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as of 20-Feb-2019

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Proposal Number: 69988ELRIP **Agreement Number: W911NF-17-1-0424**

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Final Report for Period Beginning 01-Sep-2017 and Ending 31-Aug-2018
Title: ACQUISITION OF THE AUGER ELECTRON PROBE FOR IN SITU CONTROL OF MBE GROWTH OF ULTRA NARROW GAP METAMORPHIC SEMICONDUCTOR MATERIALS
Begin Performance Period: 01-Sep-2017 **End Performance Period:** 31-Aug-2018
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STEM Degrees: 2 **STEM Participants:** 4

Major Goals: The Veeco GEN-930 solid-source MBE system was complemented with the capability to perform the efficient low temperature surface preparation of the nano-patterned heterostructure wafers and metamorphic virtual substrates for the subsequent epitaxy. The atomic hydrogen cleaning will now be performed to prepare atomically clean surfaces for growth of the novel mid-infrared photonic crystal surface emitting lasers and ultra-short period long-wave infared photodetectors. The critical aspect of this enabling technology is that both morphology and optical and electrical properties of the previously prepared nanostructured epitaxial wafers would not be compromised by high temperature oxide desorption process. In addition to addressing the needs of the on-going research programs, it will enable development of the high quality InAs- and InSb-based heterostructures. This will open the new band structure and device design capabilities to extend the operating range and enhance the efficiencies of the novel infrared photonic devices for industrial and home security applications.

Accomplishments: The funds were utilized to acquire the necessary equipment and materials to perform the wafer surface cleaning using atomic hydrogen as required for several on-going research programs at Stony Brook University, namely:
1. Development of the high power GaSb-based photonic crystal surface emitting lasers – sponsored by US Army Research Office;
2. Development of novel metamorphic heterostructures for long wave infrared optoelectronics – sponsored by US Army Research Office;
3. Development of the compact room temperature operated THz emitters with scalable architecture and low electric power consumption – sponsored by US National Science Foundation;
4. Studies of the carrier dispersion and nontrivial topological phases in ultra-low bandgap metamorphic InAsSb ordered alloys – sponsored by US National Science Foundation;

The new MBE functionality will enable new research directions, namely:
1. Development of the passively mode-locked GaSb-based cascade diode lasers for ultrafast pulse and optical frequency comb generation.
2. Development of the ultra-short period superlattice heterostructures for novel very long wave infrared

photodetectors.
3. Development of the novel epitaxial technology of metamorphic antimonides for focal plane arrays.

The items acquired using DURIP funds included:
1. Water cooled atomic hydrogen nipple for use on a MOD GEN II/930 heated station – Veeco;
2. Fine control variable leak valve – Veeco;
3. Complete liquid level display – Chart Industries;
4. Al SUMO crucible – Veeco;
5. GEN930 3” heated station – Veeco;
6. Transfer alignment assembly – Veeco;
7. Heated station transfer assembly – Veeco;
8. Nose piece assembly, 3” GEN II/930 1.115 new transfer rod adapter – Veeco.

In addition there were several charges for shipping and acquisition of small items to install and configure the complete atomic hydrogen wafer surface preparation system in buffer chamber of Stony Brook University’s GEN 930 solid source molecular beam epitaxial system.

As of February 2019, all atomic hydrogen system components have been installed and following the system bake out and calibration the system will be used for the following experiments in Spring 2019:
1. The surface cleaning of the nanostructures laser heterostructures for regrowth and fabrication of the photonic crystal surface emitting GaSb-based cascade diode lasers will be performed using now available atomic hydrogen source. The results of the wafer regrowth following the low temperature atomic hydrogen assisted highly efficient surface cleaning and native oxide desorption will be compared to those performed using standard acidic cleaning and thermal oxide removal. The expected outcome is improved surface morphology and reduction of the point defects. The critical aspect of the newly available fabrication and regrowth technique will be elimination of the blue shift associated with the intermixing resulting from high temperature oxide desorption step that was previously necessary. It is also expected that the quality of the regrown interface will be improved resulting to improved carrier transport and minimized nonradiative recombination. The surface emitting thus regrown photonic crystal lasers with improved efficiency will be characterized.
2. The metamorphic growth on the pre patterned GaSb and InAs substrates for novel mid-wave infrared and long-wave infrared photodetector development now became possible and will be explored. The expected outcome is improved surface morphology, wafer scale uniformity and reduced surface recombination on the pixel sidewalls. The corresponding InAsSb bulk and InAsSb ordered alloy photodetectors are expected to demonstrate the improved detectivity and large area uniformity necessary for focal plane arrays development.

Training Opportunities: Nothing to Report

Results Dissemination: Nothing to Report

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: PD/PI
Participant: Gregory Belenky
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Participant Type: Co PD/PI
Participant: Leon Shterengas

Person Months Worked: 1.00
Funding Support:
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Participant Type: Co PD/PI
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Funding Support:
Project Contribution:
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International Travel:
National Academy Member: N
Other Collaborators:

Report Title
Acquisition of MBE components for development of the novel regrowth technology within the antimonide material system.

Abstract
The Veeco GEN-930 solid-source MBE system was complemented with the capability to perform the efficient low temperature surface preparation of the nano-patterned heterostructure wafers and metamorphic virtual substrates for the subsequent epitaxy. The atomic hydrogen cleaning will now be performed to prepare atomically clean surfaces for growth of the novel mid-infrared photonic crystal surface emitting lasers and ultra-short period long-wave infared photodetectors. The critical aspect of this enabling technology is that both morphology and optical and electrical properties of the previously prepared nanostructured epitaxial wafers would not be compromised by high temperature oxide desorption process. In addition to addressing the needs of the on-going research programs, it will enable development of the high quality InAs- and InSb-based heterostructures. This will open the new band structure and device design capabilities to extend the operating range and enhance the efficiencies of the novel infrared photonic devices for industrial and home security applications.

Summary
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The new MBE functionality will enable new research directions, namely:
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