Mxene/Ni, Cu Composite Electrodes For Energy Conversion and Storage Application

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The exploitation of renewable wind and solar energy for sustainable development is an important part of national and international energy policies. Due to the variability of wind and solar power, energy storage systems allowing effective management of power generation are required. Nowadays there are several technologies that are considered for energy storage. The production of hydrogen by water electrolysis is now considered one of the most promising technologies. Ammonia is considered as a potential hydrogen carrier, while the NH_3 electrosynthesis from N_2 and H_2O looks attractive currently limited by its low efficiency. Electrochemical CO_2 reduction another attractive technology to production of liquid fuels. All these technologies require efficient and cheap electrocatalysts for successful industrial implementation.
The emergence of new multifunctional materials continuously increases the expectations for the performance of energy conversion and storage devices. MXenes, a family of two-dimensional transition metal carbides has been discovered as candidate for these applications [1], [2]. MXene/metal composites are considered as promising electrocatalysts for several processes. Ni and Ni-based alloy (Ni-Cu) electrodes have been employed as non-precious metal catalysts for hydrogen production owing to their substantial catalytic activity in hydrogen evolution reaction (HER) in alkaline media. However, in economical water-alkali electrolysers, the sluggish water dissociation kinetics (Volmer step) in platinum-free electrocatalysts results in poor hydrogen-production activity. MXene/nano-metal composites as electrocatalysts for hydrogen evolution reaction (HER) in an alkaline medium, demonstrate lower overpotential compared to balk metal electrode at high current densities. An enhanced catalytic activity of MXene/nano-metal composite attributed to the acceleration of the Volmer stage in HER process in alkaline media, by enhancing the water adsorption and dissociation on the catalyst surface where water dissociation is a rate-limiting step. This work proposes a concept of composite structures composed of MAX phase/metal-Al alloy and MXene/metal as functional materials. The concept is based on the combination of the initial MAX phase with metal alloys (Ni, Cu), tuning MAX phase and metal-Al alloy ratio, carbon content and synthesis conditions, followed by Al etching. In more details this work explores the possibilities for the processing of Ni-Al/MAX phase or Cu-Al/MAX phase and corresponding Ni/MXene or Cu/MXene - containing composite electrodes for energy conversion and storage application. Synthesis of powder mixtures with extra Ni or Cu and Al content (e.g. Cu:Ti:Al:C = 1:2:4.5:2) resulted in products containing modified titanium-based MAX phase material and Ni-Al or Cu-Al alloys [2]. It was found that the presence of Cu and Al excess in the reaction mixture promotes the formation process of conventional MAX phases (Ti_3AlC_2) due to generating Al-rich metal-Al alloys with a lower melting point. Further etching of these sintered products (Ni-Al or Cu-Al/ MAX phase) in HF or alkaline solution allowed the direct formation of electrodes with active surface containing MXene and nanoporous metal (Cu, Ni) composites [2, 3] with a well-developed 3D porous MXene/metal structure possessing good mechanical integrity, electrical conductivity and catalytic activity in hydrogen evolution reaction [2, 3].

References

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