Optoelectronics and Valleytronics with atomically thin 2D Materials

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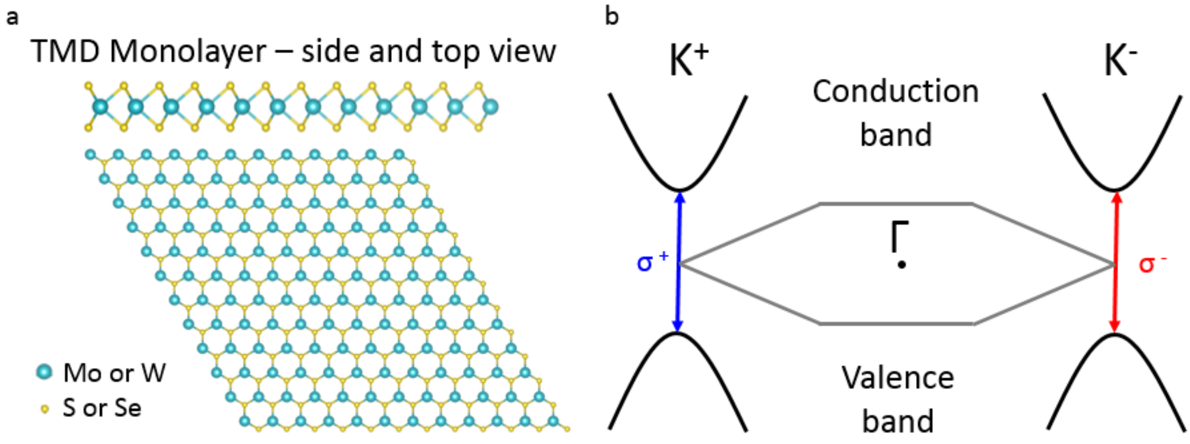
In the large family of layered crystals with strong in-plane bonds and weak van der Waals coupling between the layers it is possible to isolate atomic monolayers with simple exfoliation ('Scotch-tape') methods. The isolation of single-atomic layer graphene has led to a surge of interest in this field. The fundamental properties of the isolated monolayers can be fundamentally different, from semi-metals, semi-conductors to superconductors. Combining these atomically flat layers in heterostructures will allow for a completely new class of engineered, ultrathin structures and devices such as Field Effect Transistor, solar cells, photodetectors, LEDs, power cells, photocatalytic and sensing devices[1]. These devices are of paramount importance for the world we live in. LEDs already started to change the way we light up our cities and homes, solar cells, power cells and photocatalytic devices can provide a clean and renewable source of energy for the years to come, while optoelectronic components can make every technological device more efficient and much faster.

Among these crystals 2H Transition Metal Dichalcogenides (TMDs) are attracting a lot of attention as they are semiconductors. When thinned down to the single layer level, their light matter interaction is strongly enhanced due to the emergence of a direct bandgap. Light absorption per monolayer can be 20 %, compared to 0.6% for quasi-2D GaAs layers, currently used in optoelectronics applications. Moreover, due to the reduced dimensionality of the monolayer a very strong electron-hole (e-h) interaction is present, leading to the formation of excitons, bound complexes analogue to the hydrogen atom. This makes the design of excitonic devices possible[2]. Ultimately they present a unique band structure which allows the selective absorption of photons of well defined circular polarization. This is connected to a new degree of freedom for electrons, addressing specific valleys in momentum space. So in addition to possible device applications in optoelectronics, the emerging fields of Valleytronics and Spintronics allow scientist and engineers to investigate 2D layers for future application in (quantum-) computing.

1) Q.H. Wang, Nature Nanotech. 7, 699–712 (2012)
2) *Z. Li, ACS Nano*, 2016, 10 (11), pp 9899–9908



(a) and top view of one monolayer of the TMDs family. The blue atoms are either Molibdenum or Tungsten atom while the yellow ones represent a chalcogen (S or Se).

(b) Schematics of the chiral optical selection rules for interband optical transitions in non-equivalent valleys K+ and K- .