Supplementary information

Maintaining pronounced proton transportation of solid oxides prepared with a sintering additive

Alexey M. Mineev [a,b], Inna A. Zvonareva [a,c],
Dmitry A. Medvedev [a,c,*], Zongping Shao [d,e,*]

[a] Laboratory of electrochemical devices based on solid oxide proton electrolytes, Institute of High Temperature Electrochemistry, 620137 Yekaterinburg, Russia
[b] Boreskov Institute of Catalysis, 630090 Novosibirsk, Russia
[c] Ural Federal University, 620002 Yekaterinburg, Russia
[d] State Key Laboratory of Materials-Oriented Chemical Engineering, College of Chemical Engineering, Nanjing Tech University, Nanjing 211816, China
[e] WA School of Mines: Minerals, Energy and Chemical Engineering, Curtin University, Perth, Western Australia 6102, Australia
* Corresponding authors, e-mails: dmitrymedv@mail.ru (D.A.), shaozp@njtech.edu.cn (Z.S.).

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Table S1. Calcination and sintering regimes for $BaCeO_3$- and $BaZrO_3$-based ceramics prepared by solid-state synthesis technique: T_{calc} – calcination temperature, T_{sint} – sintering temperature, τ – holding time, ρ – relative density.

Materials	T_{calc}, °C/ τ, h	T_{sint}, °C/ τ, h	ρ, %	Refs
Doped $BaCeO_3$				
$Ba(Ce_{0.95}Ti_{0.05})_{1-y}Y_yO_{3-\delta}$	1200/24	1500/24	>90	19
$BaCe_{0.9}Y_{0.1}O_{3-\delta}$	1300/10	1550/10	92	20
$BaCe_{0.8}Eu_{0.2}O_{3-\delta}$	900/2	1600/10	97	21
$BaCe_{0.8}Ho_{0.2}O_{3-\delta}$	1250/10	1650/10	92	22
$BaCe_{1-x}Gd_xO_{3-\delta}$	1250/10	1650/10	96	23
$BaCe_{0.75}Y_{0.25}O_{3-\delta}$	1500/10	1675/10	>90	24
Doped $BaZrO_3$				
$BaZr_{0.8}Y_{0.2}O_{3-\delta}$	1150/5	1450/5	57	25
$BaZr_{0.9}Y_{0.1}O_{3-\delta}$	-	1600/3	80	26
$BaZr_{0.85}Y_{0.15}O_{3-\delta}$	1300/2	1670/24	84	27
$BaZr_{0.8}Y_{0.2}O_{3-\delta}$	-	1700/-	92	28
$BaZr_{0.9}Y_{0.1}O_{3-\delta}$	1250/10	1715/30	96	29
$BaZr_{0.9}Y_{0.1}O_{3-\delta}$	1200/-	1850/1	>99	26
$BaZr_{0.9}Y_{0.1}O_{3-\delta}$	1400/10	2200/-	98	30

Table S2. Crystallographic data used for EBSD data treatment.

Oxide	a, Å	b, Å	c, Å	α, °	β, °	γ, °	Sp. gr.
$BaSnO_3$	4.13	4.13	4.13	90.00	90.00	90.00	221
CuO	4.27	4.27	4.27	90.00	90.00	90.00	224

Table S3. EBSD data treatment results.

Oxide	Phase composition, %	MAD[a]	Standard deviation of MAD	Minimal value of MAD	Maximal value of MAD
$BaSnO_3$	96.98	0.87	0.16	0.39	1.80
CuO	2.07	1.36	0.29	0.50	1.96
Null solutions [b]	0.96	-	-	-	-

[a] MAD (Mean Angle Deviation) is the deviation from theoretical Kikuchi band position.
[b] Null solutions include null solutions in pores of the ceramic sample.

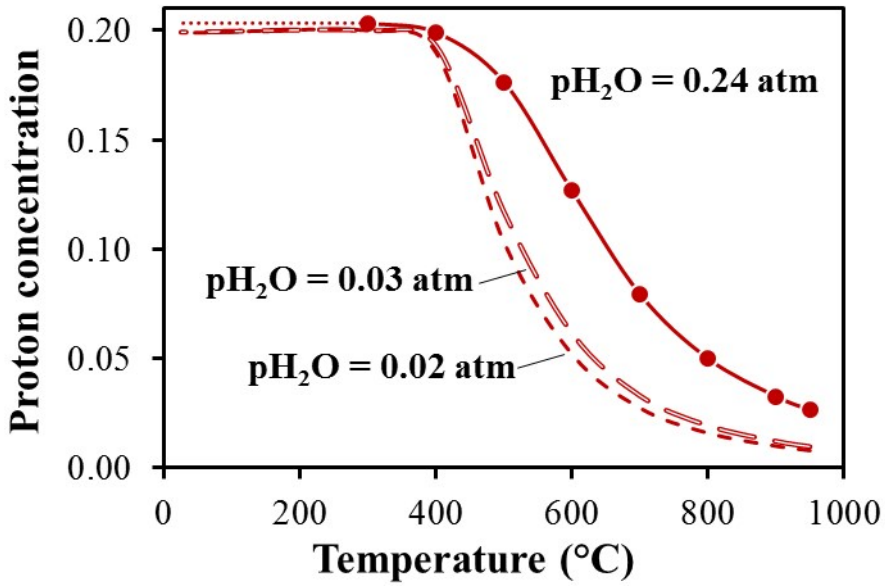

Figure S1.* Comparative analysis of proton concentrations for $BaSn_{0.8}Sc_{0.2}O_{3-\delta}$ + 0.5 wt.% CuO in a wet Ar atmosphere: pH_2O = 0.24 atm (experimental data); pH_2O = 0.02 and 0.03 atm (recalculated data).

* To compare our results with the literature data, we recalculated the proton concentrations at lower pH_2O, taking thermodynamic parameters (standard enthalpy and standard entropy) and defects relations (mass action law, electroneutrality conditions) into account. These recalculated (continuous) curves are presented in Fig. S1 based on the starting points of experimental data at pH_2O = 0.24 (red circle symbols) and determined thermodynamic parameters. As can be seen, the lower pH_2O values do not change the character of hydration curves, leading to their displacement towards lower temperatures only. The latter means that a saturation level (the same for a given material) is always reached despite of pH_2O used.

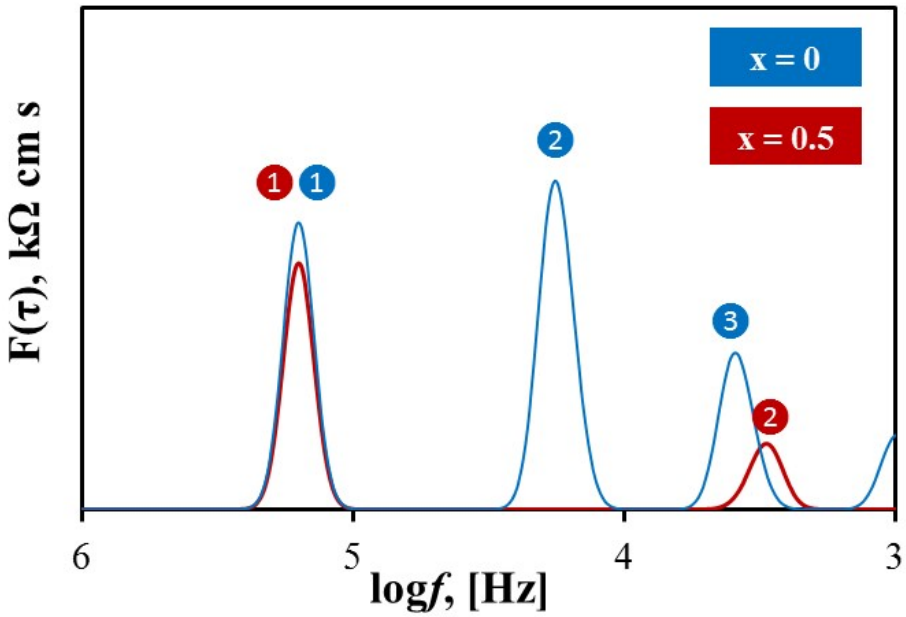

Figure S2. Comparative analysis of the DRT spectra obtained for the $BaSn_{0.8}Sc_{0.2}O_{3-\delta}$ + x wt.% CuO ceramic samples at 350 °C: ❶ is the grain process, ❷ is the grain boundary process, ❸ is the part of the electrode process.

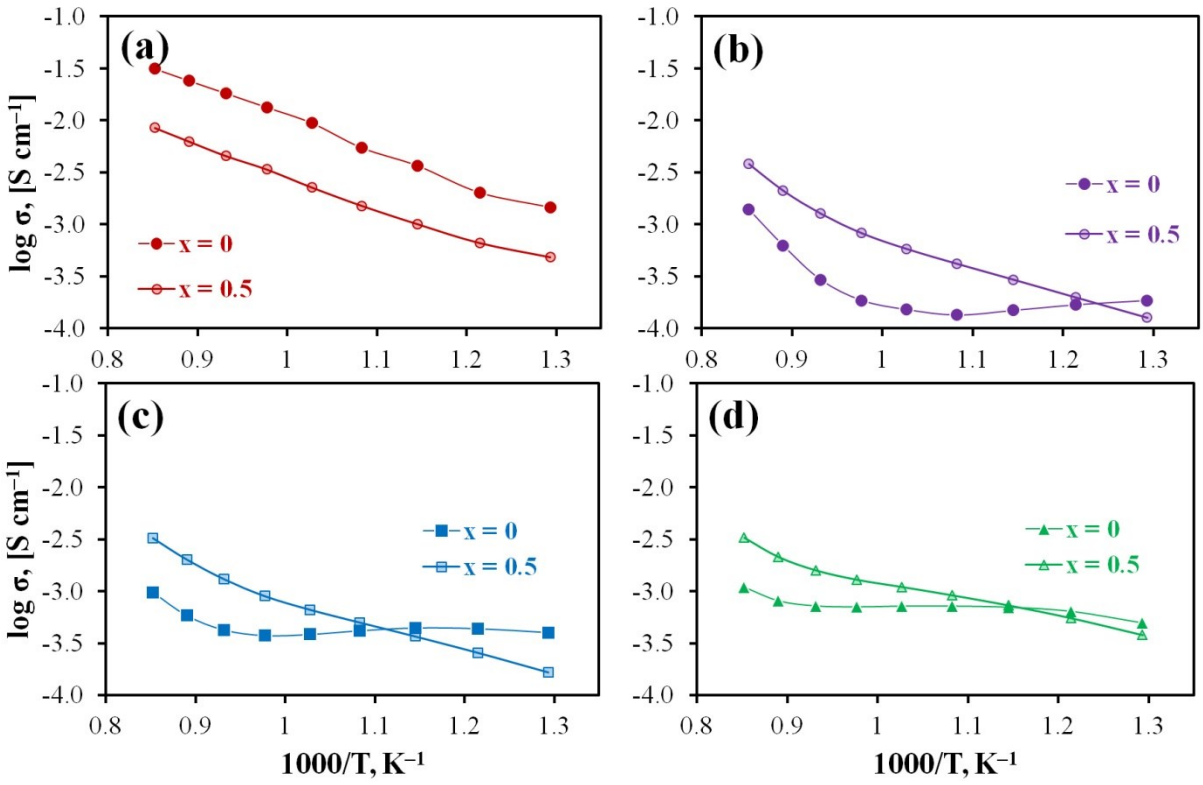

Figure S3. Comparative analysis of transport properties for $BaSn_{0.8}Sc_{0.2}O_{3-\delta}$ + x wt.% CuO: 3 vol.% H_2O/air (a), 3 vol.% H_2O/H_2 (b), 10 vol.% H_2O/H_2 (c) and 30 vol.% H_2O/H_2 (d).