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Novel Inorganic Layered Materials: From Interlayer Chemistry, Delamination, toward Energy Storage Applications

Molecularly thin two-dimensional (2D) nanomaterials, such as graphene and other inorganic analogues, delaminated from the corresponding three-dimensional counterparts with lamellar structures, are emerging as one of the most prevalent materials for their superior properties in diverse applications. The delamination arises from the unique structural characteristics of the layered parent precursor, that is, strong covalent bonding in the layers while weak van der Waals or electrostatic attractions between layers, resulting in easy interlayer expansions and even delaminations. In this talk, I will start by our study on how layered materials swell and what controls the reactions, which is critical to producing high-quality sheet materials.[1-2] It was found that the swelling behavior was regulated by the acid-base reaction and the osmotic pressure equilibrium, which are both substantially unselective and only molarity dependent. However, the nature of the intercalated ion was critical to the stability of the resulting swollen structure; that is, ions of higher polarity and smaller size help stabilize the highly expanded structure, while ions of low polarity and larger size readily lead to exfoliation. With the swelling and delamination rules, I will then move onto producing new 2D sheets, for example, titanium carbides covered with Al oxoanions showing strong optical absorption, particularly at near-infrared region.[3-5] Traditional methods in fabricating 2D MXene materials inevitably use highly noxious and strongly corrosive acid. Utilizing the amphoteric nature of interlayer Al and taking an organic base as the etchant, simultaneous surface functionalization by the hydrolyzed $Al(OH)_4^-$ and intercalation of bulky ion into the gallery space was achieved, readily producing monolayer Ti_3C_2 sheets. Finally, the nanosheets were assembled into macroscopic structure directed to energy storage applications.[6-8] Employing the two-dimensional sheet form of titanium oxide, for the first time macroscopic fiber of titanium oxides was developed through a scalable wet-spinning process. Despite of the intrinsically weak Ti-O bond in molecular titania sheets, the optimal fiber manifested mechanical performance comparable to that documented for pristine fiber of graphene or carbon nanotubes, which should be credited to the highly-aligned stacking manner and enhanced sheet-to-sheet binding interactions. By a further in situ conformal hybridization with reduced graphene oxide, serving as efficient current collectors, a novel fiber electrode was obtained displaying excellent mechanical properties combined with favorable electrochemical performance in lithium-ion battery. Importantly, the storing capacities per unit length were especially competitive, considering the high linear densities of active materials as well as their close contact with current collectors, for which the powering period of an LED light could be extended from several seconds only up to >5 h.

References

[1] F. X. Geng, R. Z. Ma, A. Nakamura, K. Akatsuka, Y. Ebina, Y. Yamauchi, N. Miyamoto, Y. Tateyama, T. Sasaki, Nat. Commun., 4 (2013) 1632.
[2] F. X. Geng, R. Z. Ma, Y. Ebina, Y. Yamauchi, N. Miyamoto, T. Sasaki, J. Am. Chem. Soc., 14 (2014), 5491.
[3] J. N. Xuan, Z. Q. Wang, Y. Y. Chen, D. J. Liang, L. Cheng, X. J. Yang, Z. Liu, R. Z. Ma, T. Sasaki, F. X. Geng, Angew. Chem. Int. Ed., 47 (2016) 14569.
[4] [W. H. Liu, Z. Q. Wang, Y. L. Su, Q. W. Li, Z. G. Zhao, F. X. Geng, Adv. Energy Mater. 22 (2017) 1602834.
[5] Z. Q. Wang, J. N. Xuan, Z. G. Zhao, Q. W. Li, F. X. Geng, ACS Nano 11 (2017) 11559.
[6] T. Hoshide, Y. C. Zheng, J. Y. Hou, Z. Q. Wang, Q. W. Li, Z. G. Zhao, R. Z. Ma, T. Sasaki, F. X. Geng, Nano Lett., 6 (2017) 3543.

[7] J. Y. Hou, Y. C. Zheng, Y. L. Su, W. K. Zhang, T. Hoshide, F. F. Xia, J. S. Jie, Q. W. Li, Z. G. Zhao, R. Z. Ma, T. Sasaki, F. X. Geng, J. Am. Chem. Soc., 40 (2015) 13200.
[8] N. Liu, Z. Q. Wang, Z. Wang, J. S. Xia, Y. Chen, Z. G. Zhao, Q. W. Li, F. X. Geng, ACS Nano 8 (2017) 7879.

Figures

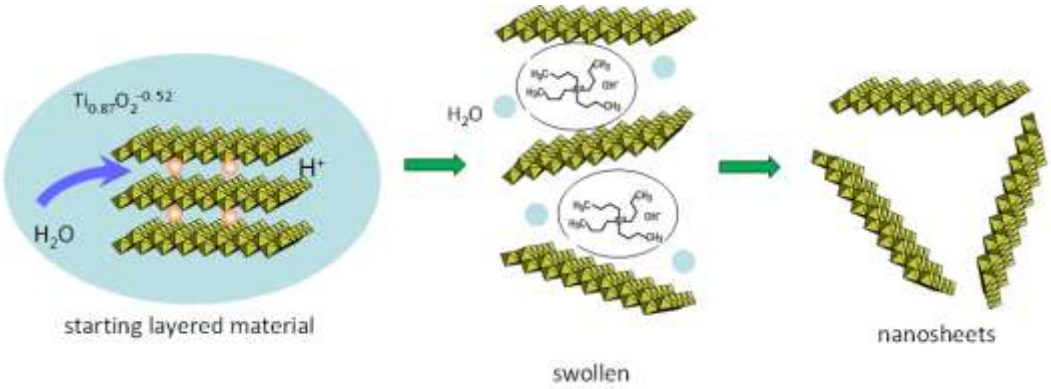

Figure 1: Delamination process of a layered structure.