Abstract

Two-dimensional (2D) nanomaterials have enabled a new paradigm in electrochemical energy storage, particularly in the area of batteries. These nanomaterials result in an extraordinarily high capacity when applied as an active anode material in Li-ion batteries (LIBs). Their high surface area results in easily accessible sites for intercalation. Furthermore, a large library of 2D materials offers a number of choices for achieving the desired interface. Our research group at IIT Gandhinagar has discovered a new family of 2D materials by nanoscaling layered metal diborides. The presence of multivalent boron makes these nanosheets promising candidates for reversible ion storage. Recently, we have been able to develop a high-yield and scalable approach to synthesize nanosheets from titanium diboride (TiB_2). The presence of oxy-functionalized titanium in these nanosheets, in addition to boron, motivated us to investigate if we can employ these to enhance the performance of LIBs. We evaluated this candidacy by carrying out electrochemical measurements in a Li-ion coin cell, in which TiB_2 based nanosheets were used as active anode material. We found that our nanostructured anode results in superlative enhancements in charge and discharge rates. This Li-ion coin cell charges in 14 s at a current rate of 15 Ag^{-1}, and in 9 s at a current rate of 20 Ag^{-1}. Furthermore, it remains as high as 80% of its capacity, even after 10,000 continuous cycles of charge and discharge. Such an ultra-fast charging and long cycling life make TiB_2 based nanosheets a potential candidate for batteries in electric vehicles (EVs). At such high current rates, these nanosheets outperform the commercial LIB anodes, including graphite and lithium titanium oxide (LTO). It is the first experimental investigation in which metal diboride based nanosheets are used as a LIB anode. We have also obtained preliminary insights into the charge-storage mechanism using ex-situ physical, chemical, and electrochemical characterizations. During these measurements, we observed that these nanosheets also present a promising construct for supercapacitive energy storage. We hope to build upon these results to optimize the energy density further.

Keywords: 2D-material, Anode, Li-ion Battery, Titanium Diboride, Fast Charging, Nanosheets