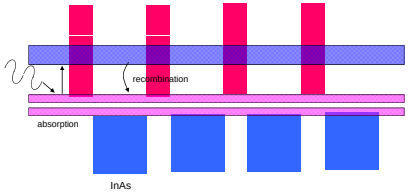
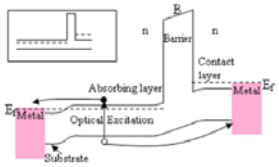
Infrared Imaging Technologies

LWIR Detection - Army Needs / Problems

- The Army needs affordable, high-performance, night-vision equipment for 24/7 theater dominance
- **State-of-the-art technology is HgCdTe, but:**
  - HgCdTe grown on bulk CZT substrate does not meet size constraints (limited substrate size availability → limits array size)
  - HgCdTe/Si material does not meet quality constraint (100 times higher dislocation density → impacts FPA operability)
- Defect modeling to understand limiting defect reduction during TCA
- Engineer New II-VI Materials to overcome above issues - HgCdSe
- Model new device architectures
- *Affordability* points towards III-V solution (leverage commercial fabs)
- Common III-V materials have bandgaps that are too large
- Superlattices can reach (V)LWIR but have performance limitations



Design of nBn photodetectors sensitive to > 8 µm radiation



Goal: Absorbing layer should work > 8 µm.

S. Maimon and G.W. Wicks
Applied Physics Letters **89**, 151109 (2006)

II-VI IR RESEARCH AT ARL

HgCdTe on Si Material and Device Development

Goal: Transition HgCdTe IR focal plane array technology to a large area scalable substrate while maintaining superior detector performance

Technical Barriers:

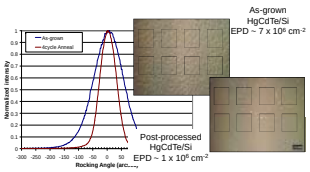
- *1-2 orders of magnitude increase in dislocation density due to lattice mismatch*
- *coefficient of thermal mismatch*

Approach:

- *Composite substrate advancement*
- *Post Growth Processing of HgCdTe/Si*

Accomplishments

- *CdSeTe/Si material developed as lattice-matched composite substrate*
- *HgCdTe/CdSeTe/Si LWIR FPA fabricated (256 x 256 and 1k x 1k); 99% operability,*
- ***HgCdTe/Si dislocation density ~ 1 x 10^6 cm^{-2} achieved (industry standard is mid 10^6 cm^{-2})***



High Temperature Operation of HgCdTe IR Devices

Goal: Increase operating temperature of HgCdTe IR focal plane arrays (both MWIR and LWIR)

Technical Barriers:

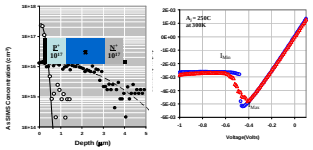
- *dark current*
- *lifetime of carriers (Auger lifetime)*
- *thermally generated noise*

Approach:

- *Engineer materials and develop new processes to obtain Auger suppression devices*
- *nBn device (HgCdTe/HgZnTe/HgCdTe)*
- *Deep etching of pixels – pillar structure*

Accomplishments

- ***Demonstrated Auger suppression in LWIR HgCdTe material (3x reduction in dark current at room temp)***
- *Grown pseudomorphic HgZnTe/HgCdTe nBn material*



IMPROVEMENT OF HgCdTe MATERIAL ON ALTERNATIVE SUBSTRATES

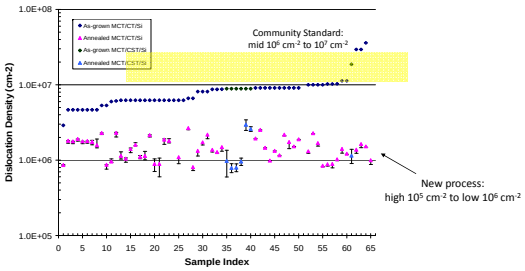
Main Issue: Relatively higher HgCdTe dislocation density

ARL is addressing this issue in LW HgCdTe by focusing on dislocation mitigation approaches

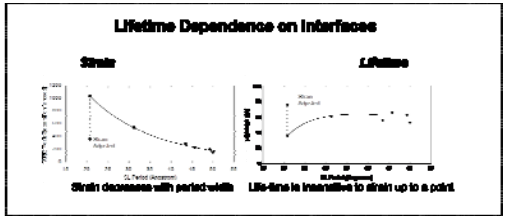
- ➢Develop lattice-matched Cd(Se)Te/Si buffers
- ➢Optimize baseline MBE process for buffer layers – in-situ annealing
- ➢ Dislocation reduction via thermal cycle annealing - in-situ, ex-situ annealing

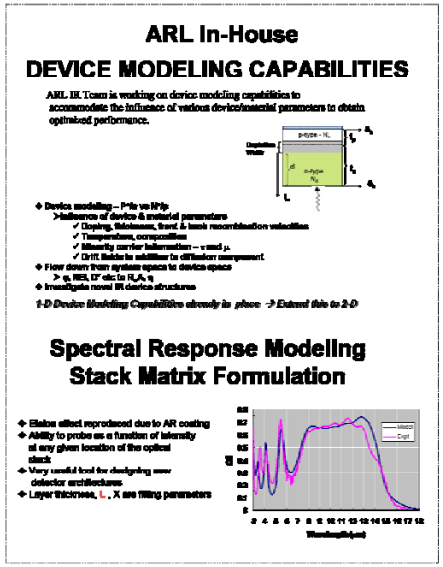
✓**HgCdTe/Si ~ 1 x 10^6 cm^{-2} -- Best results for HgCdTe/Si in community**

- ➢ Dislocation mitigation: novel junction design, impurity reduction in buffer/Si
- ➢ Understand the dominant current mechanisms in devices



POCs: Stefan Svensson, et al





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