Improved Electrochemical Performance of Phosphorous-Doped Silicon Anode in Ionic liquid Electrolyte for Lithium-Ion Battery

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Silicon (Si) is a potential candidate as a negative electrode for next-generation lithium-ion battery due to its high theoretical capacity of 3580 mA h g^{-1}, whereas it shows poor cycle stability because strains that accumulate under repeated charge-discharge cycling cause disintegration of its electrode. We have found that phosphorous (P)-doped Si electrode exhibits an improved cycle performance as a result of suppression of a phase transition from Si to crystalline $Li_{15}Si_4$ (*c*-$Li_{15}Si_4$) phases.[1] It has also reported that a Si-alone electrode shows a superior cycle performance in some ionic liquid electrolytes, compared to conventional organic electrolytes.[2,3] In the present study, we investigated the electrochemical performance of P-doped Si electrode in ionic liquid electrolytes.

100 ppm P-doped Si powders was supplied by Elkem (Silgrain e-Si). A working electrode was fabricated by gas-deposition method, which is without any binder and conductive agent. Electrochemical measurements were carried out using a 2032-type coin cell with Li metal as a counter electrode. An ionic liquid electrolyte used was 1 mol dm^{-3} (M) lithium bis(fluorosulfonyl)amide (LiFSA) dissolved in *N*-methyl-*N*-propylpyrrodinum bis(fluorosulfonyl)amide (Py13-FSA).

Figure 1 shows a cycle performance of Si-alone and P-doped Si electrodes in 1 M LiFSA/Py13-FSA under a charge capacity limitation of 1000 mA h g^{-1}. The P-doped Si electrode exhibited a superior cycle stability with a reversible capacity of 1000 mA h g^{-1} over 1400 cycles, while the Si-alone electrode retained only up to 600 cycles. On the other hand, the P-doped Si electrode delivered a remarkable rate capability of 1000 mA h g^{-1} even at a high current rate of 10 C, while the Si-alone electrode showed only a discharge capacity of 500 mA h g^{-1} at the same rate.

It is considered that lithiation of entire Si active material layer occurs due to improved lithium ion transport in Si. As a result, imhomogeneous accumulation of large strains is suppressed. In addition, the phase transition from Si to *c*-$Li_{15}Si_4$ phases is moderately suppressed.

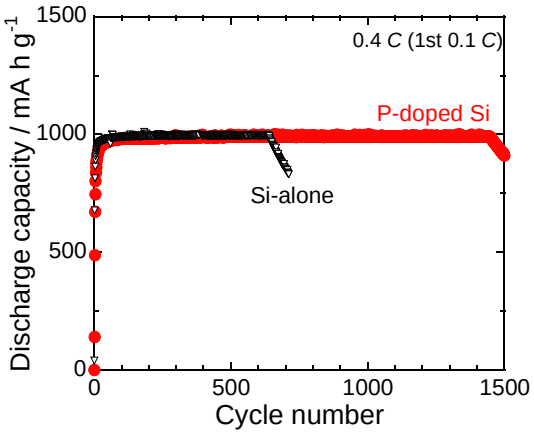

Figure 1 Cycle performance of Si-alone and P-doped Si electrodes in LiFSA/Py13-FSA under a charge capacity limitation of 1000 mA h g^{-1}.

References:

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