Etching Asymmetric Germanium Membranes with Hydrogen Peroxide for High Capacity Lithium Ion Battery Anode

Authors: Logan Williams and Emilee Larson
Advisor: Ji Wu
Department of Chemistry and Biochemistry
Analytical Research Chem 4900
Date: 3/24/2020

State of the art commercial lithium ion batteries (LIBs) use graphite as a low-cost anode material to store lithium ions safely and reversibly. Recently, alloying anodes such germanium (Ge, 1600 mAh g^{-1}), silicon (Si, 3600 mAh g^{-1}) and tin (Sn, 994 mAh g^{-1}) have been proposed as alternatives to replace low capacity graphite anode (372 mAh g^{-1}), mainly due to their outstanding theoretical capacities. However, germanium-based anode suffers from huge volume changes (~300%) during lithiation and delithiation, resulting in pulverization and fast capacity fading. In this study, the large volume change issue was tackled by etching asymmetric porous germanium membranes with hydrogen peroxide solutions. Non-etched Ge asymmetric membrane electrodes demonstrated a mediocre improvement in cyclability over micron powder Ge control electrode with a capacity retention less than 30% in 50 cycles at 160 mA g^{-1}. After being etched with concentrated H2O2 at 90 °C for 30 s, the cyclability was dramatically enhanced to above 80% in 50 cycles at 160 mA g^{-1}. To prevent the still inevitable capacity loss from the membrane surface, the etched Ge membrane was coated with porous carbonaceous membranes to create a sandwich structure. As a result, not only can more than 95% capacity be retained in 50 cycles but the electrode capacity is also raised. Ge membranes were also systematically characterized by using scanning electron microscope (SEM), energy dispersive X-ray analyzer, powder X-ray diffractometer (PXRD), Raman spectroscopy, X-ray photoelectron spectroscopy, thermogravimetric analyzer (TGA), and surface area analyzers. It was found there is a clear correlation between the electrochemical performance, membrane geometry, carbonaceous membrane coating, and concentration of Ge.