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J Material Sci Eng 2018, Volume 7
DOI: 10.4172/2169-0022-C11-123

7th International Conference on

Smart Materials and Structures

July 02-03, 2018 | Vienna, Austria

Physicochemical properties of Ti-based MXenes obtained from SHS synthesized MAX phases and their applications in energy storage

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MXenes attract attention as electrodes for energy storage applications, e.g. for supercapacitors. The problem is that the methods of MXenes preparation described in the literature are often multi-stage and complicated. So the purpose of our work is the development of a more simple and technologically acceptable method of MXenes preparation. In the literature, the synthesis of MAX phases (precursors for MXenes synthesis) has been realized by different methods. We used one stage self-propagating high-temperature synthesis (SHS) that seems most suitable due to, simplicity; short reaction time; cost-effectiveness; and little demand on external energy. Commercially available Ti, Al and carbon black powders were used. Several phases (mainly Ti_3AlC_2, Ti_2AlC, TiC) were among the products after SHS. Obtained products were crushed in a roll crusher and then an automatic agate mortar. For Al etching from the MAX phase a dilute solution of hydrogen fluoride (HF) was used. Then delamination of MXenes in N, N-dimethylformamide and isopropanol mixture with sonication lasted for three days. The content of unreacted MAX phase particles in MXene powder can be reduced by using hydrocyclone assembly and alcohol medium instead of water. Suspension stability of MAX phase particles decreases rapidly while suspension of MXene particles is fairly stable. Also, alcohol medium can protect $Ti_3C_2T_x$ Mxene from oxidation. Since both layered Ti3C2Tx and Ti_2CT_x obtained can be used as electrodes for supercapacitors, SHS method is suitable for $Ti_{x+1}AlC_x$ phases preparation. In 1M solution of Na_2SO_4 obtained electrodes demonstrated gravimetric capacitance up to 220 Fg^{-1} at charge-discharge rates 2 mVs^{-1}.

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