRD instrument. Fig. S3 shows the typical microstructural morphologies of $NaNb_{1-x}Mg_xO_{3-3x/2}$, $NaNb_{1-y}Ga_yO_{3-y}$ ceramics. As shown in the table S1, the relative density of all samples decreases with increasing Mg^{2+} and Ga^{3+} doping content. Although XRD displays the presence of a pure perovskite structure, the microstructure of the $NaNb_{1-x}Mg_xO_{3-3x/2}$ samples also indicate a small number of secondary phases (marked with yellow dashed circles). A small amount of the secondary phases is also presented in the $NaNb_{1-y}Ga_yO_{3-y}$ specimen, indicating that MgO and Ga_2O_3 are not completely dissolved into the NN lattice. As shown in Fig. S3, there are small changes in average grain size

of $NaNb_{1-x}Mg_xO_{3-3x/2}$. The average grain size decreases and then increases with increasing x, from 2.96 μm for x = 0.02 to 2.52 μm for x = 0.04 and then to 3.09 μm for x = 0.06. The average grain size of $NaNb_{1-y}Ga_yO_{3-y}$ decreases with increasing y, from 4.69 μm for y = 0.02, to 4.41 μm for y = 0.04, and 4.06 μm for y = 0.06. The presence of the secondary phase inhibits the migration of grain boundaries, which leads to a decrease in grain size.

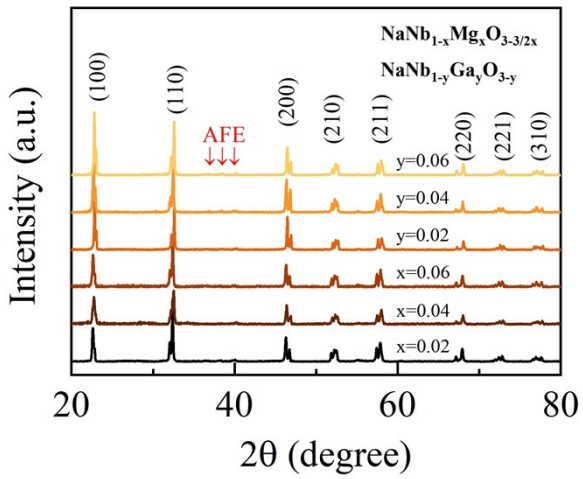

Fig. S2. XRD patterns of $NaNb_{1-x}Mg_xO_{3-3x/2}$ and $NaNb_{1-y}Ga_yO_{3-y}$.

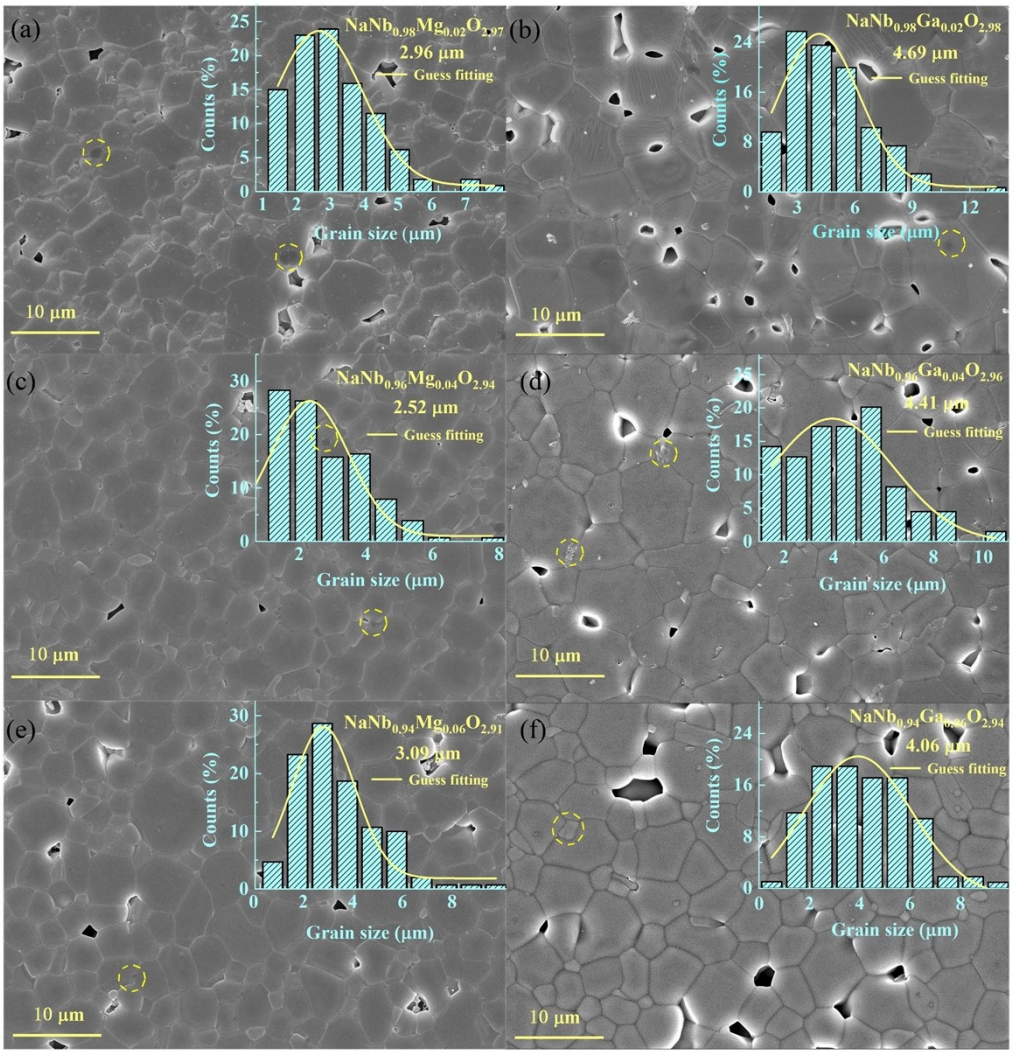

Fig. S3. SEM images of (a, c, e) $NaNb_{1-x}Mg_xO_{3-3x/2}$ and (b, d, f) $NaNb_{1-y}Ga_yO_{3-y}$ ceramics.

Table. S2. Relative density of $NaNb_{1-x}Mg_xO_{3-3x/2}$ and $NaNb_{1-y}Ga_yO_{3-y}$ ceramics.

Samples	x = 0.02	x = 0.04	x = 0.06	y = 0.02	y = 0.04	y = 0.06
Relative density	97.42%	97.20%	96.93%	96.69%	96.51%	96.33%

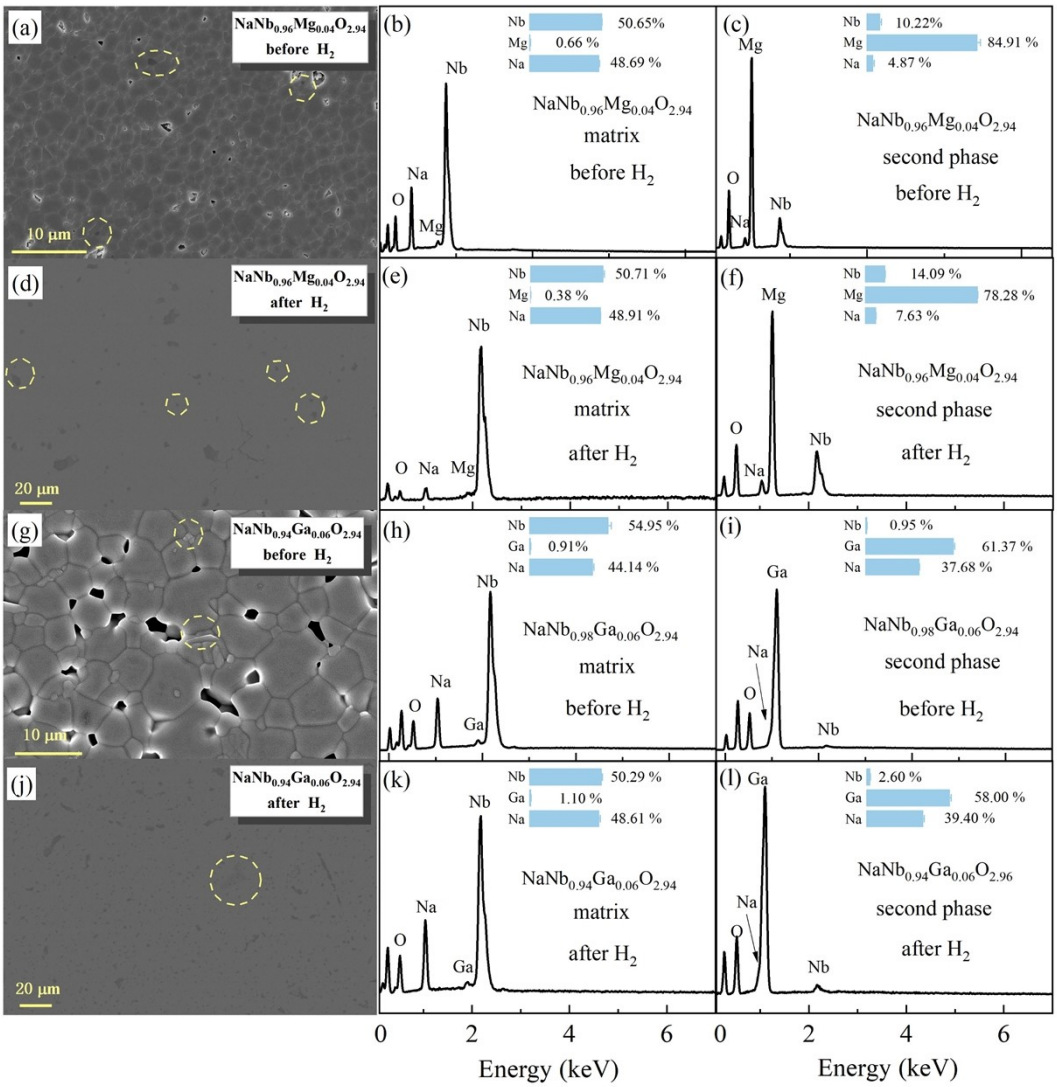

Fig. S4. SEM images and EDS spectra of $NaNb_{0.96}Mg_{0.04}O_{2.94}$ and $NaNb_{0.94}Ga_{0.06}O_{2.94}$ before and after annealed at 600 °C for 6 h in H_2. The secondary phase is marked with yellow dashed circle.