Atomic scale electronics and photonics (AtomEP) with quantum dots in 2D materials

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Shrinking electronic circuits down to nanometer scale may enable atomic scale electronics and photonics powering quantum processors and nanoscale robots. We describe here recent theoretical and experimental work aiming at design of atomically precise nanostructures in graphene and transition metal dichalcogenites (TMDCs) capable of realizing the three functionalities of a quantum circuit: electronics, photonics and spintronics. The design tools include combination of materials, number of atomic layers, lateral size, shape, type of edge, sublattice symmetry, topology and carrier density in graphene and TMDC quantum dots. In graphene, sublattice engineering allows design of magnetic moments tunable with voltage and light and size engineering leads to optical gaps from THz to UV[1-4]. Electrostatically defined quantum dots bypass the need to control the edges of finite structures. We describe the role of gates, K and Q valleys, SO, topology, number of electrons and electron-electron interactions on the electronic properties of electrostatically gated quantum dots in bilayer graphene and MoS2 [5-7]. The existence of valley polarized broken symmetry many-body states will be discussed.

REFERENCES

[1] A.D.Guclu, P. Potasz, M. Korkusinski and P. Hawrylak,"Graphene Quantum Dots", Springer 2014; P. Hawrylak, F. Peeters, K. Ensslin, Editors, Carbononics–integrating electronics, photonics and spintronics with graphene quantum dots, Focus issue, Physica status solidi (RRL)-Rapid Research Letters 10 (1), 11(2016).
[2] A.D.Guclu, P. Potasz, O.Voznyy, M. Korkusinski, P. Hawrylak, Phys.Rev.Lett.103, 246805 (2009).
[3] C. Sun, F. Figge, I. Ozfidan, M. Korkusinski, X. Yan, L-S. Li, P. Hawrylak and J. A. McGuire, NanoLetters 15,5742 (2015).
[4] Y. Saleem, L. Najera Baldo, A. Delgado Gran , L. Szulakowska and P. Hawrylak, " Evolution of bandgap with size in armchair and zigzag graphene quantum dots", Journal of Physics: Condensed Matter 31 (30), 305503 (2019).
[5] M. Bieniek, L. Szulakowska, P. Hawrylak,"The effect of valley, spin and band nesting on electronic properties of gated quantum dots in MoS2", Phys.Rev.B 101 (3), 035401 (2020).
[6] T. Scrace, Y. Tsai, B. Barman, L. Schweidenback, A. Petrou, G. Kioseoglou, I. Ozfidan, M. Korkusinski, and P. Hawrylak, Nature Nanotechnology 10, 603 (2015).
[7] L. Szulakowska, M. Bieniek, M. Cygorek, P.Hawrylak, "Valley and spin polarized broken symmetry states of interacting electrons in gated MoS2 quantum dots", Phys.Rev.B, (in print) (2020). https://arxiv.org/abs/2005.04467