Growth of extremely thin MoS_2 films by pulsed laser deposition

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Abstract

Two-dimensional (2D) materials have been one of the most extensively studied classes of materials due to their unusual physical properties. The best example is graphene – a single layer of carbon atoms arranged in a two dimensional (2D) honeycomb lattice. Many graphene´s extraordinary properties have been reported including excellent electronic and thermal conductivities and mechanical properties [1]. However, pristine graphene itself is unlikely to be used for the fabrication of logical circuits because of lacking band gap.

The discovery of graphene has stimulated an extensive research on other 2D materials. It has been shown that it is not only possible to exfoliate stable, single-atom or single-polyhedral-thick 2D materials, but that these materials can exhibit unique and fascinating physical properties. The 2D structure determines the electronic properties that may exhibit correlated electronic phenomena such as charge density waves and superconductivity [2].

Some remarkable changes in the electronic properties of layered materials as their thickness is reduced down to single or only a few layers are common among these 2D crystals. In contrast to the zero band gap of pristine graphene itself, a single-layer MoS_2 sheet is a direct band gap semiconductor. The result is that MoS_2 is a promising material that has the potential to be incorporated into digital circuits and light-emitting diodes. For instance, the current on/off ratio of single-layer MoS_2 transistors exceeds 10^8 at room temperature. This is much higher than that (approximately 100) of graphene transistors [3].

Recognizing the uniqueness of the 2D structure, one may expect that such materials will reveal new and unexpected properties providing a number of innovative opportunities. Because of their distinct properties and high specific surface areas, these 2D materials are important in various applications such as optoelectronics, spintronics, catalysts, chemical and biological sensors, supercapacitors, solar cells, and lithium ion batteries [4].

Here, we present preparation of very thin MoS_2 films on various substrates (Si, sapphire, GaN) from a stoichiometric target by a pulsed laser deposition. Combined results from Raman spectroscopy and X-ray reflectivity have shown that the thinnest samples contain two MoS_2 layers. The thickness is controlled by the number of laser pulses applied albeit no simple direct proportion between the two quantities has been observed. Selected area electron diffraction studies have confirmed that the films deposited on Si (100) are nanocrystalline and oriented perpendicularly to the substrate surface while an epitaxial growth of MoS2 films was observed on GaN substrates [5].

We also report on preliminary results on fabrication of ultrathin MoS_2 layers on graphene and graphene oxide. Hybrid systems are promising for some applications including photodetectors and field effect transistors where graphene may act as a material for electrodes with ultimate thickness.

References

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Acknowledgement

This work was supported by the Slovak Research and Development Agency, APVV-0693-15, APVV LPP-0078-07, Slovak Grant Agency for Science, VEGA 2/0120/14, VEGA 2/0178/15, the project CENTE I, R&D Operational Program funded by the ERDF, ITMS code 26240120011.