$Ti_3C_2T_x$ MXene based membranes for gas separation

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Abstract

The widespread development of hydrogen energy requires increasingly large amounts of hydrogen production. There are many methods of hydrogen production, such as coal gasification, steam reforming of methane, and water electrolysis [1]. However, the resulting products produced by economically more favorable methods is a mixture of gases (syngas). It is possible to purify hydrogen from other impurity gases using selective membranes. To date, many types of membranes have been developed: polymeric, metallic, ceramic, which can be dense or porous [2]. One of the promising materials for production of membranes for gas purification is 2D carbides – MXenes [3]. The most common method of MXenes production is etching of Al from aluminum-containing $M_{n+1}AX_n$-phases, where M is a transition metal, X is carbon, nitrogen or boron and A is an element of group IIIA or IVA [4]. The materials obtained after etching could be represented by the formula $M_{n+1}X_nT_x$, where Tx representing terminal groups (O, OH, F). The 2D structure of MXenes and the presence of terminal groups allows to create effective membranes with multiple nanochannels for gas filtration by molecular sieving. In this work, $Ti_3C_2T_x$-based membranes on porous anodic aluminum oxide (AAO) substrate were prepared by vacuum filtration of MXene $Ti_3C_2T_X$ colloidal solution.

Ti_3C_2Tx MXenes were prepared by direct etching of MAX-phase Ti_3AlC_2 powder in 30% HF acid solution for 4 h under constant stirring. After etching, the solution was washed with deionized water for several times to a Ph value of 6-7. To obtain delaminated $Ti_3C_2T_x$ sheets, etched powder was intercalated in dimethyl sulfoxide (DMSO) solution for 24 h under constant stirring. Delamination was carried out by sonification for 3 hours. The resulting solution containing the delaminated $Ti_3C_2T_x$ sheets was centrifuged at 1000 rpm for 5 minutes, then the dark colored supernatant was withdrawn for further investigation. $Ti_3C_2T_x$ colloidal solution was deposited on AAO substrate by the vacuum filtration. Figure 1 shows the SEM image of $Ti_3C_2T_x$ powder after etching in HF solution.

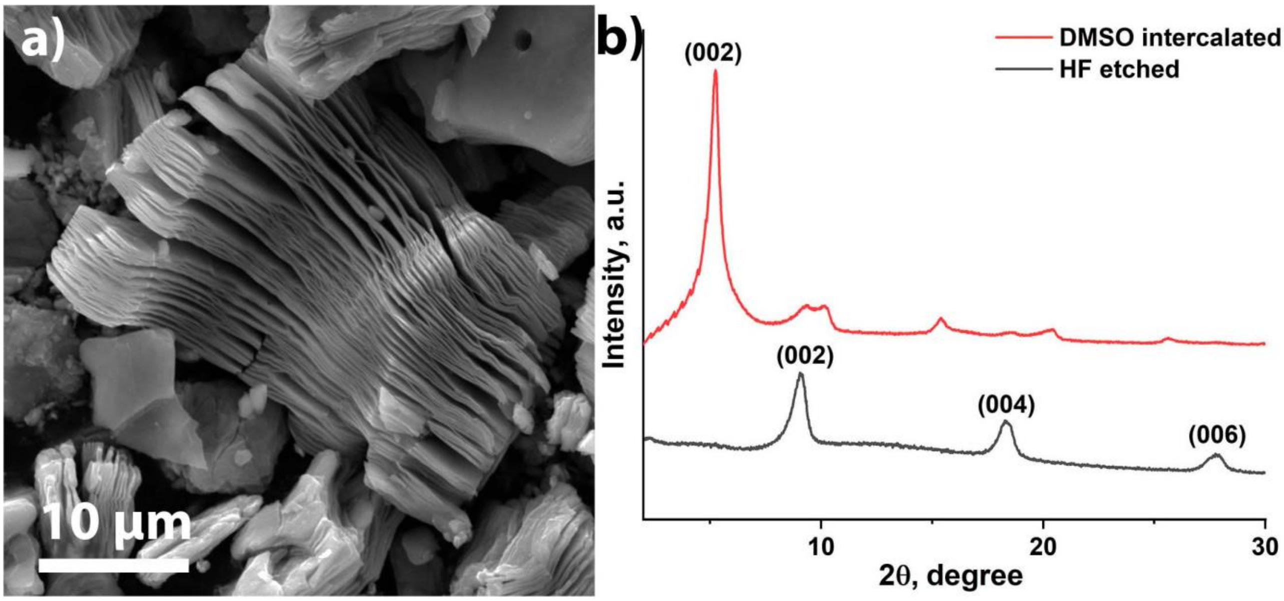

Fig.1 SEM image of HF etched Ti_3AlC_2 MAX-phase powder (a), diffraction patterns for HF etched powder and DMSO intercalated

The obtained particles have a characteristic accordion-like structure. The crystal structure is characterized by the presence of main reflection planes corresponding to the basal planes (002), (004) and (006) (Fig. 1b). The interplanar distance corresponding to the plane (002) was 9.75 Å. After intercalation with DMSO, the (002) interplanar distance increased to 16.87 Å. At the same time, the peak (002) became more pronounced. The increase in the interplanar distance leads to a decrease in binding energy and better subsequent delamination during sonification process and formation of colloidal solution for membrane production.

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