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MBE HgCdTe Heterostructure Detectors

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HgCdTe has been the mainstay for medium (3-5μm) and long (10-14μm) wavelength infrared detectors in recent years. Conventional growth and processing techniques are continuing to improve the material. However, the additional ability to tailor composition and placement of doped layers on the tens of angstroms scale using MBE provides the opportunity for new device physics and concepts to be utilized. MBE-based device structures to be discussed here can be grouped into two categories: tailored conventional structures and quantum structures.

The tailored conventional structures are improvements on familiar devices, but make use of the ability to create layers of varying composition and thus band gap at will. The heterostucture junction can be positioned independently of doping p-n junctions. This allows the small band gap region in which the absorption occurs to be separated from a larger band gap region in which the electric field is large and where unwanted tunneling can occur. Data from hybrid MBE/LPE/bulk structures will be shown.

Quantum structures include the HgTe-CdTe superlattice, in which the band gap and transport can be controlled by alternating thin layers (tens of angstroms thick) of HgTe and CdTe. The superlattice has been shown to exhibit behavior which is non-alloy like, including very high hole mobilities, two-dimensional structure in the absorption coefficient, resonant tunneling, and anisotropic transport.

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QUANTUM / CLASSICAL STRUCTURES

I. Quantum effect structure
Superlattice - New material properties.

A. Layer thickness tailorable band gaps.

B. Enhanced effective masses / reduced tunneling.

C. New physics

1. High hole mobilities
2. 2-D density of states
3. Intrinsic interface states

QUANTUM / CLASSICAL STRUCTURES

II. "Classical Devices"

A. Doping profile control.

B. Composition profile control.

C. Carrier generation / collection regions separated.

D. Hybrid devices - diodes, transistors, signal processing, lasers.

An MBE GROWN MULTILAYER STRUCTURE (In DOPED & UNDOPED)

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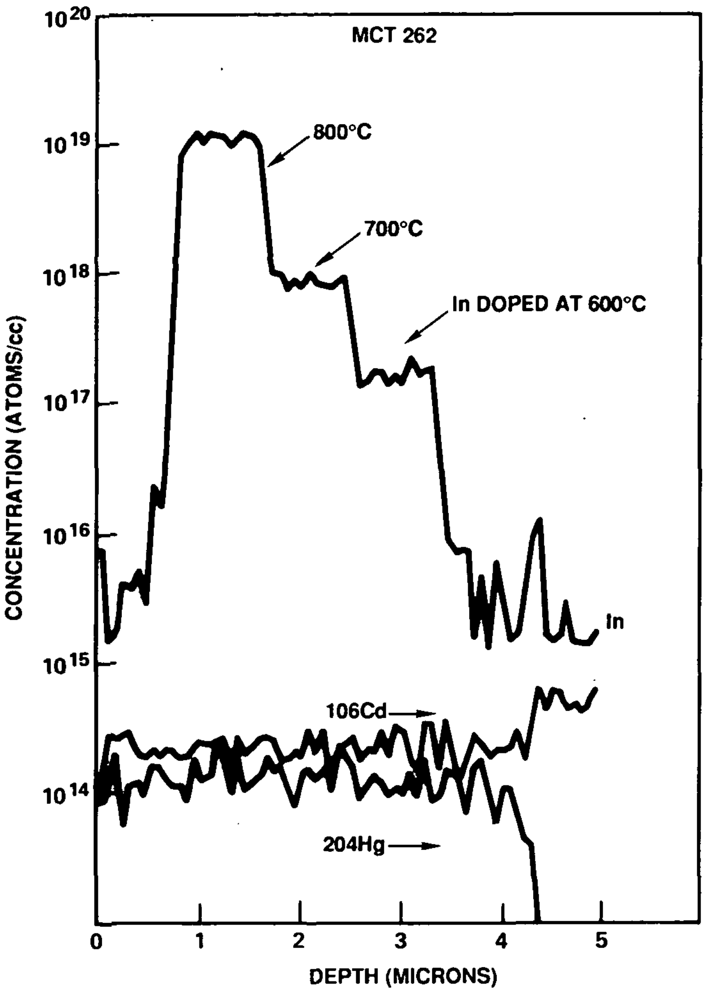
$Hg_{0.7}Cd_{0.3}Te$ UNDOPED		0.8 μm
$Hg_{0.7}Cd_{0.3}Te$ In DOPED	800°C	0.8 μm
$Hg_{0.7}Cd_{0.3}Te$ In DOPED	700°C	0.8 μm
$Hg_{0.7}Cd_{0.3}Te$ In DOPED	600°C	0.8 μm
$Hg_{0.7}Cd_{0.3}Te$ UNDOPED		0.8 μm
CdTe BUFFER		0.8 μm
CdTe SUBSTRATE		



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SIMS PROFILE OF AN n TYPE (IN DOPED) MBE GROWN HgCdTe MULTILAYER (5) STRUCTURE

A HYBRID p-on-n HETEROJUNCTION STRUCTURES

C8923-09-33

$Hg_{0.7}Cd_{0.3}Te$	As DOPED, 5 x 10^{16}/cm^3 MBE GROWN, 2 μm
$Hg_{0.8}Cd_{0.2}Te$	In DOPED, 5 x 10^{14}/cm^3 BULK GROWN

RELATIVE SPECTRAL RESPONSE OF p-on-n HETEROJUNCTION DIODES

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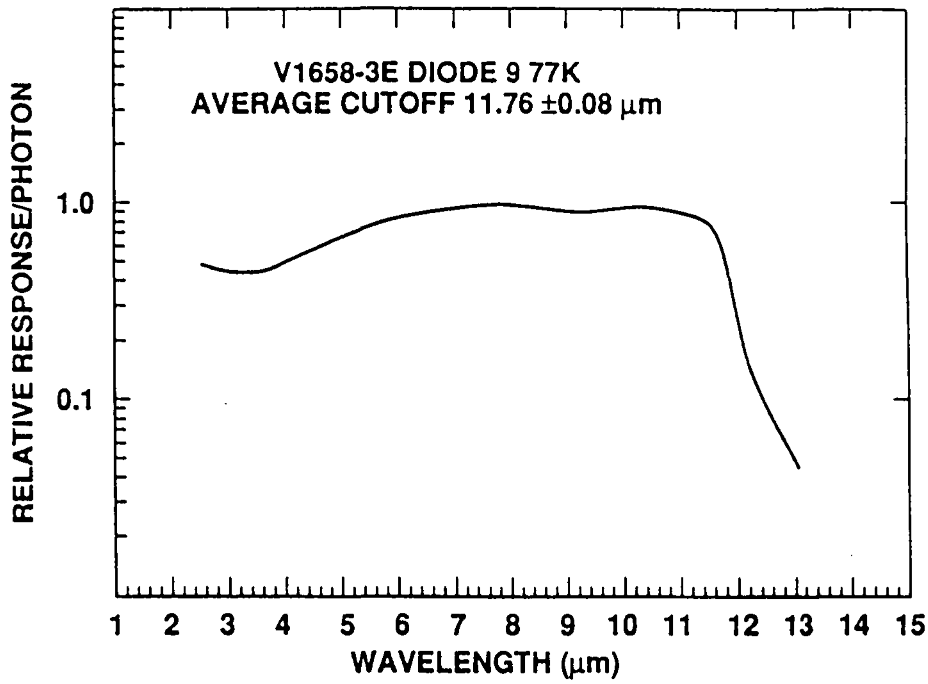

MBE p ON n DLHJ WAFERS

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MBE TECHNOLOGY PROVIDES EXCELLENT P+-N HETERO-JUNCTION CHARACTERISTICS

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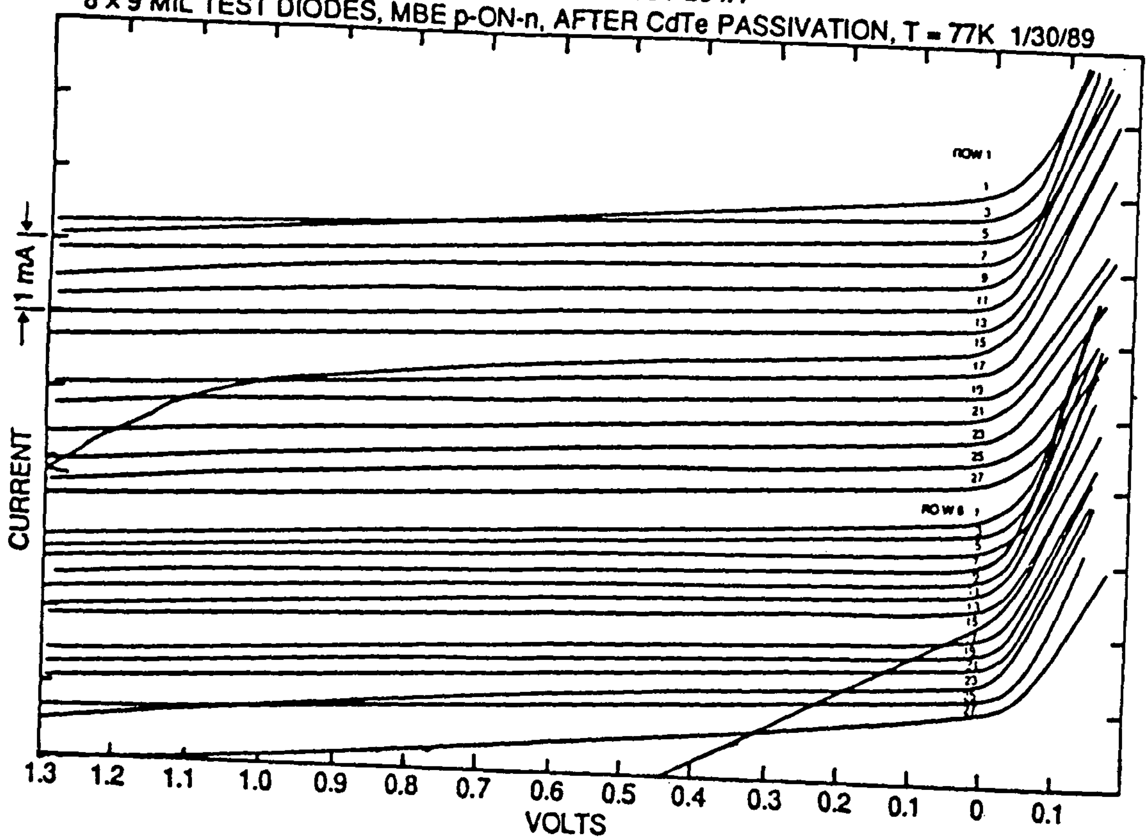
V1658-B3/SW611H/MCT 204H



DOUBLE LAYER HETEROJUNCTION STRUCTURE AND ITS BAND DIAGRAM

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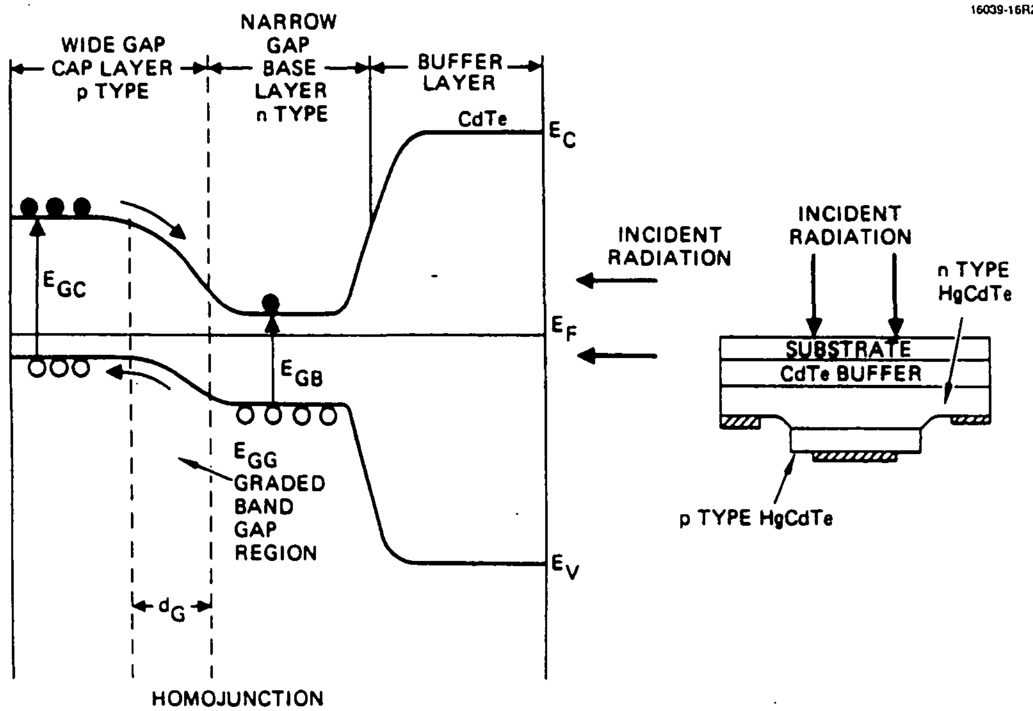
16039-16R2



A HYBRID n-on-p HETEROJUNCTION STRUCTURE

C8923-09-37

HgCdTe	X=0.35, In DOPED, 2 μm MBE GROWN, $5\times10^{17}/cm^3$
HgCdTe	X=0.3, As DOPED, 10 μm LPE GROWN, $5\times10^{16}/cm^3$
CdTe	SUBSTRATE

I-V CHARACTERISTICS OF A HYBRID n-on-p HETEROJUNCTION DIODE (30 μm x 30 μm)

HUGHES

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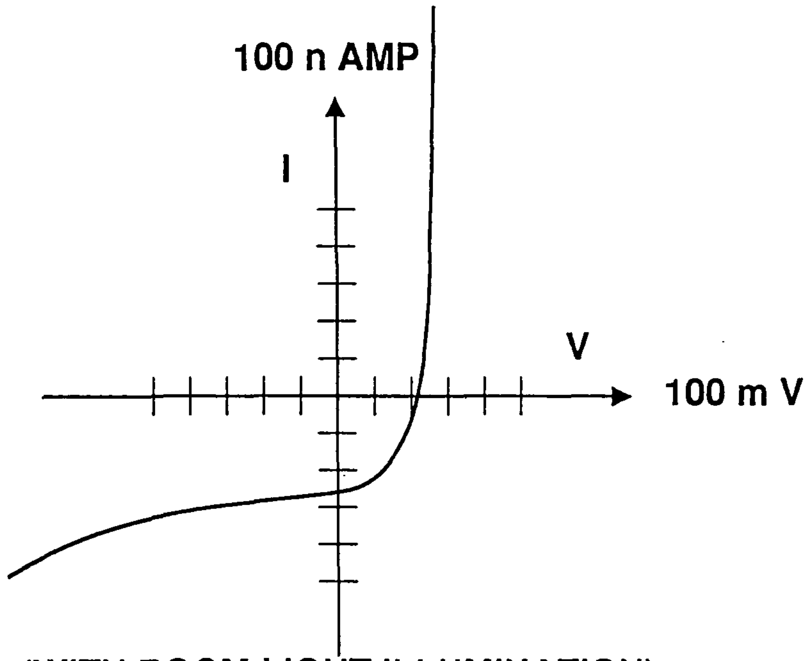


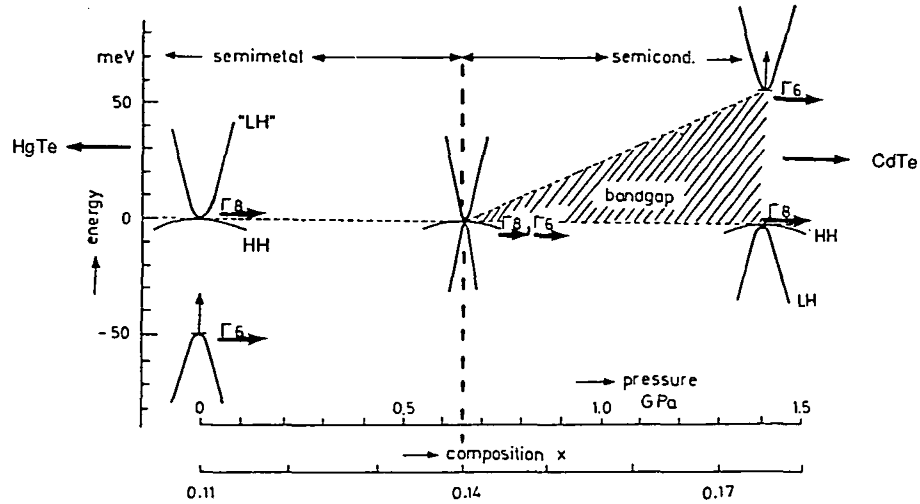
(WITH ROOM LIGHT ILLUMINATION)

An ALL MBE GROWN DOUBLE LAYER HETEROJUNCTION STRUCTURES

C8923-09-32

HgCdTe (X=0.3) As DOPED 5 x 10^{17} /cm^3, 2 μm
HgCdTe (X=0.2) In DOPED 5 x 10^{15} /cm^3, 8 μm
CdTe BUFFER LAYER
CdTe SUBSTRATE

Hg(1-x)Cd(x) Te Band Gap versus x

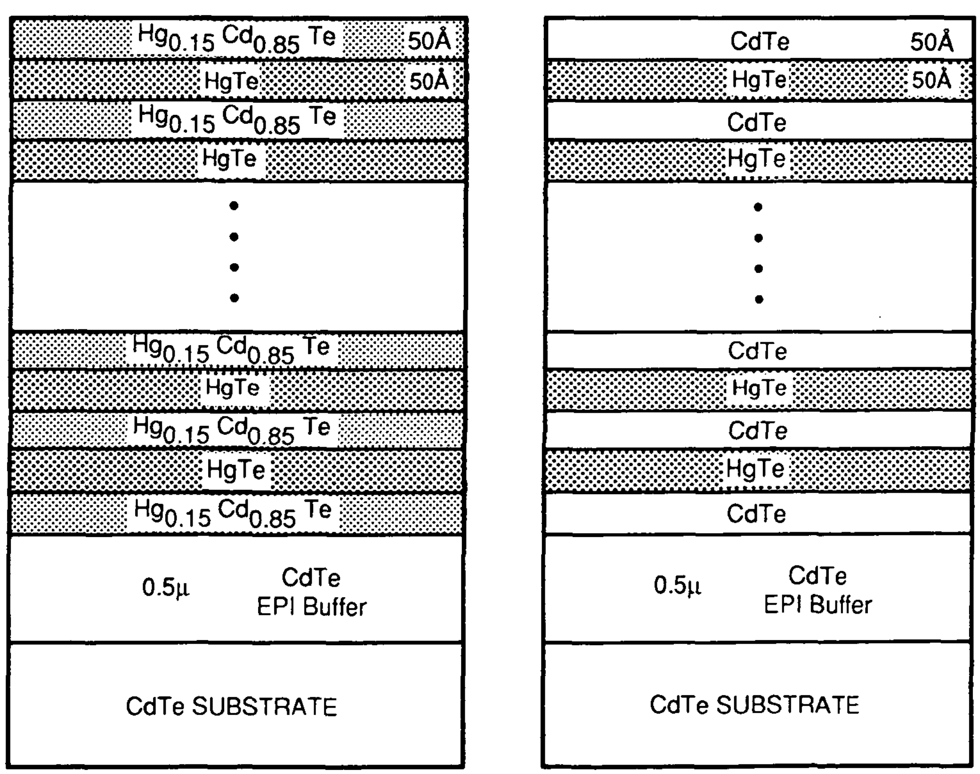


CdTe Band Gap = 1.6 eV

HgTe Band Gap = -0.3 eV

$Hg_{0.15}Cd_{0.85}Te/HgTe$ vs HgTe/CdTe SUPERLATTICES

17036-16R2



SUPERLATTICE ENERGY LEVELS

HUGHES

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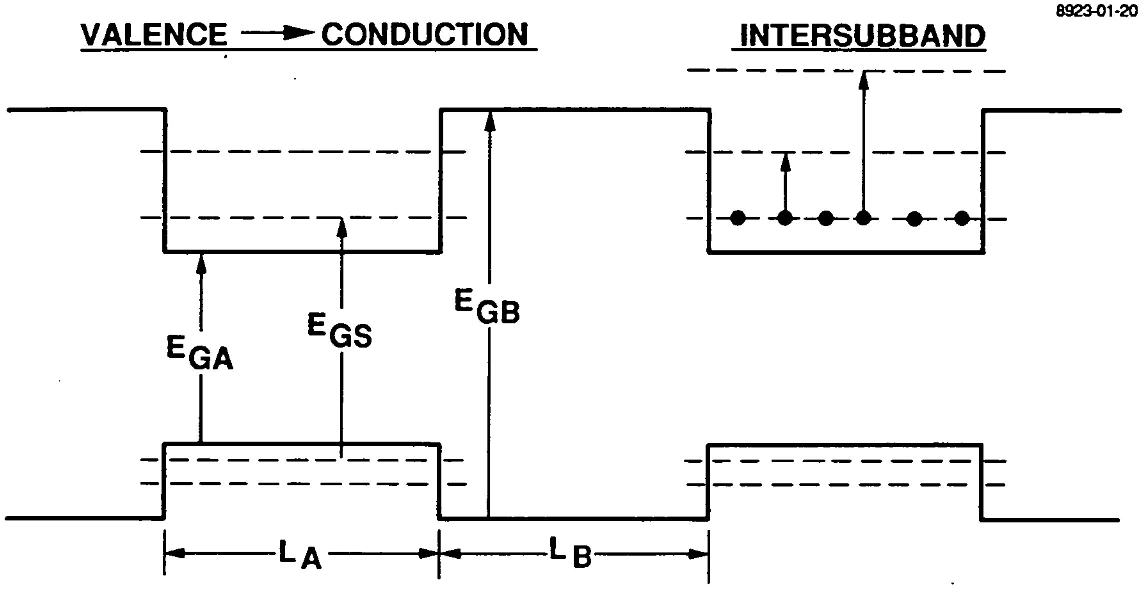
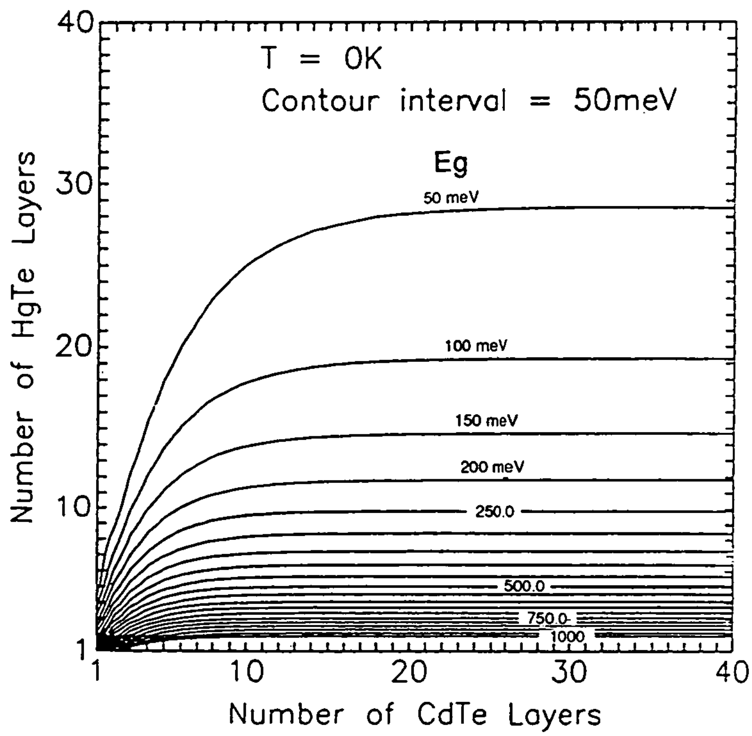


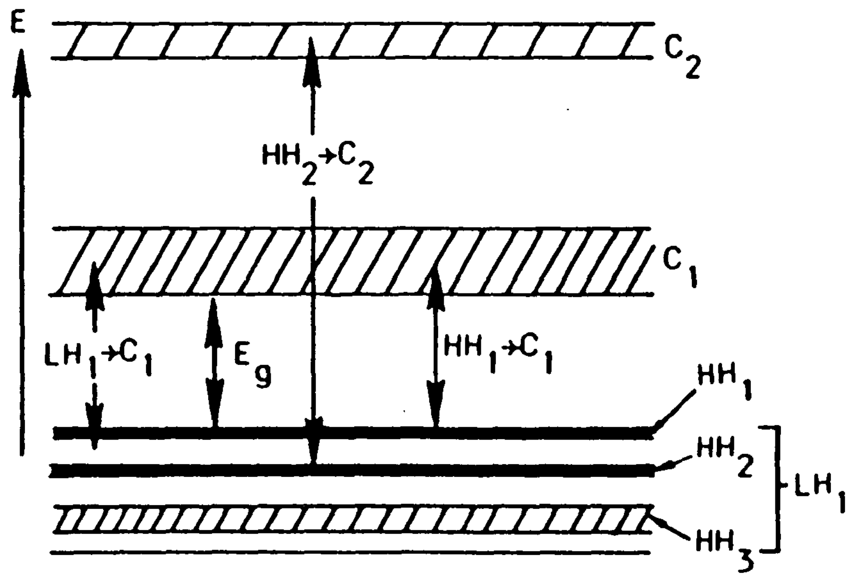
E_{GS} = SUPERLATTICE BAND GAP

HgTe–CdTe SUPERLATTICE BAND GAP



McGill, Wu, Hetzler, J. Vac. Sci. A4, 2091(86)

VALENCE TO CONDUCTION SUBBAND ABSORPTION



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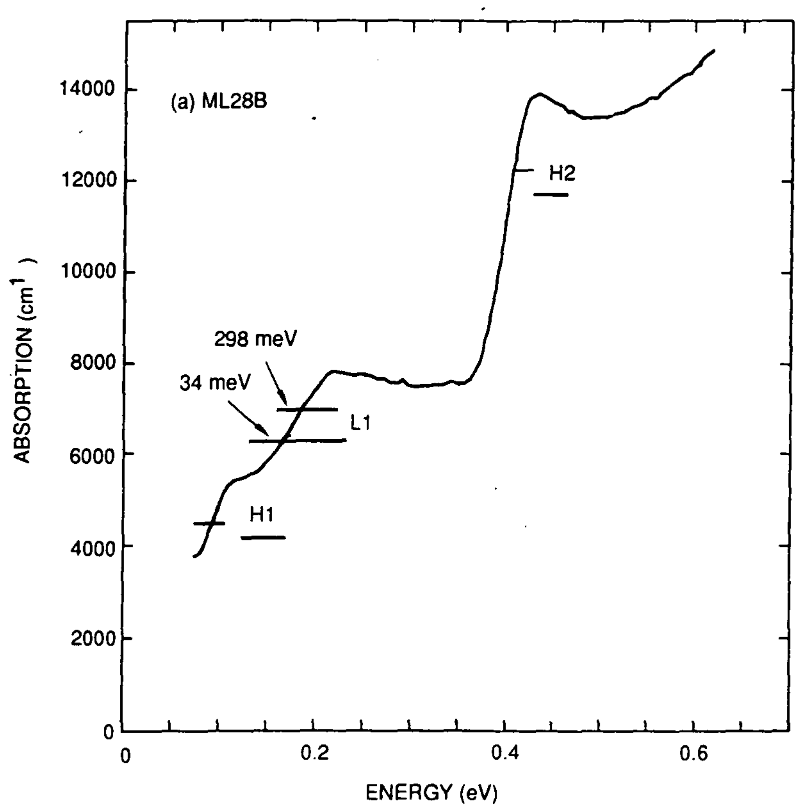
HgTe/HgCdTe

Schulman, (+7), APL 53, 2420 (1988)



CONCLUSIONS

I. MBE alloy device-quality composition / doping control available. Much progress for variety of applications soon.

II. Superlattice composition control excellent, doping control in progress. New device structures utilizing new physics needed.