Electrically tunable TMD-based tunneling light emitting diodes

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Abstract. Light-emitting diodes (LEDs) and laser-diodes provide a vital link between electronics and photonics and enable electrically driven optical sources. LEDs are also being investigated for short-range (chip-to-chip, intra-chip) optical interconnects as an energy-efficient optical source [1], where information would be transmitted over a directly-modulated, fast (tens GHz) [1] LED, rather than a power-consuming, externally-modulated laser [1]. However, solid state LEDs are mostly made of compound (III-V) semiconductors and have a fixed emission wavelength [2]. These can lead to difficulties in integration with emerging silicon photonics because of poor compatibility with CMOS technology [3], and can limit the interconnect data capacity compared to a wavelength tunable light source [4]. A wavelength-tunable solid-state LED in a single device has not yet been realized. Monolayer transition metal dicalcogenides (1L-TMDCs) are direct bandgap [5], chemically stable [6], CMOS compatible semiconducting materials suiting the LED applications. Recent studies on TMD-based LEDs are mainly based on the lateral p-n junctions [7,8] and quantum-well structures [9]. Here, we present a new class of electrically-tunable LED operating at room temperature in the visible and near-infrared. The LED is designed as a single tunneling junction produced by vertically-stacking of a single layer graphene (SLG) electrode for charge injection, an insulating hexagonal boron nitride (hBN) layer (2-6 layers) used as a tunnel barrier and a semiconducting monolayer TMD (such as MoS_2 and WSe_2) for light emission. In this configuration, a tunneling current from SLG creates an excess carriers in the optically active, n- and p-doped 1L-TMDs, and as a result triggers radiative recombination and light emission. By controlling the emission of neutral and charge excitons [10] we tune by means of a back gate the electroluminescence spectra and obtain wavelengths shift of ~20nm in TMD-based LEDs at room temperature, with a quantum efficiency up to 0.4%. The obtained efficiency is 4 times larger than that in p-n junctions [7,8] and one order of magnitude larger than that in quantum wells [9]. Our work opens up a way for developing advanced tunable LEDs and lasers.

References

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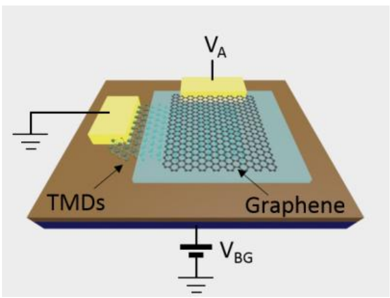
Figures

(a)



(b)

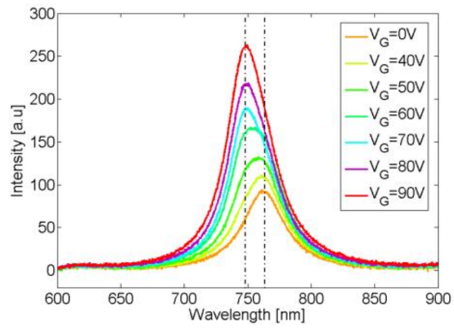


Fig 1. (a) Schematic drawing of gate-controlled TMD-LED. (b) Gate tunable EL spectrum of WSe_2-based LED.