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Electroluminescence from perylene diimide monolayers encapsulated in van der Waals tunnel diodes

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Well-ordered monolayer islands of perylene diimide can be grown on hexagonal boron nitride (hBN) with lateral dimensions well in excess of 1 µm. We explore the functional properties of PTCDI monolayers incorporated into vertical heterostructures. These molecular/2D hybrid devices are fabricated by adapting established transfer techniques[1] to facilitate the van der Waals pick-up of hBN flakes on which molecular monolayers have been pre-deposited. This technique enables the encapsulation of a molecular layer between two hBN tunnel barriers sandwiched between few layer graphene electrodes[2]. These devices exhibited an exponential current-voltage dependence which was accompanied by electroluminescence from the molecular monolayers with an emission maxima observed at approximately 2.1 eV with an associated vibronic peak. Above-threshhold luminescence is also observed in the regime where the photon energy $h\nu > eV$, where V is the applied voltage, suggesting a multi-electron excitation process and we discuss this in terms of a possible triplet-triplet annihilation mechanism.

References

[1] Pizzocchero, F. et al. The hot pick-up technique for batch assembly of van der Waals heterostructures. Nat. Commun. 7, (2016).
[2] Withers, F. et al. Light-emitting diodes by band-structure engineering in van der Waals heterostructures. Nat. Mater. 14, 301–306 (2015).

Figures

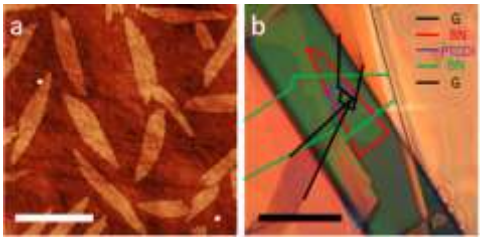

Figure 1: An atomic force microscopy (AFM) image, scale bar 10 µm, of PTCDI grown on hBN (a) reveals large monolayer islands. Using existing transfer techniques, a monolayer of PTCDI on ultra-thin hBN was picked up and incorporated into a stack featuring BN, few-layer graphene, BN, PTCDI, BN, few layer graphite and BN (b, scale bar 30 µm).