MXenes

Subjects: Others

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Recent progress in the application of new 2D-materials—MXenes—in the design of biosensors, biofuel cells and bioelectronics is overviewed and some advances in this area are foreseen. Recent developments in the formation of a relatively new class of 2D metallically conducting MXenes opens a new avenue for the design of conducting composites with metallic conductivity and advanced sensing properties. Advantageous properties of MXenes suitable for biosensing applications are discussed. Frontiers and new insights in the area of application of MXenes in sensorics, biosensorics and in the design of some wearable electronic devices are outlined. Some disadvantages and challenges in the application of MXene based structures are critically discussed.

Keywords: MXenes,MAX phases ; 2D-nanoparticles ; 2D-nanomaterials ; catalytic electrochemical biosensors ; redox enzymes ; nonstoichiometric titanium oxides TiO2−x/TiO2 and ; immunosensors ; antibodies ; enzymatic biofuel cells ; microbial biofuel cells ; bioelectrochemistry

1. Introduction

MXenes have appeared very recently (in 2011) as a new class of 2D materials with either metallic conductivity[1][2],or some attractive semiconducting properties, or both, which can be well exploited in the design of sensors, biosensors, biofuel cells and in the development of some wearable bioelectronic devices. MXenes have some structural relation and even similarity of some physical properties with other 2D materials, for example, graphene.

2. Composition

Most MXenes are based on 2D transition metal carbides[2] . In addition to the carbides, 2D material – graphene[3][4]. The most of MXenes are based on 2D transition metal nitrides carbonitrides are appointed to this class of MXene materials[5]. MXenes are usually prepared by etching of initial materials, called “MAX phases”, which can be presented by generalized formula $M_{n+1}AX_n$ in which “M” representing the transition metals (that are Ti, Sc, Zr, Cr, V, Mn, Hf, Nb, Mo or Ta), “A” is an element from group 12, 13, 14, 15 or 16 (that are Al, Cd, Si, S, P, Ga, As, Ge, In, Tl, Sn or Pb) in the periodic table, “X” is either carbon (C), nitrogen (N) or a mixture of both of them [6–9], and “n” in this formula can be in the range of 1–3[6][7][8][9][10][11] (Figure 1).

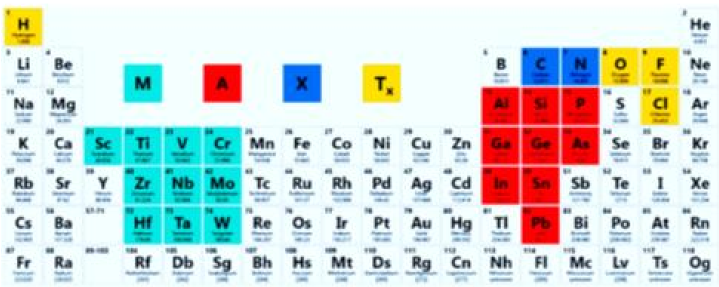

Figure 1. The composition of MXenes and MAX phases from the periodic table. Reprinted from[12].

3. Properties and Application

It should be noted that MAX phases are characterized by metal-like electrical/thermal conductivity behavior and they are mostly chemically stable materials. MXenes possess great and rather unusual physical and chemical properties that can be well adapted for the design of electrochemical sensors and biosensors. The properties of MXenes can be well tailored through proper variation of M and X elements in MXene structure and by the introduction of various surface terminal groups[13][14][15]. Due to this option of applying very different surface “finishing”, recent advances in surface chemistry enables the introduction of particular surface “terminal functional groups”[13][14][15], which can be suitable for the immobilization of enzymes and some other proteins. Hence, MXenes can be efficiently modified by particular biomolecules and many other compounds that are required for the action of biosensors. In addition, the above mentioned "terminal functional groups" can provide tailored electronic, electrochemical and optical properties to MXene-based biosensing structures[13][14][15]. Optical properties of MXenes are highly applicable for biosensing purposes[16], especially those which are based on fluorescence resonance energy transfer and induce changes in photoluminescence signal[17].

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