Runsheng Gao [a,b]
Jie Tang [a,b,*], Kazuya Terabe [c], Xiaoliang Yu [a], Taizo Sasaki [a], Ayako Hashimoto [a], Kiyoshi Ozawa [a], Kun Zhang [a], Shuai Tang [a], Ta-Wei Chiu [a,b], Luhao Kang [a,b], Shiqi Lin [a,b], Wanli Zhang [a,b], Lu-chang Qin [d]
[a] National Institute for Materials Science (NIMS), 1-2-1 Sengen, Tsukuba, Ibaraki 305-0047, Japan
[b] University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-0006, Japan
[c] National Institute for Materials Science, 1-1 Namiki, Tsukuba, Ibaraki 305-0044, Japan
[d] University of North Carolina at Chapel Hill, Chapel Hill (USA)
Tang.Jie@nims.go.jp

Preparation of Layered Si Materials as Anode for Lithium-Ion Batteries

Silicon (Si) materials have attracted a lot of research interest as anodes in lithium-ion batteries (LIBs) due to their inherently high theoretical capacity (4200 mAh g^{-1}). However, the electrode structure is usually fractured due to the volume change during Si-Li alloying reactions, which greatly hinder their practical applications [1-3]. To date, there have been many approaches reported to improve the performance of silicon anode by using various structures. However, the drawbacks of using these methods to construct Si anode structure are evident. Such as, the process is complex, and the high-temperature operations make many strategies impractical. In addition, the Li ion diffusion is slow sluggish in bulk silicon [4,5]. Therefore, constructing a feasible Si anode structure is still a challenge to receive the benefits of the silicon anode. Two-dimensional materials are worth investigating because of their unique structure [6-8]. Many two-dimensional materials and their derivatives have been recently utilized to great success in various purposes [9-11]. One of the most important characteristics is that the two-dimensional structure can generate more space without modification but stack by themselves. To address the above-mentioned issues of complex processing, low practicality, and sluggish Li ion diffusion. Hence, we developed a new approach which starts with a two-dimensional layered Si material (LSM) without involving complex processes. The layered structure has abundant gaps and pores to accelerate electrolyte ion transportation. It forms an amorphous lithiation product after the initial discharge process with improved electrochemical performance. The microstructure has been characterized using techniques including x-ray diffraction, transmission electron microscopy and electron energy-loss spectroscopy without the formation of Si-Li alloys. As a result, the LSM anode shows a higher specific capacity as well as a much better cycling performance when compared to common bulk Si anodes. The LSM developed in this work shows potential as an alternative high-performance Si anode for LIBs.

References

[1] Obrovac M N, Christensen, L, Le D B, Dahnb J R. J. Electrochem. Soc. 154 (2007): A849−A855.
[2] Obrovac M N, Krause L J. J. Electrochem. Soc. 154 (2007): A103−A108.
[3] Liu X H, Zhong L, Huang S, Mao S X, Zhu T, Huang J Y. ACS Nano 6 (2012): 1522−1531.
[4] Kim N, Park H, Yoon N, and Lee J K. ACS nano, 12 (2018): 3853-3864.
[5] Choi S, Kwon T, Coskun A, Choi J W. Science, 357 (2017): 279-283.
[6] Georgakilas V, Tiwari J N, Kemp K C, Perman J, Bourlinos A B, Kim K S, Zboril R. Chem. Rev. 116 (2016): 5464-5519.
[7] Raccichini R, Varzi A, Passerini S, Scrosati B. Nat. Mater. 14 (2015): 271.
[8] Zhang Z, Penev E S, Yakobson, B I. Chem. Soc. Rev. 46 (2017): 6746-6763.
[9] Cheng Q, Tang J, Ma J, et al. Phys. Chem. Chem. Phys. 13 (2011): 17615-17624.
[10] Li J, Tang J, Yuan J, et al. Electrochim. Acta, 258 (2017): 1053-1058.
[11] Sun Y, Tang J, Qin F, et al. J. Mater. Chem A, 5 (2017): 13601-13609.

Acknowledgement

This work was supported by the Panasonic-NIMS Center of Excellence for Advanced Functional Materials. A part of this work was supported by NIMS microstructural characterization platform as a program of "Nanotechnology Platform" of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

Figures

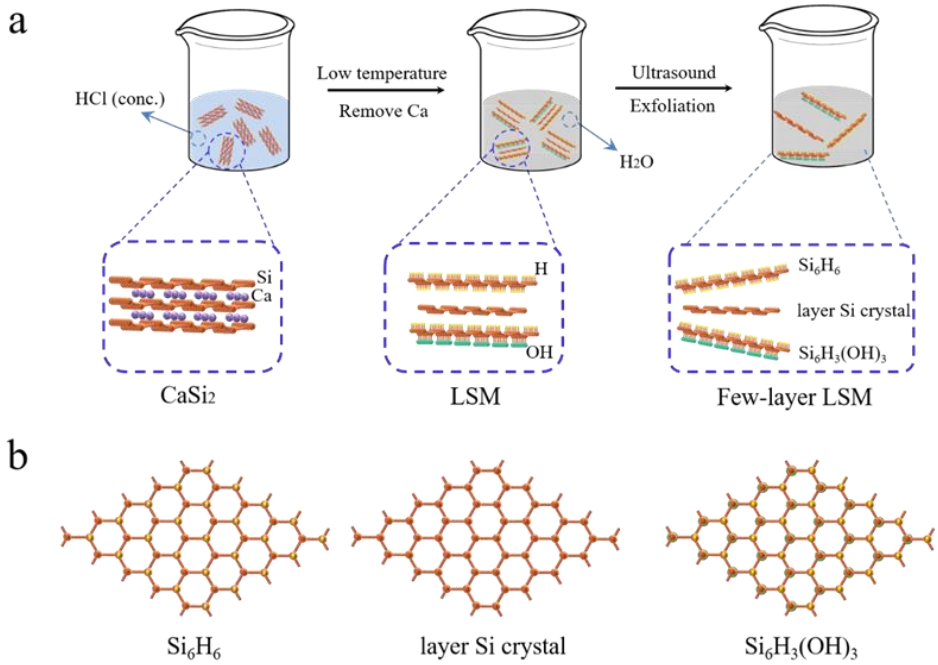

Figure 1. (a) Schematic illustration of the synthesis process of LSM, (b) top view of the model structure.