The Case for Missing Sulfur

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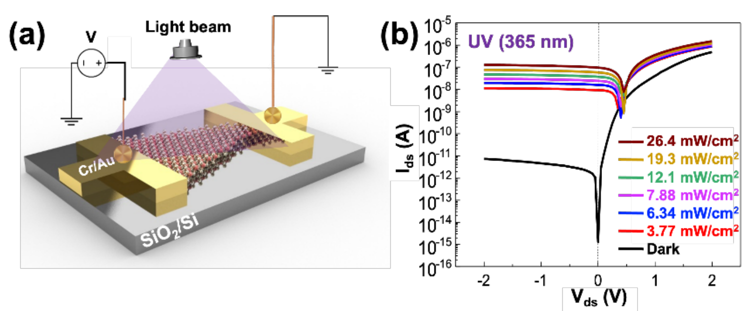
A common strategy for obtaining an ohmic contact to any semiconductor is to form a tunnel junction using a heavily doped surface layer. Independent of the magnitude of the interfacial barrier, the narrow width of the depletion layer allows for efficient tunneling and a linear current-voltage transport. This has worked well for classical bulk devices where transport is through a thick crystal. The low resistance ohmic contact can be a large area, placed for example at the bottom of a wafer. For two-dimensional semiconductors, such as MoS_2, the transport of interest is typically parallel to the surface meaning lateral contacts are required. However, if the semiconductor is an exfoliated triangular flake, parallel contacts become naturally asymmetric in area once the metal is evaporated and patterned on top. It was also soon noticed by a few groups that different area contacts resulted in rectification (10^5 decades), even when the same metal was used, with the *smaller* area contact having the lower resistance ohmic transport. In particular, the application of different area reactive Cr/Au contacts on (20-60) nm thick exfoliated MoS_2 flakes has been an effective method to fabricate a two terminal diode that has been applied towards optoelectronics and biosensing applications [1-2].

The latest example from our collaboration is the sensing of volatile gases using a UV optically powered asymmetric MoS_2 diode [3]. Shown in the figure is a schematic diagram of the device (55 nm thick MoS_2) with a set of I-V characteristics as a function of UV power. This presentation will discuss the likely mechanisms as a function of metal thickness, contact edge lengths, and MoS_2 source and thickness. Topics such as Fermi level pinning, sulfur reaction and diffusion, and buried depletion regions might be discussed.



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[1] Flexible High-Performance Photovoltaic Devices based on 2D MoS_2 Diodes with Geometrically Asymmetric Contact Areas, Amin Abnavi, Michael M. Adachi, et al. *Adv. Funct. Mater*. **33** (2022) 2210619. DOI: 10.1002/adfm.202210619

[2] Ultrasensitive rapid cytokine sensors based on asymmetric geometry two-dimensional MoS_2 diodes
Thushani de Silva, Mirette Fawzy, et al., *Nature Comm.* **13**, 7593 (2022).

[3] A Photovoltaic Self-Powered Volatile Organic Compounds Sensor Based on Asymmetric Geometry 2D MoS_2 Diodes, Mirette Fawzy, MR Mohammadzadeh, et al. *ECS Sensors Plus,* in press (2024).