2D Material based Optoelectronics by Electroplating

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Abstract

Developing scalable techniques for growing transition metal dichalcogenides (TMDCs) 2D materials is a major challenge that needs to be overcome before these materials can make an impact on the (opto-) electronic industry. Electroplating (electrodeposition) is an industrially acceptable deposition technique that has unique advantages. In this work, we present a novel electrode design that enable MoS_2 to be grown laterally over an insulator. Photodetector devices were developed based on electrodeposited TMDCs. We will then present vertical growth of large area and micropatterned MoS_2 and WS_2 monolayers on graphene electrodes. These results demonstrate that electrodeposition is an attractive method for producing device quality 2D materials which can be scaled to wafer sizes for fabrication industries.

Background

Industrial methods such as chemical vapor deposition (CVD) have shown significant success in producing scalable graphene films. On the other hand, limited progress was achieved in making TMDC films by CVD continuous and uniform over large areas. Furthermore, the requirement to deposit these materials at very high temperatures creates defects on existing materials such as graphene. Defects also arise on graphene when plasma sputtering is employed to deposit TMDCs due to ion bombardment, thus, limiting the usability of these techniques in TMDC/graphene 2D heterostructures. In comparison, electrodeposition is a room temperature and industrially acceptable technique that can deposit materials selectively over conductive electrodes.

Results and Discussions

This presentation splits into two main parts. The lateral electrodeposition of MoS_2 for photodetector applications [1]; and the vertical growth of MoS_2 and WS_2 over graphene electrodes [2, 3].

Part 1 - By fabricating a new type of microelectrodes (Fig. 1 (a)), MoS_2 2D films grown from TiN electrodes across opposite sides are connected over an insulator substrate, hence forming a lateral device structure through only one lithography and deposition step. Using a variety of characterisation techniques, the growth rates of MoS_2 is shown to be highly anisotropic with lateral to vertical growth ratios exceeding 20 folds. Electronics and photo-response measurements on the device structure demonstrate that the electrodeposited MoS_2 layers behave like semiconductors and show responsivity of 1 mA/W (Fig. 1 (b).

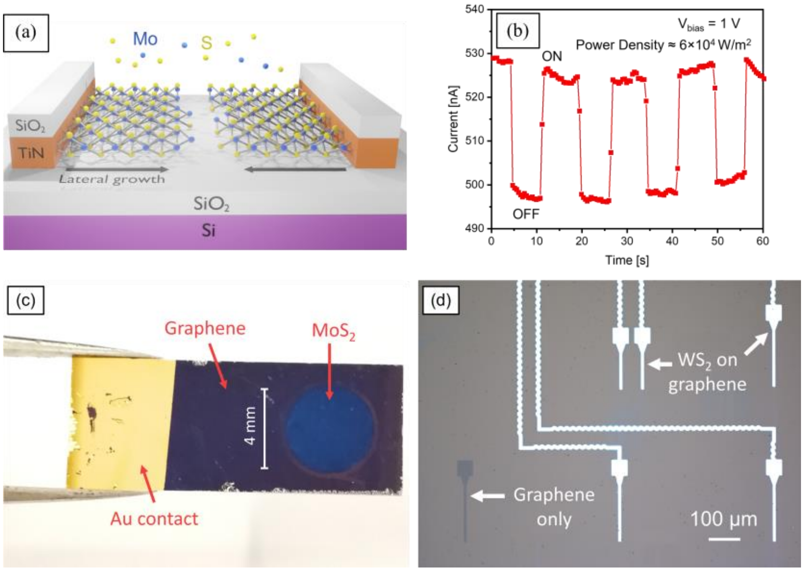

Fig. 1: (a) Illustration schematic of the concept of the lateral growth electrodes for TMDC electrodeposition. (b) Optical microscope image of a series of fabricated Tin electrodes with laterally grown MOS_2 films. (c) Image of a large area MoS_2 film grown over graphene (d) Optical microscope image showing the difference between patterned WS_2/graphene heterostructures and bare graphene.

Part 2 - Using large area graphene films grown and transferred on Si, we were able to electrodeposit large and micro-patterned areas of MoS_2 (Fig. 1 (c)) and WS_2 (Fig 1 (d)) over the graphene electrodes. We were able to control our electrodeposition thickness to the monolayer level and demonstrate site selective deposition of continuous and atomically uniform layers of TMDC on micropatterned graphene.

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