Ultrathin 2D nanomaterials; Challenges to overcome

[1]Sanoop Paulose and [1]Nirmala K. N.

[1]Department of Chemistry,
[1]St. Mary's College, Sulthan Bathery, India.

Abstract : 2D nanomaterials was known as potential candidates for a myriad of applications ranging from electrochemical energy storage materials (Batteries and supercapacitors), sensors, and electronic devices. Here we proposing the challenges to lookafter to produce 2d nanomaterials with good properties.

IndexTerms – **nanosheets, metal nitride, 2d materials, metal dichalcogenides.**

To date, 2D nanomaterials with sheet-like structure have been studied in more than 30000 published academic articles every year, suggesting that they are among the hottest topics in academic research and have great impacts on industry and our lives.[1] These ultrathin 2D nanomaterials can be prepared via wide ranges of well-developed synthetic methods, which have their own advantages and limitations. As a result ultrathin 2D nanomaterials with varying structural features including size, thickness, crystallinity, crystal phase, defect, doping, strain, and surface property, has been synthesized and is for various applications.

Currently, a broad range of 2D nanomaterials has been prepared and evaluated in different applications, including graphene, metal dichalcogenides, metal carbides, metal nitrides, layered oxides and hydroxides, layered metal-organic frameworks, and their derivatives. Among these 2D nanomaterials layered double hydroxide (LDH) has become the focus of an extensive scientific research, mainly due to its exceptional electrocatalytic activity. Several techniques, such as reversed co-precipitation, ball milling, co-precipitation using long-chain organic acid, were implemented in order to synthesize high-quality LDH. However, these synthesis routes do not necessarily assure phase purity and the desired morphology of the obtained material. In order to overcome this problem recently "atrane route"2 by using capping agents was introduced which gives highly purified LDH. As a modification of this method, Sonia Jaśkaniec[3] was able to synthesize highly crystalline Ni-Fe LDH hexagonal platelets by homogeneous precipitation at a relatively low temperature of 100 °C. This is quite interesting and thus this method can be adapted to synthesize other LDH.

Another potential candidate in this category, a prominent one being transition metal dichalcogenides (TMDs). The TMDs are represented by a general formula of MX2 where M is a transition metal of group 4-10 and X is a chalcogen (S, Se and Te), and therefore offers a wide range of materials with different constituents and resulting properties. Particularly, Molybdenum disulphide (MoS2) has recently attracted much interest as a prominent example of monolayer materials with remarkable physical properties.[4] Molybdenum covalently bonded to sulphur can form two-dimensional sheets that are linked to each other by weak van der Waals interactions, similar to graphene in graphite. The unique structural and optical properties of TMD monolayers and their material tunability makes them technologically relevant for various applications ranging from photodetectors, batteries and catalytic applications to the solar cells.

Even though Extensive research has been reported in literature some of the main aspects are still to be explored in this area.[5] First, from the material synthesis point of view, the current production yield, quality, quantity, and production rate of ultrathin 2D nanomaterials are still far from the criteria that are required for industry or commercialization. Therefore, one of the major challenges in this hot field is to realize the high-yield and massive production of ultrathin 2D nanomaterials to meet the industry requirements which is one of the areas I am looking for. The physical, chemical and electronic properties of ultrathin 2D nanomaterials are highly dependent on their structural features, which determine their performances in their applications. However, a controlled synthesis of ultrathin 2D nanomaterials with desirable structures is still difficult to realize by most current well-developed methods. Therefore, the preparation of ultrathin 2D nanomaterials with desired structural characteristics in a highly controllable manner is one of my objectives.

Second, most current ultrathin 2D nanomaterials lack the longterm stability and durability thus restricting their potential applications. Their relatively low stability mainly arises from the following situations: (1) Ultrathin 2D nanomaterials dispersed in liquid solution cannot be stored for a long time. High tendency to irreversible aggregation leads to the significant loss of advances arising from their 2D structural features. (2) Most of the ultrathin 2D nanomaterials are easy to oxidize in ambient conditions, resulting in the structural decomposition/degradation. (3) Structural change, decomposition, or collapse may occur during the chemical reaction in applications. Therefore, it is clear that the stability of 2D nanomaterials is critical, and required to be maintained not only during their storage and processing but also in applications. Hence, one of the most critical challenges in this field lies in the exploration of simple but reliable methods to stabilize these ultrathin 2D nanomaterials to dramatically prolong their stability.

Third, the current research on this topic is defined by their dimensionality rather than material compositions. Hence I believe that any kind of ultrathin 2D nanomaterials could be prepared if their growth can be confined into two dimensions and down to single- or few-atomic layers using proper experimental conditions. As a result, the most straightforward idea is to use those well-developed methods or develop new ways to prepare new ultrathin 2D nanomaterials with varying single-composition or multi compositions, which can be expected to exhibit new properties and functionalities. The well-developed exfoliation methods, such as the micromechanical cleavage, sonication-assisted liquid exfoliation, and ion intercalation assisted liquid exfoliation, might be also used to exfoliate new layered compounds into single- or few-layer nanosheets.

Fourth, hetero nanostructures which are the right way to overcome the drawback of a 2D nanomaterials. Graphene has been widely used as a highly conductive matrix to hybridize with other low conductive materials such as metal oxides, to enhance their electrical conductivity, thus optimizing their performance in some specific applications. More intriguingly, the synergistic effect between different components could bring some new appealing properties or functionalities. It has been reported that both the graphite oxide nanosheets and the iron oxide nanosheets exhibited low catalytic activities, but their composite gave rise to an excellent activity toward the decomposition of propellant oxidizer. Bearing this in mind, this is one of the promising research directions is to construct hybrid nanomaterials or well-defined hetero-nanostructures by using ultrathin 2D nanomaterials as building blocks, thus further optimizing their properties and/or functionalities.

References

1) Chaoliang T., et. al., Chem. Rev., 117, 6225−6331, 2017
1) Ni B. and Wang X., Chem. Sci., 6, 3572–3576, 2015
2) Sonia J., et. al., Scientific Reports, 8, 4179-4187, 2018.
3) Pengzhan S., Renzhi M. and Takayoshi S., Chem.Sci., 0, 1-3, 2013,
4) Leanddas N., Renzhi M., Nobuyuki S., Takayoshi S., Dalton Transactions, DOI: 10.1039/C7DT03706F, 2017
5) Xiangkai K., Qiangchun L., Changlin Z., Zhenmeng P. and Qianwang C., Chem. Soc. Rev., DOI: 10.1039/c6cs00937a, 2017.