

Supplementary Materials

Sintering aids engineering for high-performance energy storage in tungsten bronze ceramics

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Table S1. Comparisons of W_{rec} and η of the S2 ceramic against recently reported TTB-structured ceramics

Materials	W_{rec}	η	References
SBNSNT	4.3	91%	[1]
SBGNT	3.1	92.73%	[2]
SCBNN-CuO	3.99	85.4%	[3]
SBGNTS	3.26	91.95%	[4]
SBNNT	4.08	84.59%	[5]
BNBNT	3.41	72%	[6]
SHANNZS	2.54	86%	[7]
CNSBNT	3.04	90%	[8]
SKNS	4.57	89.3%	[9]
SLNHN	2.9	80%	[10]
CBLNF	3.42	86.23%	[11]
SSANNT	3.38	84.5%	[12]
CRBN	2.59	85.3%	[13]
SBCNS	3.9	90.5%	[14]
SCBNN-CuO	4.41	93.4%	This work

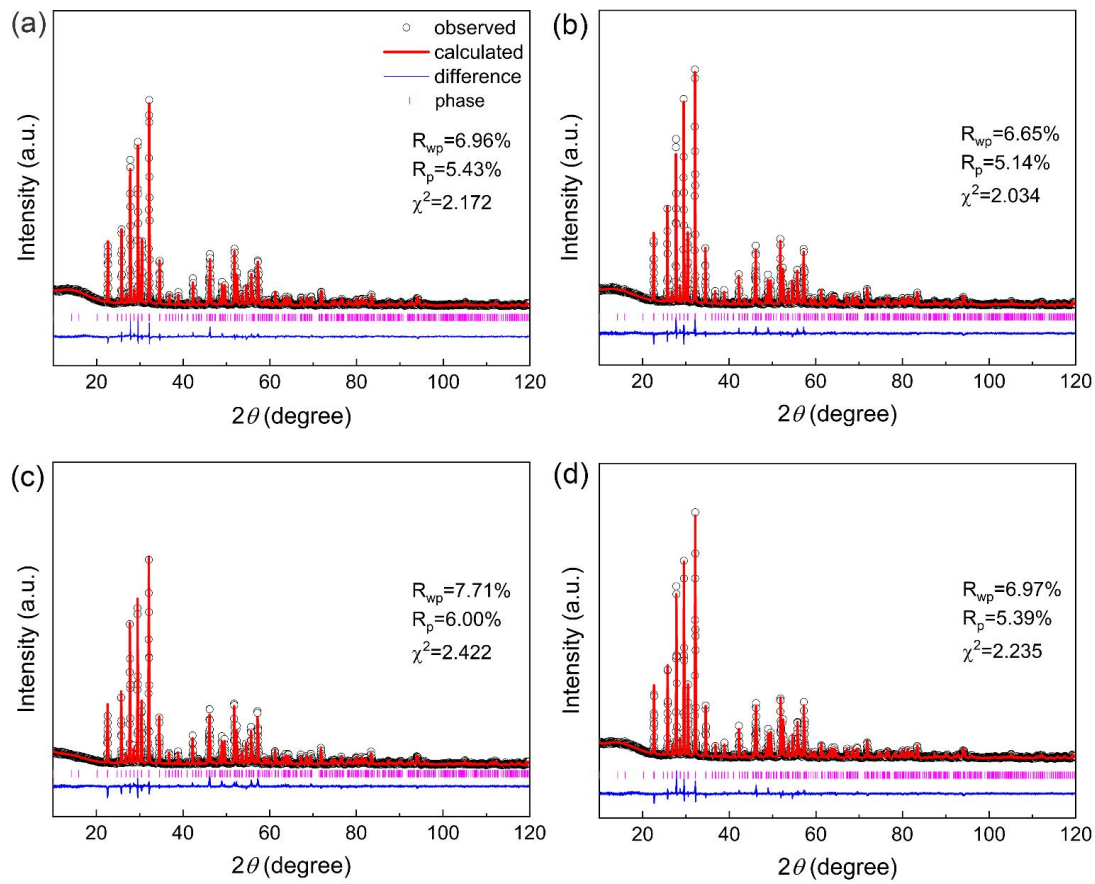


Figure S1. Structural Rietveld refinement of the measured X-ray diffraction (XRD) data for all SBN ceramics.

Table S2. Refined structural parameters for all SBN ceramics

Composition	S0	S1	S2	S3
Space group	<i>P4bm</i>	<i>P4bm</i>	<i>P4bm</i>	<i>P4bm</i>
<i>a</i> /Å	12.472508	12.468538	12.470614	12.473479
<i>b</i> /Å	12.472508	12.468538	12.470614	12.473479
<i>c</i> /Å	3.931816	3.932390	3.932233	3.931523
α /°	90	90	90	90
β /°	90	90	90	90
γ /°	90	90	90	90

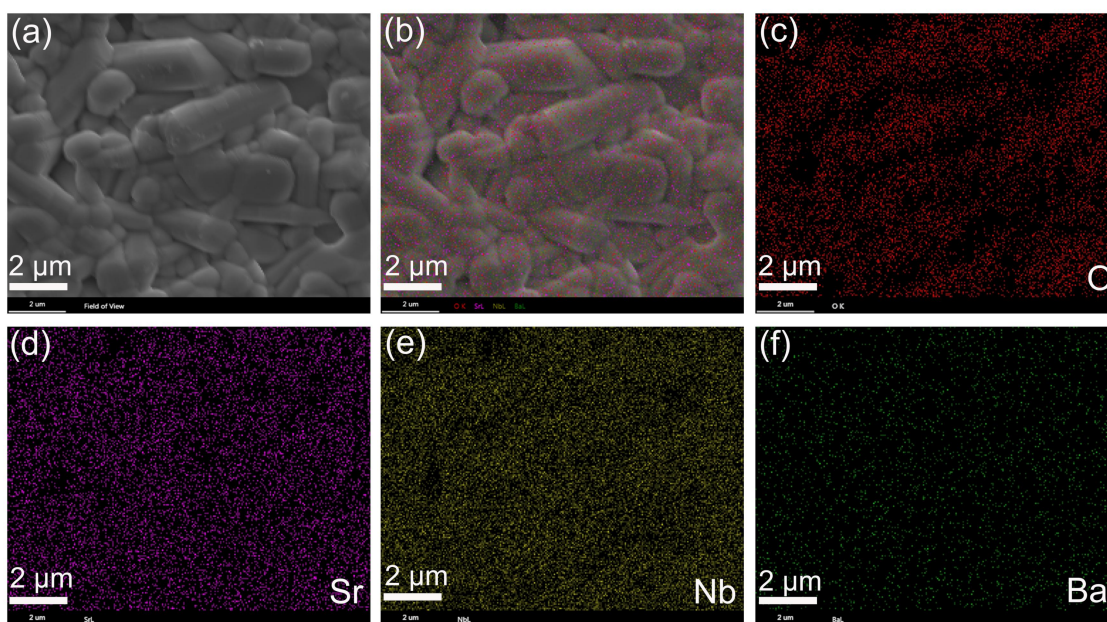


Figure S2. SEM images and EDS mappings of S0 sample.

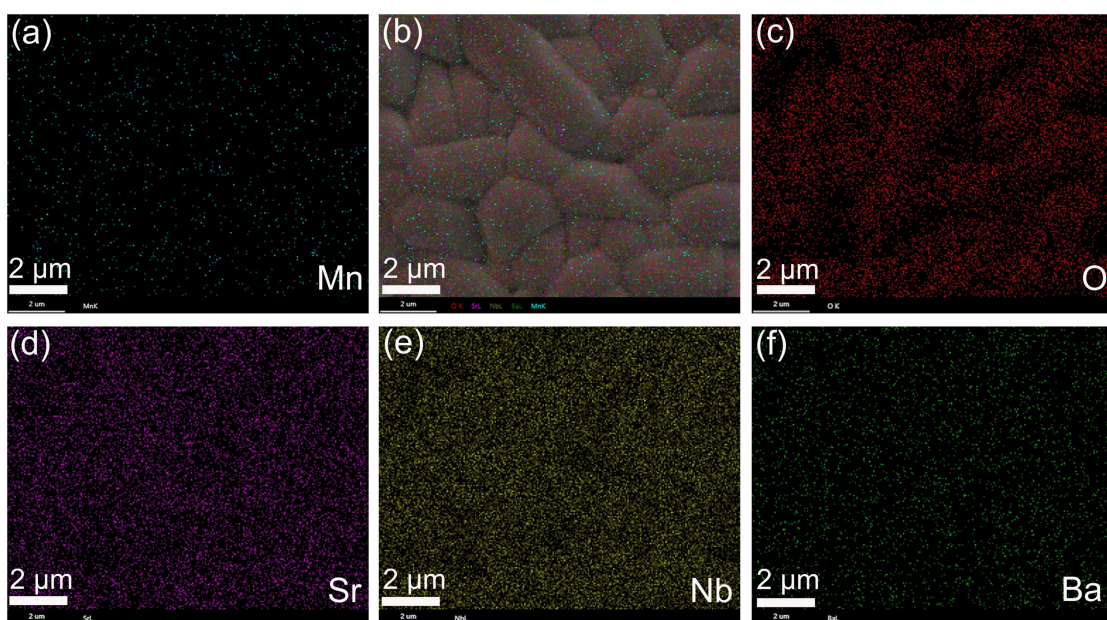


Figure S3. SEM images and EDS mappings of S1 sample.

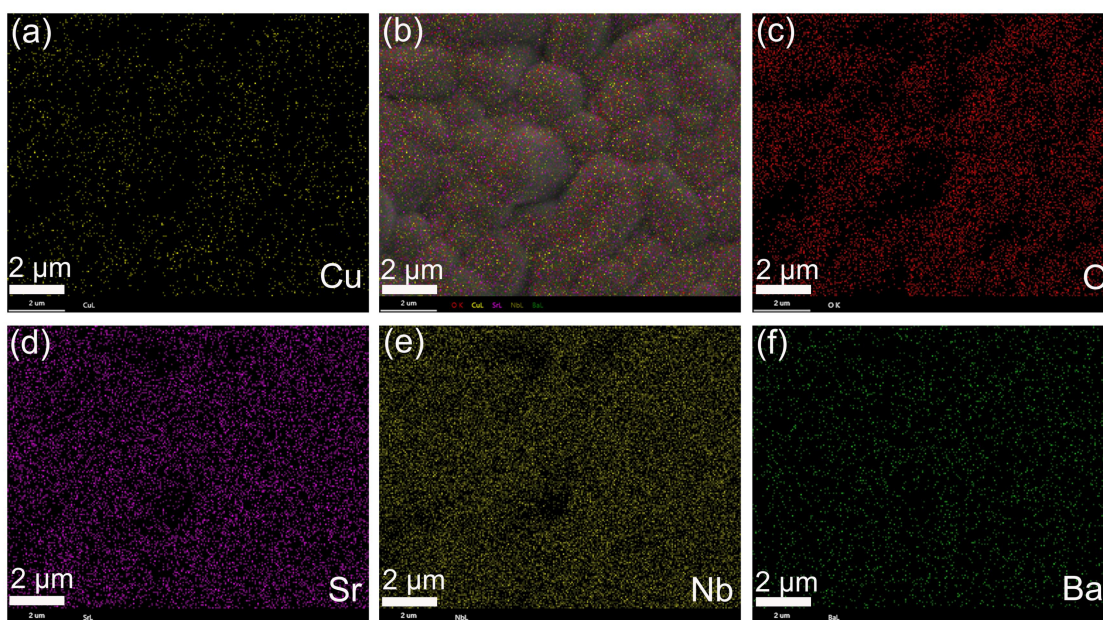


Figure S4. SEM images and EDS mappings of S2 sample.

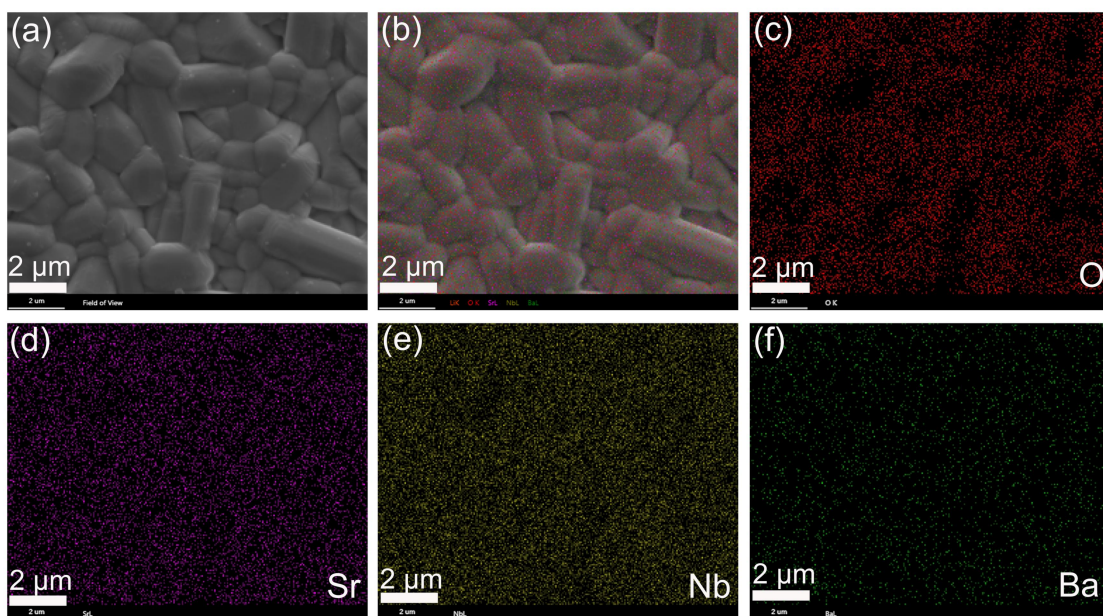


Figure S5. SEM images and EDS mappings of S3 sample.

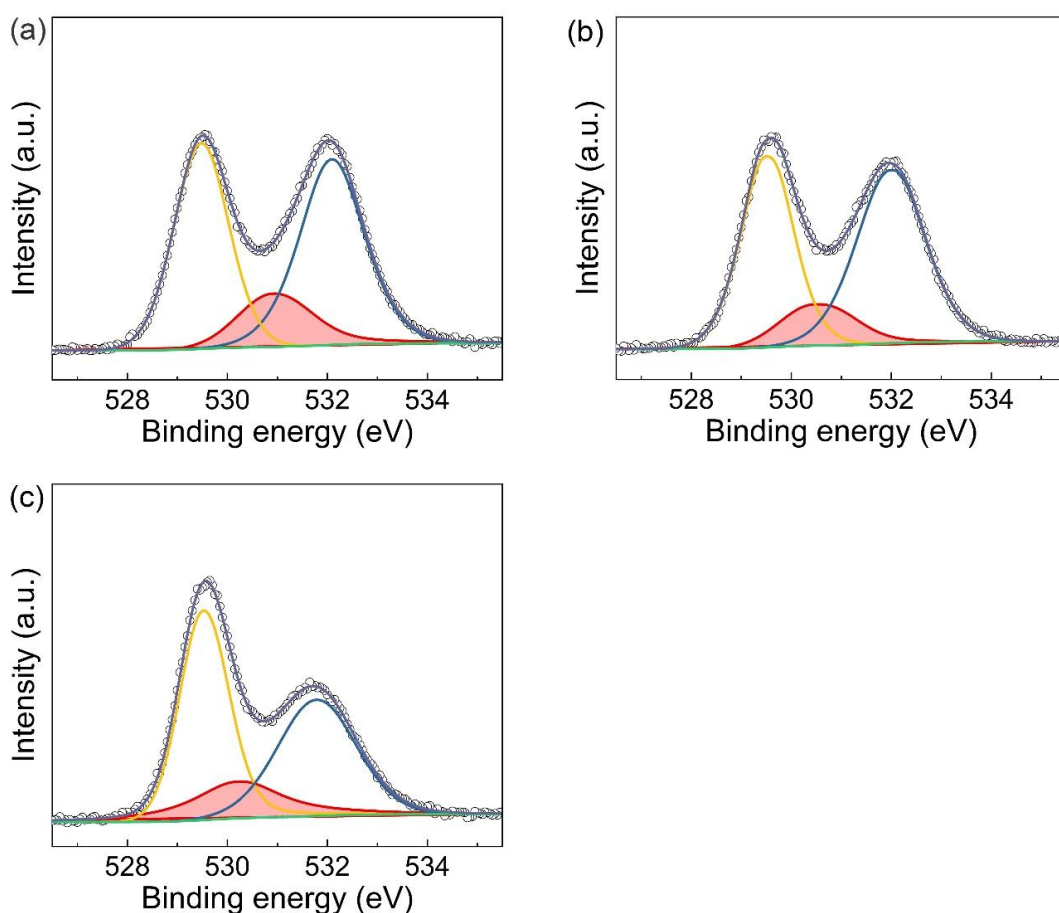


Figure S6. XPS results of O1s for (a) S1, (b) S2, (c) S3 sample.

REFERENCES

- [1] Qiuyu Zheng, Qi Wang, Yuntong Li, Feng Qiao, Mingshan Qu, Bing Xie, Hua Su, Xiaoli Tang, *J. Eur. Ceram. Soc.* **2026**, 46, 118476.
- [2] Bian Yang, Zhi Wang, Lingling Wei, Zongfan Duan, Jie Cui, Dongjie Liu, Yuan Yang, Shaodong Sun, *Ceram. Int.* **2026**.
- [3] Xiaolong Zhu, Haotian Wang, Jiexing Xu, Dongxu Luo, Ming Zheng, *J. Alloy. Comp.* **2026**, 1064, 187862.
- [4] Bian Yang, Jiayu Zhang, Xiaojie Lou, Yangfei Gao, Peng Shi, Yaodong Yang, Man Yang, Jie Cui, Lingling Wei, Shaodong Sun, *ACS Appl. Mater. Interfaces* **2022**, 14, 34855.
- [5] Peixiaokan Si, Xiangting Zheng, Liang Zheng, Peng Zheng, Yang Zhang, *Int J. Appl. Ceram. Technol.* **2023**, 21, 532.
- [6] Wenxuan Luo, Fan Zhang, Kang Xu, Jinyu Yang, Xiangyu Long, Xue Zhang,

- Yiwen Niu, Zhanjie Wang, *Mater. Today Commun.* **2024**, 41, 110624.
- [7] Shudong Xu, Mengping Tian, Ping Yu, Wei Pu, Zemin He, Yuzhen Zhao, Haiyan Yang, Wenqi Song, Lingling Wei, Zongcheng Miao, *J. Alloy. Comp.* **2025**, 1036, 182069.
- [8] Yan Wang, Shuiting Hou, Yihan Tong, Shudong Xu, Xiaoqian Ju, Pu Guo, Xue Dong, Lingling Wei, *Ceram. Int.* **2025**, 51, 9923.
- [9] Ruifeng Wan, Hongfei Zhang, Linsheng Sheng, Peng Zheng, Xuyu Liu, Hailiang Wang, Qiaolan Fan, Liang Zheng, Wangfeng Bai, Yang Zhang, *Ceram. Int.* **2024**, 50, 37126.
- [10] Wenbin Feng, Lele Ding, Jiajia Zhang, Chunyi Zhu, Shenzhenyi Song, *RSC Adv.* **2024**, 14, 35064.
- [11] Lang Zhang, Jie Wang, Matjaz Spreitzer, Leontev Viktor Sergeevich, Yasemin Tabak, Atilla Evcin, Alexander Korotkevich, Dawei Wang, Ying Yuan, Lei Cao, Yao Hu, Kaixin Song, *J. Energy Storage* **2025**, 113, 115699.
- [12] Suwan Li, Zhen Yan, Yangfan You, Kaiyun Zheng, Liang Zhang, Xiaolian Chao, Di Wu, Pengfei Liang, Zupei Yang, Jiangbo Lu, Lingling Wei, *Ceram. Int.* **2024**, 50, 14223.
- [13] Lei Cao, Yuanyuan Wang, Ying Yuan, Jianguo Zhu, Hadi Barzegar Bafrooei, Minmin Mao, Bing Liu, Hao Li, Dawei Wang, Zhilun Lu, Ge Wang, Kaixin Song, *Chem. Eng. J.* **2024**, 479.
- [14] Yangfan You, Mengping Tian, Qizhen Chai, Yihan Tong, Pengfei Liang, Di Wu, Xiaolian Chao, Zupei Yang, Lingling Wei, *J. Alloy. Comp.* **2024**, 1002, 175469.