Semiconductor and Graphene Quantum Dots

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We describe here recent theoretical and experimental results on both lateral gated and self-assembled semiconductor quantum dots and on graphene quantum dots. Using LCHO-CI, extended Hubbard, CI and DMRG methods we describe lateral quantum dot molecules with controlled electron numbers in each dot and discuss potential use of such molecules as building blocks of a field effect transistor with a macroscopic quantum state based on artificial Haldane gap material, of a coded qubit based on chirality, GHZ maximally entangled state and Berryˆs phase generators[1]. We also describe topological phases driven solely by e-e interactions in a quadruple quantum dot molecule[2] and by spin orbit interaction in InAs [3] and HgTe based quantum dots[4]. We next turn to CdTe quantum dots containing single magnetic ions and discuss quantum interference and Kondo-like effects in fine structure of Mn ions interacting with excitons[5] and bi-excitons[6]. Finally, we describe one atom thick semiconductor quantum dots made of graphene and compare them with semiconductor quantum dots. Using a combination of DFT, tb, HF, CI and GW-BSE approaches we show that their electronic, optical and magnetic properties can be engineered by the size, shape, type of edge, topology and number of layers [7-12]. We focus on their optical and magnetic properties, and their control with external gate, carrier density, electric field and light. A possibility of realizing a fully integrated carbon-only quantum circuit will be discussed.

[1] C-Y. Hsieh, Y.P. Shim. M. Korkusinski and P. Hawrylak, Rep. Prog. Phys. **75**, 114501 (2012).
[2] I.Ozfidan,A.Trojnar,M.Korkusinski and P.Hawrylak, Solid State Comm172,15(2013).
[3] M. F. Doty, J. I. Climente, M. Korkusinski, M. Scheibner, A. S. Bracker, P. Hawrylak, and D. Gammon, Phys. Rev. Lett. **102**, 047401 (2009).
[4] M.Korkusinski and P.Hawrylak, Nature: Scientific Reports 4, 4903, (2014).
[5] A. Trojnar, M. Korkusi´nski, E. Kadantsev, P. Hawrylak, M.Goryca, T. Kazimierczuk, P. Kossacki, P. Wojnar, and M. Potemski, Phys. Rev. Lett. 107, 207403 (2011).
[6] A. H. Trojnar, M. Korkusinski, U.C. Mendes, M.Goryca, M. Koperski, T. Smolenski, P. Kossacki, P.Wojnar, and P.Hawrylak, Phys.Rev.B87, 205311 (2013).
[7] A.D. Guclu, P. Potasz, O. Voznyy, M. Korkusinski, P. Hawrylak, Phys.Rev.Let,**103**,246805(2009).
[8] A. D. Güçlü, P. Potasz and P. Hawrylak, Phys. Rev. B 84, 035425 (2011).
[9] P. Potasz, A. D. Güçlü , A.Wojs and P. Hawrylak, Phys. Rev. B **85**, 075431 (2012).
[10] D.Guclu and P.Hawrylak, Phys. Rev**. B**87, 035425 (2013).
[11] D.Guclu, M.Grabowski and P.Hawrylak, Phys.Rev. **B**87, 035435 (2013).
[12] I.Ozfidan,M.Korkusinski,A.D.Guclu,J.McGuire,P.Hawrylak, Phys.Rev. **B**89, 085310 (2014).