Intensely illuminated Excitons and Tightly Bound Trions in 2-D Phosphorene achieved through Optical Dimensional Transformation

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Phosphorene a recently discovered 2-D material has interesting optical properties and applications in low dimensional photonic devices [1]. Here we describe a method to enhance the illumination of excitons in 1L phosphorene through introducing luminescent local states using PECVD oxide substrates in contrast to the commonly used silicon based substrates. These 0-D excitons are extremely localized in nature and emit bright photons at ≈920 nm. We use this interface to demonstrate the anistropic optical properties of phosphorene and discuss the dynamics of quasi 1-D excitons and trions in a specific polarization/orientation (armchair direction) of its crystal lattice through linearly polarized Photoluminescence(PL) measurements. The quantum yield of 0-D like localized excitons is reported to be ~33.6 times higher than intrinsic quasi 1-D free excitons in single layer phosphorene [2]. Further, we report extremely large binding energies of trions (~162meV) in 3L phosphorene observed experimentally at room temperature by fabricating a simple MOS based transistor device, which were earlier considered to be unstable and only observed at cryogenic temperatures [3]. We further find a coherence with our experimental observations and theoretical calculations of binding energy of trions by using a Variational quantum Monte Carlo method [4], further confirming the reason for high binding energy of trions as the strongly confined quasi 1-D excitons. These observations provide a platform to study fundamental particle interactions and properties at room temperature which have profound applications in development of few layer photonic devices.

References

[1] H. Liu, ACS Nano 2014, 8, 4033.
[2] Zhang, Shuang, et al., ACS nano 8.9 (2014): 9590-9596.
[3] S. Tongjay et al., Sci. Rep. 2013, 3, 2657.
[4] Matsunaga, R et al., Phys. Rev. Lett. 2011, 106, 037404.

Figures

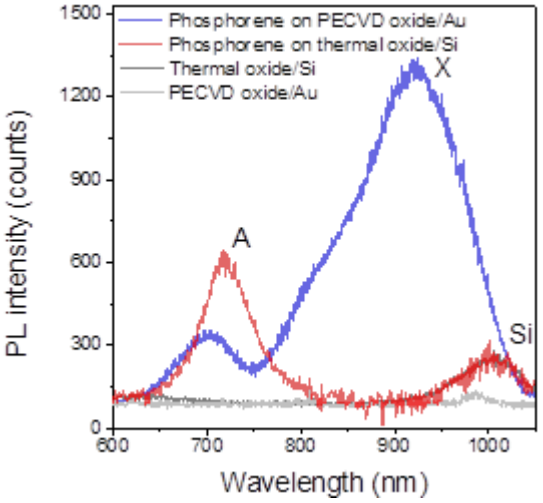

Figure 1: Measured PL spectra of the monolayer phosphorene on PECVD oxide/Au and thermal oxide/Si substrates.

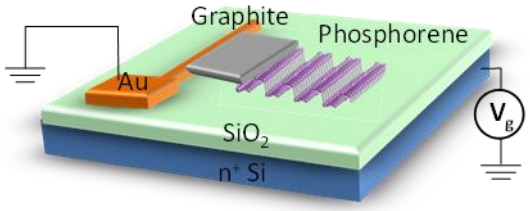

Figure 2: Schematic plot of a phosphorene MOS device used for trion demonstration.