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Spin-Dependent Phenomena in Semiconductor Micro- and Nanoparticles for Biomedical Applications

Vladimir Fomin[1,2,3]

[1] *Institute for Integrative Nanosciences, Dresden, Germany*
[2] *Laboratory of Physics and Engineering of Nanomaterials, Department of Theoretical Physics, Moldova State University, Chisinau, Republic of Moldova*
[3] *Institute of Engineering Physics for Biomedicine, National Research Nuclear University "MEPhI", Moscow, Russia*

This talk represents an overview of spin-dependent phenomena in nonmagnetic semiconductor microparticles (MPs) and nanoparticles (NPs) with interacting nuclear and electron spins [1]. Its goal is to covering a gap between the basic properties of spin behavior in solid-state systems and a tremendous growth of the experimental results on biomedical applications of those particles. I will focus on modern achievements of spin-dependent phenomena in the bulk semiconductors from the theory of optical spin orientation under indirect optical injection of carriers and spins in the bulk crystalline silicon —via numerous insightful findings in the realm of characterization and control through the spin polarization—to the design and verification of nuclear spin hyperpolarization in semiconductor MPs and NPs for magnetic resonance imaging (MRI) diagnostics. Semiconductor MPs and nanoparticles NPs exhibit interesting electronic, optical and magnetic properties, which depend on a preferential orientation of electron and nuclear spins in those particles. These properties are essential for their biomedical applications. Spatial confinement of charge carriers (electron and holes) in a semiconductor nanostructure results in an increase of the spin-lattice relaxation time. Going from itinerant to immobile, fully-localized electrons, while inducing the hyperfine dephasing, can be also beneficial in quenching the spin-lattice relaxation. The dynamic nuclear polarization in semiconductor nano- and microstructures opens fascinating prospects for creation of new efficient contrast agents in MRI, which is a powerful diagnostic tool in biomedicine. Perspective applications of silicon MPs and NPs in hyperpolarized 29Si MRI are discussed. For instance, spin-dependent energy transfer from excitons confined in Si nanocrystals (nc-Si) to molecular oxygen in the ground triplet state is promising for application of nc-Si based NPs and MPs in photodynamic therapy of cancer [2]. Both the bioimaging and therapeutic functionality of Si NPs are being combined in theranostics of cancer [3].

References

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