doi:10.1017/S1431927620013586
Microsc. Microanal. 26 (Suppl 2), 2020

TEM Studies on the Role of Local Chemistry and Atomic Structure in Battery Materials

Yifei Yuan[1], Khalil Amine[2], Jun Lu[2] and Reza Shahbazian-Yassar[1]

[1]University of Illinois at Chicago, Chicago, Illinois, United States, [2]Argonne National Laboratory, Lemont, Illinois, United States

To meet future needs for industries from personal devices to automobiles, energy storage devices such as lithium ion batteries, sodium ion batteries and metal-air batteries require both improved durability and lowered costs. To enhance the performance and lifetime of battery materials, understanding the material dynamics and kinetics associated with the energy storage processes is of critical importance to further gain atomic level control. As the imaging and analytical capability of modern (scanning) transmission electron microscopy ((S)TEM) has been continuously improving, a substantial amount of research on battery materials has been reported in the past decade, indicating the critical role of STEM in the fundamental understanding of energy storage materials. The development of *in situ* diagnostic methods has further advanced the application of TEM in this area [1].

Our group have recently advanced battery material sciences via a combination of various in situ/ex situ electron microscopic methods, which cover lithium ion battery, sodium ion battery and high-energy lithium oxygen battery. Nanoscale-to-atomic level details are revealed in terms of the energy storage property of various materials, and in situ TEM further discloses the structural, compositional and phase evolution of battery materials under their specific working conditions. We will herein summarize our group's recent electron microscopic studies in advanced battery materials. Example include: (1) in situ TEM study of the structural degradation mechanism of alloying-based anode material (shown in **Figure 1**) [2], and novel Sn-Cu alloying nanoglue design for endurable structure surviving long cycling (**Figure 2**) [3]; (2) the catalytic effect on the configuration and morohology of Li-O_2 discharge product-Li_2O_2 [4], and the surface engineering of catalytic materials for Li-O_2 battery catalysis [5]; (3) phase degradation mechanisms in high-voltage spinel $LiMn_2O_4$ cathode [6], and the effect on atomic layer deposition in suppressing such degradation behavior [7] [8].

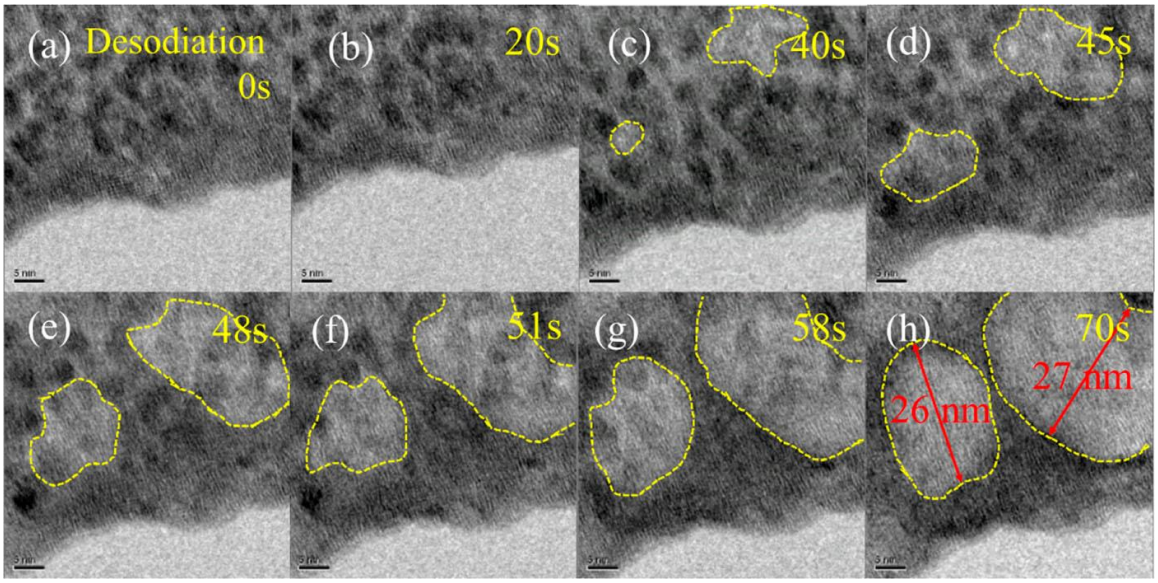

Figure 1. Figure 1. In situ TEM studying the morphology evolution of the alloying-based anode material (Sb2Se3 nanowire) during repetitive (de)sodiation. Reprinted (adapted) with permission from Nano Letters 19 (2019), p. 3074-3082. Copyright (2019) American Chemical Society.

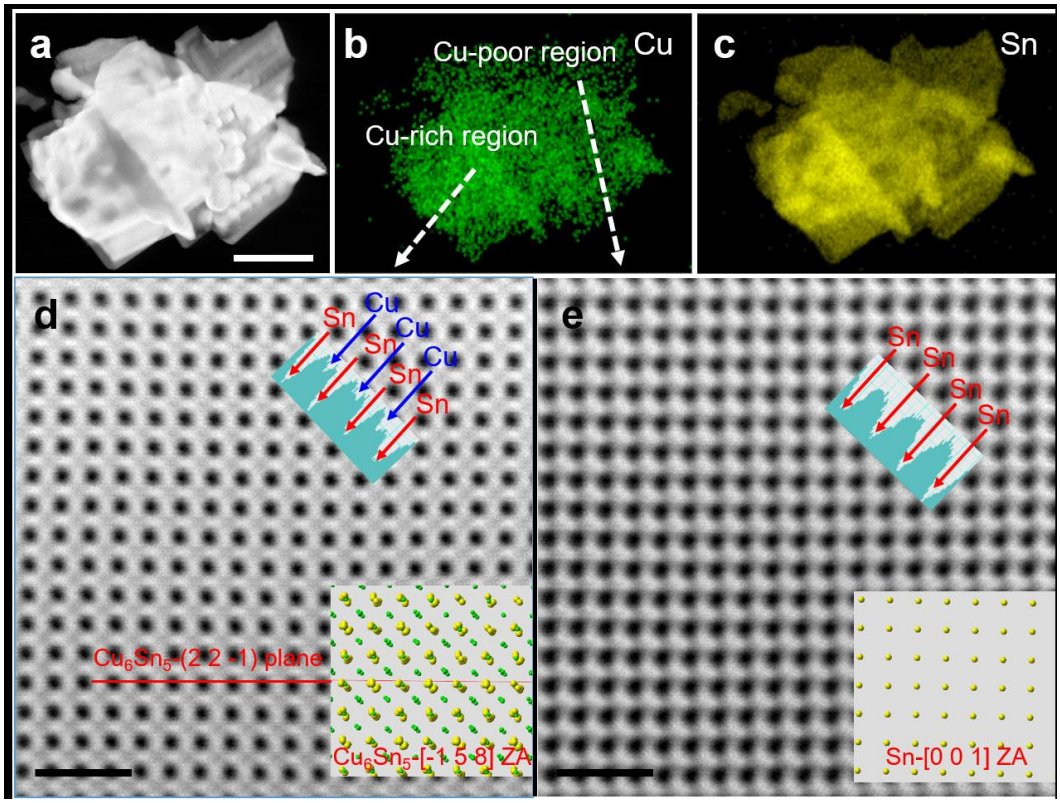

Figure 2. Figure 2. Morphology and structure analyses of SnNA. (a) Low-mag STEM-HAADF image of one SnNA. (b,c) EDS mapping of Cu (green) and Sn (yellow). (d) STEM-ABF image of the Cu6Sn5 atomic structure viewed along the zone axis of [-1 5 8]. (e) STEM-ABF image of the Sn atomic structure viewed along the zone axis of [0 0 1]. In (d, e), the line profiles are given and compared in the insets to highlight the presence of Cu columns in Cu6Sn5. Atomic models matching each experimental observation are also given in the right bottom insets with yellow sphere for Sn and green sphere for Cu. Scale bar: (a) 1 μm, (d, e) 1 nm. Appropriate credit to the source: https://creativecommons.org/licenses/by/4.0/

References

[1] Y Yuan, *et al*, Nature Communications **8** (2017), 15806.
[2] Q Li, *et al*, Nano Letters **19** (2019), p. 3074-3082.
[3] J Ni, *et al*, Nature Communications (2020), DOI: 10.1038/s41467-020-15045-x.
[4] G Tan, *et al*, Advanced Energy Materials **9** (2019), p. 1900662.
[5] W Yao, *et al*, Journal of American Chemical Society **141** (2019), p. 12832−12838.
[6] T Liu, *et al*, Nature Communications **10** (2019), 4721.
[7] S Deng, *et al*, Nano Energy **65** (2019), p. 103988.
[8] Work at Argonne National Laboratory was supported by the U. S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy, Vehicle Technologies Office. Argonne National Laboratory is operated for DOE Office of Science by UChicago Argonne, LLC, under contract number DE-AC02-06CH11357. This work made use of instruments in the Electron Microscopy Service (Research Resources Center, UIC). R.S.Y acknowledges financial support from the National
Science Foundation (DMR-1620901, CBET-1805938, DMR-1809439).