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SJSU Undergraduate Research Grants

Si/C nanoparticles as anode material for lithium ion batteries

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Abstract

The focus of this project is to develop a silicon carbon core shell structure (Si/C) as anode material for lithium ion batteries. Silicon is considered a promising material for anodes because of a high theoretical charge capacity of over 4000 mAh/g [1]. Be that as it may, silicon is subject to great amounts of expansion during the (de)lithiation processes, and therefore is subject to large mechanical stress. This results in degradation of the electrode and improper SEI growth, resulting in low cycling stability [2]. Carbon coating is used to primarily promote volume retention of silicon, and to improve electrochemical performance. The ultimate goal of this project is to determine optimal Silicon to glucose ratio and carbonization temperature to produce an anode that maintains both high charge capacity as well as more efficient cycling stability.

Project Activities or Findings

- Commercial silicon nanoparticles were carbon coated with varying ratios of glucose [3]
- Based on Raman spectroscopy, a greater glucose to Silicon ratio promotes better carbon coating
- Based on XRD analysis, the ideal annealing conditions are in nitrogen gas at milder temperatures due to severe Si reduction in argon atmosphere at elevated temperatures
- Amorphous silica present among active material, regardless of glucose content and carbonizing conditions
- Coin cell battery testing will be executed with a water in salt electrolyte using lithium bis(trifluoromethanesulfonyl)imide (LiTFSi) salt [4]

Experimental Setup

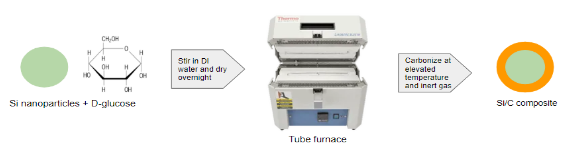

Figure 1. Synthesis of Si/C active material .

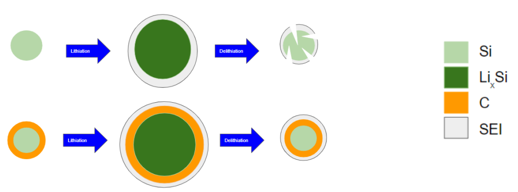

Figure 2. Electrode behavior during cycle of Si only (top), and Si/C (bottom). The Si only electrode is prone to self-pulverization after severe expansion during lithiation.

Results

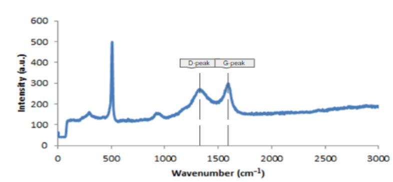

Figure 3. Raman spectra of Si/C active material. A greater G-peak relative to D-peak suggests a graphitic carbon layer.

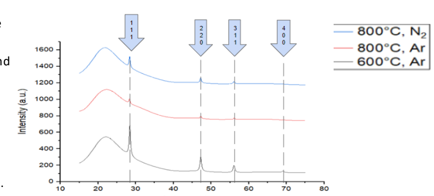

Figure 4. XRD plots of three different Si/C samples with same Si to glucose ratios and varying carbonization atmospheres. Crystallographic planes of silicon are listed. The peak broadening around 22° is suspected to be either amorphous silica or carbon.

Research Questions

- What is the ideal silicon to glucose ratio for efficient carbon coating?
- What is the ideal annealing temperature and atmosphere for carbon coating silicon?
- Is the resulting carbon layer graphitic or amorphous?
- Is the resulting carbon layer adequate in hindering the expansion of the silicon core?
- What is the thickness of the carbon layer?

Citations

[1] Wu, H., & Cui, Y. (2012). Designing nanostructured Si anodes for high energy lithium ion batteries. Nano Today, 7(5), 414–429. doi: 10.1016/j.nantod.2012.08.004

[2] Andersen, H. F., Foss, C. E. L., Voje, J., Tronstad, R., Mokkelbost, T., Vullum, P. E., … Mæhlen, J. P. (2019). Silicon-Carbon composite anodes from industrial battery grade silicon. Scientific Reports, 9(1). doi: 10.1038/s41598-019-51324-4

[3] Li, X., Wu, M., Feng, T., Xu, Z., Qin, J., Chen, C., … Wang, D. (2017). Graphene enhanced silicon/carbon composite as anode for high performance lithium-ion batteries. RSC Adv., 7(76), 48286–48293. doi: 10.1039/c7ra09818a

[4] Subramanya, U., Chua, C., Leong, V. G. H., Robinson, R., Cabiltes, G. A. C., Singh, P., … Oh, D. (2020). Carbon-based artificial SEI layers for aqueous lithium-ion battery anodes. *RSC Advances*, *10*(2), 674–681. doi: 10.1039/c9ra08268a

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