NANOHETEROSTRUCTURES WITH PRE-DESIGNED MAGNETO-ELECTRONIC PROPERTIES FOR QUANTUM INFORMATION TECHNOLOGIES

Increasingly, quantum information processing concept is being viewed as a dominant approach to facilitate further advances in electronics, communication and information processing, thus providing for the continuing technological growth of the U.S. society. Utilization of entangled dynamic electron spin states as qubits manipulated with by the external electromagnetic (em) fields and/or electric current suggests a cost-effective opportunity to integrate quantum information concept with existing electronic nanomaerials technologies. This, however, requires fundamental understanding of evolution of entangled (E), polarized (P) and otherwise coherent (C) dynamic electron spin states, and their contributions to quantum spin/charge transport properties of the atomic-scale systems, necessary to design and operate quantum logic gates.

This intellectually challenging project is focused on the development of fundamental, systematic and synergetic theoretical, computational and experimental methods to relate synthesis, processing and microstructure of novel quantum electronic nanomaterials to their spin/charge transport properties defined by EPC electron spin states (EPC, or intrinsic quantum contributions to the quantum spin/charge transport properties). The **virtual (i.e., fundamental theory-based, computational) methodology** developed in this project will be implemented experimentally in the case of exchange-biased core (Co or Ni) – shell (CoO or NiO, respectively) small quantum dots and wires (QDs and QWs) of about 1 to 5 nm in diameter confined in well characterized nanopores of alumina or silica membranes. Predictive capabilities of the fundamental, first-principle, equilibrium two-time temperature Green function (TTGF)-based theoretical approaches developed in the course of this project will far exceed those of the case-specific, semi-heuristic “quantum” kinetic equation-derived methods and similar *ad hoc* “models” that constitute the mainstream of the existing theoretical descriptions of spin/charge transport at nanoscale. Moreover, while significantly simplifying and decreasing the volume of computations, the novel TTGF-based methods will be specifically designed to **include quantum confinement into consideration**, reveal its effects on the spin/charge transport in the quantum-confined atomic-scale systems, and use the confinement as an important tool to stabilize and manipulate with the EPC dynamic electron spin states. The EPC contributions to the conductivity, magnetic and dielectric susceptibilities will be correlated to the microstructure of these systems, their confinement, and the parameters of the external em fields and/or electric current. On the other hand, the EPC transport properties will be directly related to the corresponding EPC dynamic electron spin states, thus providing an opportunity to realize and manipulate with dynamic electron spin qubits. The project outcome will include a **fundamental theory-based methodology, library of virtual templates and the corresponding innovative experimental methods and systems** of small quantum-confined QDs/QWs with pre-designed EPC quantum transport, that support field/current-operable EPC dynamic electron spin qubits. These results will pave a road toward technology-friendly realization of quantum information processing concept.

Advanced theoretical methods developed in the course of this project are crucial for much needed breakthrough in quantum electronics and numerous technologies derived from it, to support further technological growth of the U.S. society. The project results will provide a foundation for joint work with industry focused on development of quantum information processing devices and circuits. Several patents are expected to be applied for. Experience gained by the faculty and students directly involved with or exposed to the project will significantly contribute to education of the work force that is mandatory to develop novel quantum information technologies. The project development process and results will be relayed to wider circles of academic and industrial scientists, engineers, business and public, to generate support of the cause. The project website, electronic news-letters, professional and popular publications, presentations, lectures and briefs will be available internationally, nationwide, at Birmingham Business Resource Center, local technology incubators and schools, specifically targeting groups underrepresented in high-tech and education.