COUPLING OF GRAPHENE LAYERS WITH MOLYBDENUM DISULFIDE FOR BOOSTING OF LITHIUM AND SODIUM STORAGE

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The large interlayer distance in hexagonal MoS_2 (0.62 nm) favors the intercalation of lithium and sodium ions. Intercalates decompose to form molybdenum and alkali metal sulfides, which can dissolved in the electrolyte. As a result, the battery capacity decreases. The combination of MoS_2 with conducting carbon component prevents this undesirable process and also improves the electrical conductivity of the electrode material. We propose a simple approach, based on simultaneous thermal decomposition of the precursors of MoS_2 and graphene in an inert atmosphere, to provide a tight coupling of the components at nanoscale. The mixtures of graphene oxide (GO) and ammonium tetrathiomolybdate, $(NH_4)_2MoS_4$, are used to obtain few-layer MoS_2 nanocrystals distributed on the graphene surface or between the graphene layers. Under thermal shock conditions some carbon atoms from graphene lattice are removed together with oxygen atoms. Carbon atoms at the boundaries of atomic vacancies interact with sulfur of MoS_2 edges. A firm bonding between graphene and MoS_2 layers was confirmed by electron energy loss spectroscopy (EELS) measurements for graphene areas rarely populated by MoS_2 nanoparticles and completely covered by MoS_2.

The obtained MoS_2/graphene materials were tested in Li-ion and Na-ion batteries using the respective alkali metal sheets as counter electrodes. The best performance in the Li-ion batteries showed the material with a ratio of MoS_2 to carbon of about 4 to 1 by the weight synthesized at 400 °C. At current densities of 0.1, 5, and 10 A g^{-1}, its specific capacity was 1044, 717, and 564 mAh g^{-1}. In Na-ion batteries, materials produced at 600 °C were out of competition. They were able to deliver 445 mAh g^{-1} at 0.1 A g^{-1} and 200 mAh g^{-1} at 10 A g^{-1}, showing a high rate capability. The obtained characteristics are among the best ones currently reported in the literature. This phenomenon is related to the enlarging atomic vacancies in graphene layers, accommodation of several alkali metal atoms around on a Mo atom, and complete extraction of ions from metal sulfides. The last two processes are attributed to anchored and dispersed molybdenum and sulfur species on and between defective graphene layers.

References

1. Koroteev V.O. et. al. ∕ Carbon 2021. Vol. 173. P. 193–204.