MAP-fis Essay Proposal, 2013-2014

(*please write in English*)

Supervisor

Name: Rui N. Pereira

e-mail: rnpereira@ua.pt

Title

Electronic doping and magnetic anisotropy in nanocrystal quantum dot systems

Area

(*Materials, Optics, Condensed Theory, High Energy Theory,....*);

Nanoscience and nanotechnology

Summary of Proposal

Crystalline nanocrystals (NCs) of inorganic semiconductors are crystallites a few nanometers in scale with unusual size-specific optical, electronic, and magnetic properties that are not present in the bulk situation, such as efficient light emission [1], tunable band-gap [2], and extremely high surface-to-volume ratio. These novel and exciting properties have already proven useful for the application of NCs in various technologies, such as wavelength-tunable lasers [3] bioimaging systems [4, 5], solar cells [6], and high-density recording media [7]

This essay aims at reviewing the recent advances on two of the most prominent phenomena for future technologies based on NCs: electronic doping and magnetic anisotropy. Electronic doping of NCs, i.e. the introduction of additional charges in the NCs, is a promising means to tailor the electronic behavior of NCs and thus many research efforts have been directed towards this topic in recent years [8]. Several advances have already been reported on this subject, namely the successful incorporation of donor and acceptor impurities in NCs of e.g. CdSe [9], ZnO [10], and Si [11,12]. But despite these current advances, the electronic structure of doped NCs remains largely unresolved. In this essay, the major advances in the doping of NCs of semiconductor materials will be reviewed. Particular emphasis on the advances made on the electronic doping of Si NCs which are non-toxic, environmentally inert, highly abundant, biocompatible, and compatible with the well established silicon-based CMOS microelectronics. Moreover, magnetic anisotropy critically determines the utility of magnetic NCs in new nanomagnetism

technologies such as high-density recording media [7] and magnetic resonance imaging [13]. These applications rely on magnetic anisotropy to preserve the orientation of magnetization against e.g. thermal fluctuations. Nonetheless, the origin of magnetic anisotropy in NCs systems lacks physical understanding. This essay will cover the most relevant strategies developed to control the magnetic anisotropy of NCs systems, as well as the physical reasoning developed to explain this phenomenon.

(*continue if necessary*)

References

(*to allow students first look at topic*)

[1] R. Anthony and U. Kortshagen, *Phys. Rev. B* **80**, 115407 (2009)

[2] A. P. Alivisatos, *Science* **271**, 933 (1996)

[3] V. I. Klimov, S. A. Ivanov, J. Nanda, M. Achermann, I. Bezel, J. A. McGuire, and A. Piryatinski, *Nature* **447**, 441 (2007)

[4] X. Michalet, F. F. Pinaud, L. A. Bentolila, J. M. Tsay, S. Doose, J. J. Li, G. Sundaresan, A. M. Wu, S. S. Gambhir, and S. Weis, *Science* **307**, 538 (2005)

[5] A. Levy, A. Dayan, M. Ben-David, and I. Gannot, *Nanomedicine* **6**, 786 (2010)

[6] I. Gur, N. A. Fromer, M. L. Geier, and A. P. Alivisatos, *Science* **310**, 462 (2005)

[7] C. Stamm, F. Marty, A. Vaterlaus, V. Weich, S. Egger, U. Maier, U. Ramsperger, H. Fuhrmann, and D. Pescia, *Science* **282**, 449 (1998)

[8] D. J. Norris, A. L. Efros, and S. C. Erwin, *Science* **319**, 1776 (2008)

[9] C. Tuinenga, J. Jasinski, T. Iwamoto, and V. Chikan, *ACS Nano* **2**, 1411 (2008)

[10] S. B. Orlinskii, J. Schmidt, E. J. J. Groenen, P. G. Baranov, C. de Mello Donegá, and A. Meijerink, *Phys. Rev. Lett.* **94**, 097602 (2005)

[11] A. R. Stegner, R. N. Pereira, K. Klein, R. Lechner, R. Dietmueller, M. S. Brandt, and M. Stutzmann, *Phys. Rev. Lett.* **100,** 026803 (2008)

[12] R. N. Pereira, A. R. Stegner, T. Andlauer, K. Klein, H. Wiggers, M. S. Brandt, and M. Stutzmann, *Phys. Rev. B* **79**, 161304(R) (2009)

[13] G. Zabow, S. Dodd, J. Moreland, and A. Koretsky, *Nature* **453**, 1058 (2008)