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Interaction between the morphology and the kinetics of the (de)lithiation reactions of novel SiNW based anodes in lithium ion batteries

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Carbon coated silicon nanowires (SiNW) are the nanostructure of choice for binder-free high capacity anodes. These anodes with adjusted active mass loading and advanced morphology were grown by chemical vapor deposition (CVD). The high mass loadings (up to 6 mgSi/cm^2) in combination with the lightweight carbon foil used as substrate and current collector predestines these anodes for applications where high energy densities are required, e.g. for automotive applications. The requirements in high power devices are especially challenging with respect to the (de)lithiation reactions. Thus, (complex) carbon coated SiNW anodes with varying morphology and mass loading are examined regarding their performance as well as the kinetics of the charge-discharge reactions. The specific capacity and cycle stability as well as the achievable C-rates strictly depend on these parameters. The anodes offer capacities up to 2 mAhcm^{-2}, initial coulomb efficiencies higher than 80% and capacity fading of less than 10% over 100 cycles. The established process with high uniformity allows detailed examinations of the charge-discharge curves of samples with tuned properties and clearly shows an effect of the SiNW morphology on the phase transitions in the initial cycles, which in turn can be crucial regarding the degradation behavior of the anodes. Finally, galvanostatic intermittent titration technique (GITT) is applied to analyze the charge transfer and diffusion overpotentials of the (de)lithiation reaction. The overpotentials are basic kinetic parameters of these reactions, and they enable the estimation of the rate determining processes.

Recent Publications

1. Krause A, Dörfler S, Piwko M, Wisser F M, Jaumann T, Ahrens E, Giebeler L, Althues H, Schädlich S, Grothe J, Jeffery A, Grube M, Brückner J, Martin J, Eckert J, Kaskel S, Mikolajick T and Weber W M (2016) High area capacity lithium-sulfur full-cell battery with prelitiathed silicon nanowire-carbon anodes for long cycling stability. Scientific Reports 6:27982.
2. Jaumann T, Balach J, Langklotz U, Sauchuk V, Fritsch M, Michaelis A, Teltevskij V, Mikhailova D, Oswald S, Klose M, Stephani G, Hauser R, Eckert J and Giebeler L (2017) Lifetime vs. rate capability: understanding the role of FEC and VC in high energy Li-ion batteries with nano-silicon anodes. Energy Storage Materials 6:26-35.
3. Heubner C, Langklotz U and Michaelis A (2018) Theoretical optimization of electrode design parameters of Si based anodes for lithium-ion batteries. Journal of Energy Storage 15:181-190.
4. Freitag A, Langklotz U, Rost A, Stamm M and Ionov L (2017) Ionically conductive polymer/ceramic separator for lithium-sulfur batteries. Energy Storage Materials 9:105-111.
5. Krause A, Grube M, Mikolajick T and Weber W M (2015) Comparison of silicon nanowire growth on SiO2 and on carbon substrates. ECS Transactions 70:69-78.

Biography

Ulrike Langklotz works in the field of Electrochemistry, mainly for applications in the field of energy storage, for ten years. The general attempt bases on the complementation of electrochemical results with suitable non-electrochemical measuring methods, e.g. spectroscopy. Main topics are the preparation and characterization of thin dielectric oxide films as well as the investigation of electrode materials used in lithium ion and lithium sulfur batteries. Recently, the investigation of nanostructured silicon as anode material was one main topic.

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