*ICCES, 2025, vol.33, no.2*

Tech Science Press

DOI: 10.32604/icces.2025.010939

**PROCEEDINGS**

# Quantitative Analysis of Energy Dissipation in Thin Film Si Anodes Upon Lithiation

**Zhuoyuan Zheng***

School of Energy Science and Engineering and Jiangsu Key Laboratory of Process Enhancement and New Energy Equipment Technology, Nanjing Tech University, Nanjing, 211816, China

*Corresponding Author: Zhuoyuan Zheng. Email: zhuoyuan@njtech.edu.cn

**ABSTRACT**

Silicon (Si) anodes are promising candidates for lithium-ion batteries due to their high theoretical capacity and low operating voltage. However, the significant volume expansion that occurs during lithiation presents challenges, including material degradation and decreased cycle life. This study employs an electrochemical-mechanical-thermal coupled finite element model, supported by experimental validation, to investigate the impact of lithiation-induced deformation on the energy dissipation of Si anodes. We quantitatively investigate the effects of several key design parameters—C-rate, Si layer thickness, and lithiation depth—on energy losses resulting from various mechanisms, such as mechanical energy loss, polarization, and joule heating. Our results reveal that substantial plastic deformation leads to significant mechanical energy loss, meanwhile affects chemical potential and polarization. High polarization is identified as the predominant factor in energy dissipation, typically accounting for over 60% of the total loss, and is exacerbated by high C-rates and thicker Si layers. In contrast, mechanical energy loss remains relatively constant at about 6% regardless of the parameters. Consequently, the energy efficiency exhibits an inverse linear relationship with C-rate, film thickness, and lithiation depth. This highlights the benefits of advanced Si anode designs that optimize thin film topology, balancing fast-charging capabilities with cycling stability and capacity retention.

**KEYWORDS**

Si thin film anode; lithium-ion battery; energy dissipation; plastic deformation; finite element model

**Funding Statement:** This work was supported by National Natural Science Foundation of China (12402213).

**Conflicts of Interest:** The author declares no conflicts of interest to report regarding the present study.