EXPERIMENTAL FABRICATION AND NON-DESTRUCTIVE CHARACTERIZATION OF NOVEL SEMICONDUCTOR NANOMATERIALS FOR SENSOR AND SOURCE APPLICATIONS

Experimental Problem Formulation

Modern growth technologies has made possible nanometer-scale materials with controllable dimensions and opto-electronic (OE) and magneto-optical (MO) properties that provide a foundation for band-engineered quantum dot (QD)-based nanoheterostructures (NHS), long infrared (IR) photodetectors and lasers, nanophotonic LO switches, waveguides, optical near-field probes, high-density-speed optical memory systems, spintronics, etc. With the characteristic dimensions approaching a few nanometers, contributions to the OE-MO properties due to quantum confinement effects become dominant and extremely sensitive to sub-nanoscale irregularities of size and shape that contribute to undesirable photon/electron/quasiparticle scattering/absorption/propagation that limit useful properties of such QD-based NHS. While many sophisticated techniques of nanomaterials fabrication have been suggested and used in recent years, only a few of them are capable of furnishing QD-based NHS with precisely controlled dimensions and periodicity of elements up to several angstroms. This project is devoted to (i) innovative improvement of one of the most promising of such techniques, nanoporous membrane-templated synthesis, (ii) non-destructive characterization of the synthesized sub-nanostructured OE/MO materials, and (iii) development of reliable methodologies of measurements of the OE-MO properties of such nanomaterials.

Timeliness and Significance of the Proposed Research

OE/MO nanomaterials synthesized and studied in the course of this project will be major candidates for long wavelength IR photodetectors, lasers and MO-based sensors that will enhance by orders of magnitudes the existing device capabilities. Immediate USAF applications will include near IF lasers (1.3 to 1.55 μm) for the use in air/space platforms, and novel mid- to far- IR photodetectors for the use in space-based surveillance.

Goals and Objectives of this project fall into two major categories,

- **Sub-Nanostructure Materials Synthesis**: experimental synthesis of alumina and silica membranes with well-characterized vertical pore arrays filled with (1) GaAs, GaAs/P, InAs, and InAs/P QD "alloys" for the IR detector/source use; (2) ZnS, ZnS/Fe or Co, CdSe and CdSe/Fe or Co QD "alloys" for the diluted magnetic semiconductor (DMS)-based source use; (3) synthesis of parallel arrays of carbon nanotubes filled with Ga, In, As, P, S and metal (Fe, Co) atoms to evaluate their properties and possible use in OE-MO NHS fabrication.
- **Characterization of the Synthesized Materials and Their Properties**: (1) using TEM, STM, AFM and other available devices, study structural characteristics of the synthesized membranes with unfilled and filled pores; (2) complete current-voltage (I-V) and magnetic measurements of the synthesized membranes with unfilled and filled pores; (3) on the basis of these measurements, develop an experimental methodology of structural/I-V/magnetic property characterization of the synthesized nanoscale semiconductor materials.

Innovative nature of this project concerns

- (a) development of experimental methodologies and tools for synthesis of three-dimensional (3D) alumina and silica membranes, and carbon nanotubes possessing precisely-characterized parallel pore arrays with pore diameters below 10 nms, both unfilled and filled with quantum dots/wires (QDs/QWs) composed of the Ga, In, As, Si, Zn, Cd and S atoms doped by P and "magnetic" Fe and Co atoms; (b) synthesis of a range of 3D small semiconductor QD/QW-based sub-nanomaterials with desirable OE-MO properties that can be intelligently manipulated by changes in the synthesis conditions;

- development of experimental characterization methods and tractable correlations between parameters governing synthesis of the above sub-nanomaterials and their major OE-MO properties for further applications in engineering.