Seeking New Ti-based Anodes for Sodium-ion Batteries

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Sodium-ion batteries (SIBs) have been intensively investigated as a low cost alternative for lithium-ion batteries due to the abundance of sodium-ion the earth and its similar chemical properties to lithium.[1] Taking low cost, wide abundance and high security into consideration, titanium based intercalation materials should be the most promising choice for their low redox potential (Ti^{3+}/Ti^{4+}) relative to the Na^+/Na redox potential and abundant reserves among various sodium storage anode materials.[2] In the past few years, researchers have explored many titanium-based materials as potential anode materials for SIBs, such as various TiO_2 polymorphs, including anatase, rutile, TiO_2-B. Sodium titanate based materials with related crystal structures also greatly enrich the kinds of anode materials. However, the practical application of Ti-based anodes in SIBs is severely hindered by its unsatisfied rate capabilities and relatively low capacity resulting from both extremely poor electronic conductivity and sluggish sodium ion diffusion.

We first start our investigation from layered $Na_2Ti_3O_7$ and find it is sensitive to moisture. By removing the interlayer water molecules in the wet precursor, the material will thermotenuously convert to tunnel structured $Na_2Ti_6O_{13}$ with good air stability.[3] To increase the free volume in the structure to facilitate Na^+ diffusion, we further develop $K_2Ti_6O_{13}$ with an analogue tunnel structure with $Na_2Ti_6O_{13}$ as a new anode for sodium-ion batteries. This new titanium based anode material exhibits a high charge capacity of 186 mAh g^{-1} at 20 mA g^{-1} and excellent rate performance of 61 mAh g^{-1} at 1000 mA g^{-1}.[4] By further introducing a carbothermal reduction process, we can turn the [1x1] tunneled $K_2Ti_6O_{13}$ to a hollandite-type K_xTiO_2 with much larger [2x2] tunnels. This K_xTiO_2 material with in-situ carbon coated surface can deliver a capacity of about 120 mAh g^{-1} at 20 mA g^{-1} and exhibit an improved rate capability due to its large tunnels.[5] It is obvious that these new potassium titanates with high capacity and excellent rate performance can serve as potential anodes for sodium ion batteries.

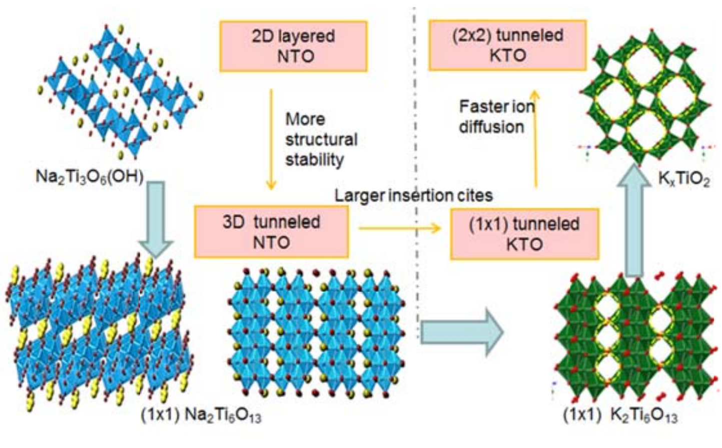

Figure 1. The development roadmap of new Ti-based anodes for sodium ion batteries

References:
[1] N. Yabuuchi, K. Kubota, M. Dahbi and S. Komaba, Chem. Rev., 2014, 114, 11636.
[2] M. Doeff, J. Cabana and M. Shirpour, J. Inorg. Organomet. Polym., 2014, 24, 5.
[3] Q. Zhang, K. Guo, H. Li, et al, Chem. Commun, 2016, 52(37), 6229-6232.
[4] Q. Zhang, Y. Wei, H. Li., et al, ACS Appl. Mater. Interfaces, 2017, 9, 7009-7016.
[5] Q. Zhang, T. Q. Zhang, Y. Q. Wei, H. Li, J. Mater. Chem. A, 2017, 5, 18691-18697.