IV-VI Micro-/Nano-structures
And Opto-electronic Devices

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Current Opto-Electronic Group members:
Dr. Jiangang Ma, Dr. Gang Bi, Dr. Fanghai Zhao (partial),
Mr. Donghui Li, Mr. Shaibal Mukherjee, Mr. Guangzhe Yu, Mr. Binbin Weng

Current Sponsor: NSF EPSCoR, DoD DEPSCoR, DoD ARO, DoD MDA,
OCAST & Industry

November 6th 2008
Impact Of NSF EPSCoR And State Match To Research In My Group

• Collaborations among the center members, e.g. my group with Drs. Johnson’s and Dr. Mao’s group

• Research Interaction among faculty members and students e.g. with Drs. Santos, Murphy, McCann, and Yang,

• Share of the Center equipment

• Support of a research associate (Dr. Frank Zhao)
Research Activities: (I) IV-VI semiconductor Micro-structures
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EDXA of micro-cuboids
Research Activities: (II) IV-VI semiconductor Nano-Structures (In Collaboration with Dr. Mao’s Group)
Research Activities: (III) Development Of Mid-IR Diode Lasers

Bottom contact connection
Top contact connection
Laser Clap
Laser head

Current injection 400 mA
@ 100 kHz, 500 ns pulse width
0.39 cm⁻¹
Research Activities: (IV) Development Of Mid- and Long-Wave Detector Array on Si

Growth of high quality Pb-salt material on Silicon

novel p-n junction growth techniques

Fabrication of in-situ PbSnSe p-n junctions

First successful demonstration of PbSe p-n junction !!!!

Custom MBE housed at the University of Oklahoma Opto-Electronics Group Laboratories
IV-VI Semiconductor Detectors: The Untapped Potential

“Optimized” $Pb_{1-x}Sn_xSe$ p-n junctions @ 77K

$PbSe; \lambda_c = 7.3 \mu m$

$Pb_{0.94}Sn_{0.06}Se; \lambda_c = 11.4 \mu m$

$Pb_{0.91}Sn_{0.09}Se; \lambda_c = 15.9 \mu m$


High IV-VI semiconductor crystalline quality in spite of 12% lattice parameter mismatch and 700% thermal expansion with Si.

Unlike GaAs-on-Si, IV-VI-on-Si structures do not exhibit degradation from repetitive thermal cycling.
CW and Pulsed Mode PL

300 K is Optimal Temperature for Maximum Light Extraction

Pulsed PL
P_{\text{Peak}} = 3.3 \text{ KW}

Reflectance
300 K

CW PL
P = 460 mW

Interband Absorption
PbSe L_z = 20.6 \text{ nm}, \#H017
Data from APL 78, 2199 (2001)

300 K is Optimal Temperature for Maximum Light Extraction
Excellent agreement between calculated sub-band energies and peaks in pulsed PL spectra.

Theoretical and Experimental Results

W356
$T_{Heatsink} = 200 \text{ K}$

PbSe $E_g (200 \text{ K}) = 243 \text{ meV}$

(2-2)$^N = 274 \text{ meV}$

(1-1)$^D = 257 \text{ meV}$

(1-1)$^N = 251 \text{ meV}$

P$_{Peak} = 16.7 \text{ kW}$

P$_{Peak} = 3.3 \text{ kW}$

Cavity Mode

CO$_2$
MBE Growth of IV-VI Nanostructures on Silicon

- Completely in-situ process for MBE growth of IV-VI nanostructures on Si.
- CW PL emission observed for a single-layer structure.
- Applications include mid-IR optoelectronic devices and thermoelectric cooling and power generation devices.
Template Formation

CaF₂ growth on Si(110) immediately adopts a ridge and groove surface morphology.
Self-Organized Template

[Diagram showing experimental results and structures with annotations such as \([\overline{1} 10]\), \(200\,\text{nm}\), and \(1\,\mu\text{m}\).]
PbSe Dots/Dot-Chains

Some preferential alignment of PbSe dot-chains
Quasi-One-Dimensional Nanostructures

First known MBE growth of quasi-one-dimensional PbSe nanostructures on technologically relevant silicon.
Publications and Conference Presentations

Refereed Publications


Oral Presentations


Poster Presentations


