Applications of MoS_2 as a Two-Dimensional Material Beyond Graphene

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An article usually includes an abstract, a concise summary of the work covered at length in the main body of the article.

I. INTRODUCTION

II. GRAPHENE AS A NEW TWO-DIMENSIONAL MATERIAL

A. The Discovery of Graphene

By the end of the last century microelectronics had revolutionized the world, the majority which are silicon-based devices. Today, millions of these silicon-based devices are used in many common electronic devices and have become unavoidable throughout everyday life. Though the first field-effect device was patented in 1925, it was not until 1960 that the first metal-oxide semiconductor field effect transistor was demonstrated [8, 11, 18]. A decade after the first device, devices were being made with several thousand components on a single chip. From there the progress increased at a rapid rate, a process now known as Moore's law, predicting that for each new generation of memory chip and microprocessor unit, the device size would be reduced by 33%, the chip size would be increased by 50%, and the number of components on a chip would quadruple every three years [14, 18]. This proven to be true, and up until recently had shown no signs of stopping. Many times the material limitations were overcome by advances in technology that were seemingly insurmountable and effectively had placed a cap on Moore's law, which ultimately led to new techniques and even more pristine silicon-based materials. However, the limit to oxide thickness has finally placed a maximum on the growth of the silicon-based semiconductor device industy [18]. This impending limit caused many to look for solutions that involved the use of SiO_2 devices and also alternatives to silicon. The result of the latter has given way to a breadth of literature and research that was unforseen a decade before. The search for alternatives to silicon resulted in research into many new, nontraditional materials. Several notable examples are organic conductors and carbon nanotubes [1, 3]. Arguably one of the most interesting nontraditional materials to come out of such research was graphene.

In 1985, with the discovery of fullerenes the amount of known carbon allotropes increased [9, 12]. Fullerenes suggested the existence of a one-dimensional form of carbon, known as carbon nanotubes, which were first demonstrated in 1991 [7]. Despite several theoretical studies involving the use of a single layer of graphite, it was not until 2004 that the first monolayer graphene sheet was isolated [15, 16]. In the most basic sense, graphene is simply a single layer of carbon atoms densely packed into a honeycomb lattice. It is used to describe properties several carbon-based materials (graphite, fullerenes, nanotubes, etc..., see Fig.1) [4, 15, 19]. This was significant because scientists had tried for many years to synthesize monolayers of graphite, though only succeeding in obtaining materials around 10 layers thick [12].

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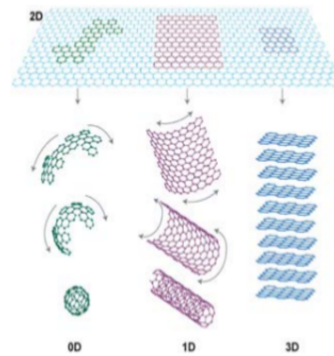

FIG. 1. Graphene can be envisioned in several dimensions. 0-dimensional buckyballs, 1-dimensional nanotubes, or 3-dimensional graphite (Originally found in [17].)

B. Properties of Graphene

III. TRANSITION METAL DICHALCOGENIDES

Graphene is being studied for its unique porperties, however, many other two-dimensional materials are known. Some of the two-dimensional materials being studied in addition to graphene are known as transition metal dichalcogenides (TMDs) [13, 21]. TMDs consist of hexagonal layers of metal atoms (M) in between two layers of chalcogen atoms (X) such that the stoichiometry of the material is MX_2 [23]. The material is dependent on the combination of transition metal, typically one of: Mo, W, Nb, Re, Ni, or V, and chalcogen, typically one of: S, Se, or Te [21]. These materials are commonly are stacked together which involves van der Waals interactions between adjacent sheets and covalent bonding within each individual sheet [23]. There are wide variety of properties exhibited by these structures, which include insulator or metal. In addition, they can also display some interesting properties like the topological insulator effect, superconductivity, and thermoelectricity [6, 10, 22, 24]. Ongoing research also includes graphene-like nano materials like silicene and germanene, which are the silicon and germanium-based versions of graphene and are found to show properties that are similar to graphene [2, 20]. These two-dimensional materials are becoming increasingly attractive for a wide-range of applications due to their distinct properties.

A. Properties of MoS_2

As discussed in sec. II B, pristine graphene has no band gap. Though it is possible introduce a band gap in bilayer graphene and graphene nanoribbions, the appeal of many TMDs is that they have direct band gaps which make them ideal candidates for electronic material applications [23]. One such example of a semiconducting TMD is MoS_2. TMDs, and more specifically MoS_2 and the properties it exhibits have been studided to some extent for several decades [5].

IV. SYNTHESIS METHODS

V. APPLICATIONS OF MoS_2

VI. STATE OF THE ART

VII. PROBLEMS AND OUTLOOK

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