Chapter 1
Introduction

Two-dimensional (2D) materials have formed a new family of low-dimensional materials, which have drawn numerous attentions of the research community. Although various 2D materials have been proposed and synthesized, it is necessary to mention the titanium carbide, Ti_3C_2, which was first obtained by removing the Al atoms from the hexagonal ternary carbide, Ti_3AlC_2, through selective etching with aqueous hydrofluoric acid (HF) solution [1]. There are nearly one hundred similar ternary carbides and nitrides which are similar to Ti_3AlC_2, which have a general chemical formular of $M_{n+1}AX_n$, with M, A and X to stand for early transition metals, elements from the groups of IIIA or IVA and carbon/nitrogen, respectively, while n could be integer of 1–3 [2]. Moreover, the $M_{n+1}AX_n$ phases can be present as solid solutions, with different combinations of elements at the sites of M, A and X. As a result, the number of $M_{n+1}X_n$ should unlimited [3–16].

There are two formula units in each unit cell of the layer-structured hexagonal phases of $M_{n+1}AX_n$, with the M layers to be strongly adhered by the X atoms that are filled in between the octahedral sites, while the $M_{n+1}X_n$ layers are sandwiched by the A atom layers [17, 18]. As a consequence, the structures are of laminar architecture, thus having anisotropic characteristics. The M-X bond is a mixture of ionic, covalent and metallic behaviors, whereas the M-A is a pure metallic bond. The $M_{n+1}AX_n$ nanolayers are strongly bonded due to the bonding characteristics. In comparison, relatively weak van der Waals force is usually dominant the layer-structured materials, like graphite and transition metal dichalcogenide compounds (TMDs) [19]. As a result, they can be readily exfoliated through mechanical action to form 2D materials.

Owing to the difference in bonding properties, the strengths of the M-X and M-A interactions are different, so that the A layers can be taken away, thus forming $M_{n+1}X_nT_x$ layers, where T_x stands for surface functional groups, including =O, –OH and –F, which are linked to the M atoms on the surfaces generated during the etching reaction process. The layer thickness of the $M_{n+1}X_nT_x$ items is determined by the value of n, i.e., the number of the building blocks. They are single, two and three building blocks for n = 1, 2 and 3, respectively. This newly emerged group

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of materials are named as MXenes, in order to demonstrate the elimination of the component A from the initial compounds of $M_{n+1}AX_n$ and the 2D characteristic structure of graphene.

Besides the extensive studies on properties and applications of MXenes, the 2D materials have also been employed to form hybrids or composites, for a wide range of potential applications [20–22]. In this book, the advancement of MXenes and their nanohybrids and nanocomposites, in terms of synthesis, characterization and utilization. The synthesis and processing of representative MXenes will be covered in Chap. 2. In Chap. 3, the fabrication and characterization of MXenes-based hybrids and composites will be presented and discussed. The applications of MXenes in energy storage and conversion will be described in Chap. 4, such as anode materials of batteries, electrodes of supercapacitors, storage of hydrogen and so on. Other applications, including biosensing, environmental remediation, piezoelectric effects and electromagnetic interference (EMI) and shielding/absorption, etc., will be summarized in the last chapter.

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