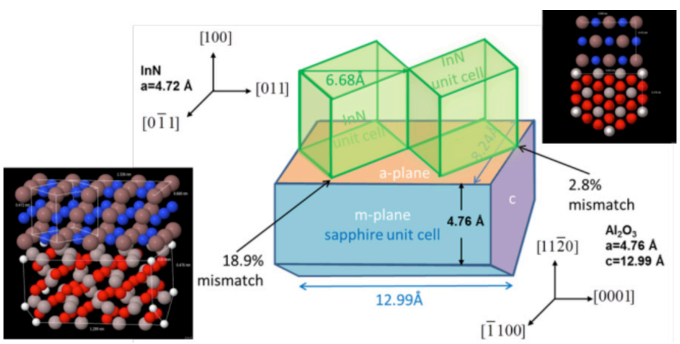
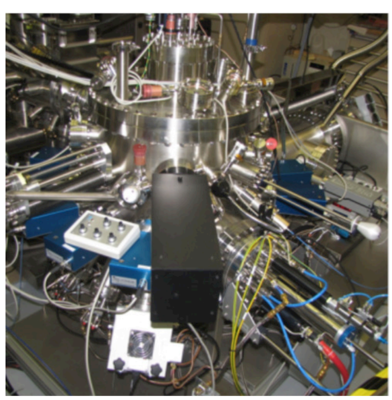
Compound Semiconductor Growth – Research Highlights

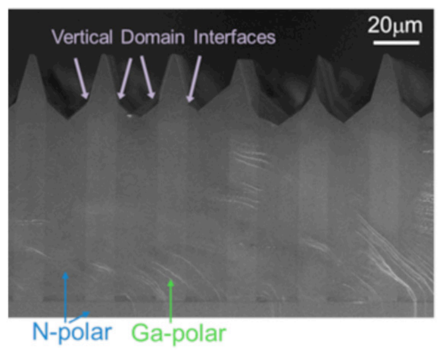
New Phase of InN Realized by Atomic Layer Epitaxy
ESTD researchers, in collaboration with the NRL Materials Science and Technology Division, have discovered a new phase of indium nitride through the employment of a nonequilibrium atomic layer epitaxy growth method. This cubic phase material has the NaCl fcc crystal structure when grown at low temperatures (~180°C) and has been verified by x-ray diffraction and transmission electron microscopy. Numerical simulations corroborate such a phase, which requires the strain due to lattice mismatch with the sapphire substrate for metastability. Cubic InN has a smaller bandgap and lower phonon scattering, which make it superior to hexagonal InN for infrared devices and solar cell applications.



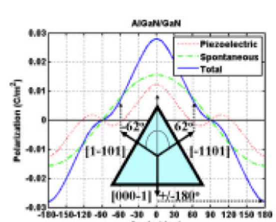
RF-Plasma MBE of III-N Semiconductors and Refractory Nitride Materials
ESTD researchers have designed a unique RF-plasma molecular beam epitaxy (MBE) system for the growth of new epitaxial refractory nitride materials. The system incorporates ten conventional effusion sources, a six-pocket electron beam evaporator for refractory materials, and extensive in situ growth monitoring. This combination of capabilities enables the growth of novel III-N semiconductors containing refractory elements, and the in situ deposition of transition metals and epitaxial transition metal nitrides on crystalline III-N and SiC semiconductors. Using this new MBE tool, ESTD scientists can fabricate unique nitride heterostructures and electronic devices with enhanced properties, and gain greater understanding of the interfaces between these important materials.

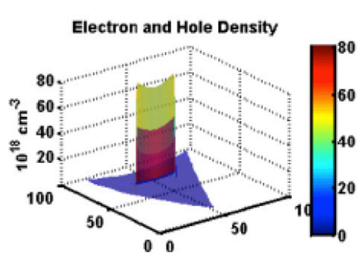


GaN for Frequency Conversion
ESTD researchers have created a new method to control GaN polarity growth on GaN substrates. Using this method, GaN structures with controlled, alternating crystallographic orientation on a single GaN substrate have been demonstrated. Extensions of the structures have successfully reached 80 µm thicknesses, with sharp vertical interfaces maintained between domains. These structures enable the use of GaN as a frequency converter and show a path to high-power, high-efficiency frequency conversion from the mid-IR to blue-green wavelengths.



Polarization Fields in III-Nitride Nanowire Devices
ESTD researchers have theoretically and experimentally demonstrated that the polarization fields in III-nitride nanowires display a complex dependence on orientation and facet geometry of the nanowire. Control of these fields enabled fabrication of undoped heterostructure nanowire transistors with either n-type or p-type conductivity based solely on polarization induced carriers. Polarization induced carriers do not originate from dopant atoms and thus avoid deleterious ionized dopant scattering. Furthermore, it is possible to design a nanowire with a large accumulation of polarization induced holes and electrons at opposing facets, which may enable nanowire light emitters or photovoltaics with enhanced efficiency.

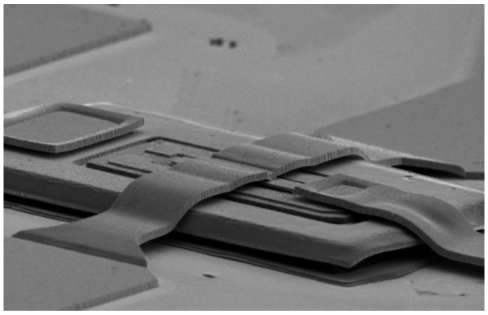




(continued)

ABCS for Low-Power Electronics and Lasers/Detectors

The ESTD includes two molecular beam epitaxy systems for the growth of antimonide/arsenide compound semiconductors. Scientists perform basic research on topics including growth mechanisms and quantum dot formation. These materials have intrinsic performance advantages for low-power electronics due to the attractive electron and hole transport properties, narrow bandgaps, and unique band-lineup design flexibility. ESTD researchers have demonstrated InAs(Sb)-channel high electron mobility transistors which operate at high speeds (>200 GHz) with record low power consumption. ESTD is also investigating p-channel FETs for complementary digital circuits, and holds the world record for hole mobility. ESTD is also a leader in the use of antimonide superlattices for infrared detectors and lasers.



Improved SiC Epitaxy Quality for Bipolar Devices

Basal plane dislocations (BPDs) currently prohibit high-voltage bipolar SiC device technologies needed by the Navy. ESTD researchers have developed a method to nearly eliminate all such defects in a thin, highly doped N+ buffer layer, significantly reducing the BPD density in the active region of a device, thereby enhancing bipolar device performance and reliability. PiN diodes were tested using a low BPD process where it was demonstrated that the forward voltage remained steady after 100 hr of biasing at 100 A/cm^2 for 70% of the devices tested. This advance clears a critical hurdle to high-voltage bipolar power switch development for Navy applications.