LWIR HgCdTe - INNOVATIVE DETECTORS IN AN INCUMBENT TECHNOLOGY

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ABSTRACT

HgCdTe is the current material of choice for high performance imagers operating at relatively high temperatures. Its lack of technological maturity compared with silicon and wide-band gap III-V compounds is more than offset by its outstanding IR sensitivity and by the relatively benign effect of its materials defects. This latter property has allowed non-equilibrium growth techniques (MOCVD and MBE) to produce device quality LWIR HgCdTe even on common substrates like GaAs and GaAs/Si. Detector performance in these exotic materials structures is comparable in many ways with devices in equilibrium-grown material. Lifetimes are similar. RoA values at 77K as high as several hundred have been seen in HgCdTe/GaAs/Si with 9.5 µm cut-off wavelength. HgCdTe/GaAs layers with ~15 µm cut-off wavelengths have given average 77K R_0As of >2. Hybrid focal plane arrays have been evaluated with excellent operability.

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OVERVIEW

- O PACE BACKGROUND AND MATERIALS
- O TEST DIODE PERFORMANCE AND TECHOLOLGY LIMITS
- O PRELIMINARY LWIR ARRAY DATA
- O DIRECTIONS AND CONCLUSIONS

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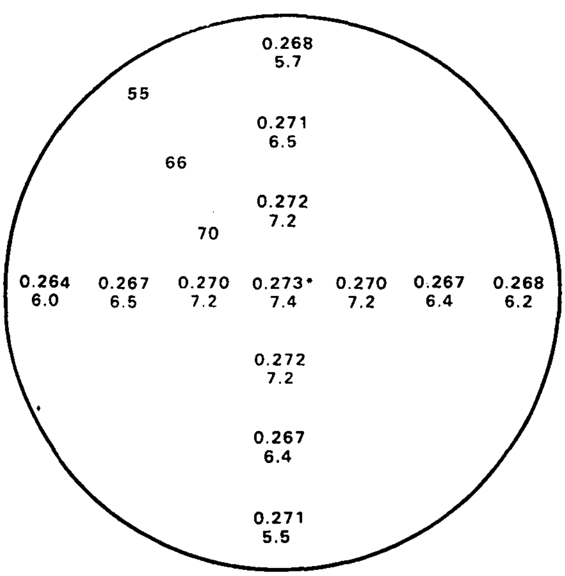
DEFINITIONS

- **CONVENTIONAL TECHNOLOGY**
  - -- MCT GROWN BY LIQUID PHASE EPITAXY ON CdTe OR SIMILAR COMPOUND
- **PACE** (PRODUCIBLE ALTERNATIVE TO CdTe FOR EPITAXY)
  - -- ROCKWELL APPROACH TO OVERCOME MCT PRODUCIBILITY ISSUES
  - -- **PACE-1:** MCT GROWN BY LIQUID PHASE EPITAXY ON VAPOR PHASE EPITAXIAL CdTe/SAPPHIRE -- SUITABLE FOR SWIR (1-3 MICRONS) AND MWIR (3-5+) MICRONS
  - -- **PACE-2:** MCT GROWN BY VAPOR PHASE EPITAXY ON GaAs (OR EVENTUALLY Si) -- SUITABLE FOR ALL IR WAVELENGTHS

PACE-2 HAS BETTER COMPOSITIONAL UNIFORMITY THAN LPE



3″ DIA GaAs WAFER

$$\max \frac{\Delta x}{\bar{x}} = 3.3\%, \ \max \frac{\Delta \bar{d}}{d} = 29\% \text{ OVER 3'' DIA}$$

$$\max \frac{\Delta x}{\bar{x}} = 2.2\%, \ \max \frac{\Delta d}{\bar{d}} = 17\% \text{ OVER 2'' DIA}$$

LEGEND
* — COMPOSITION, X VALUE
— THICKNESS, μm
— CRYSTALLINITY, ARC-SEC

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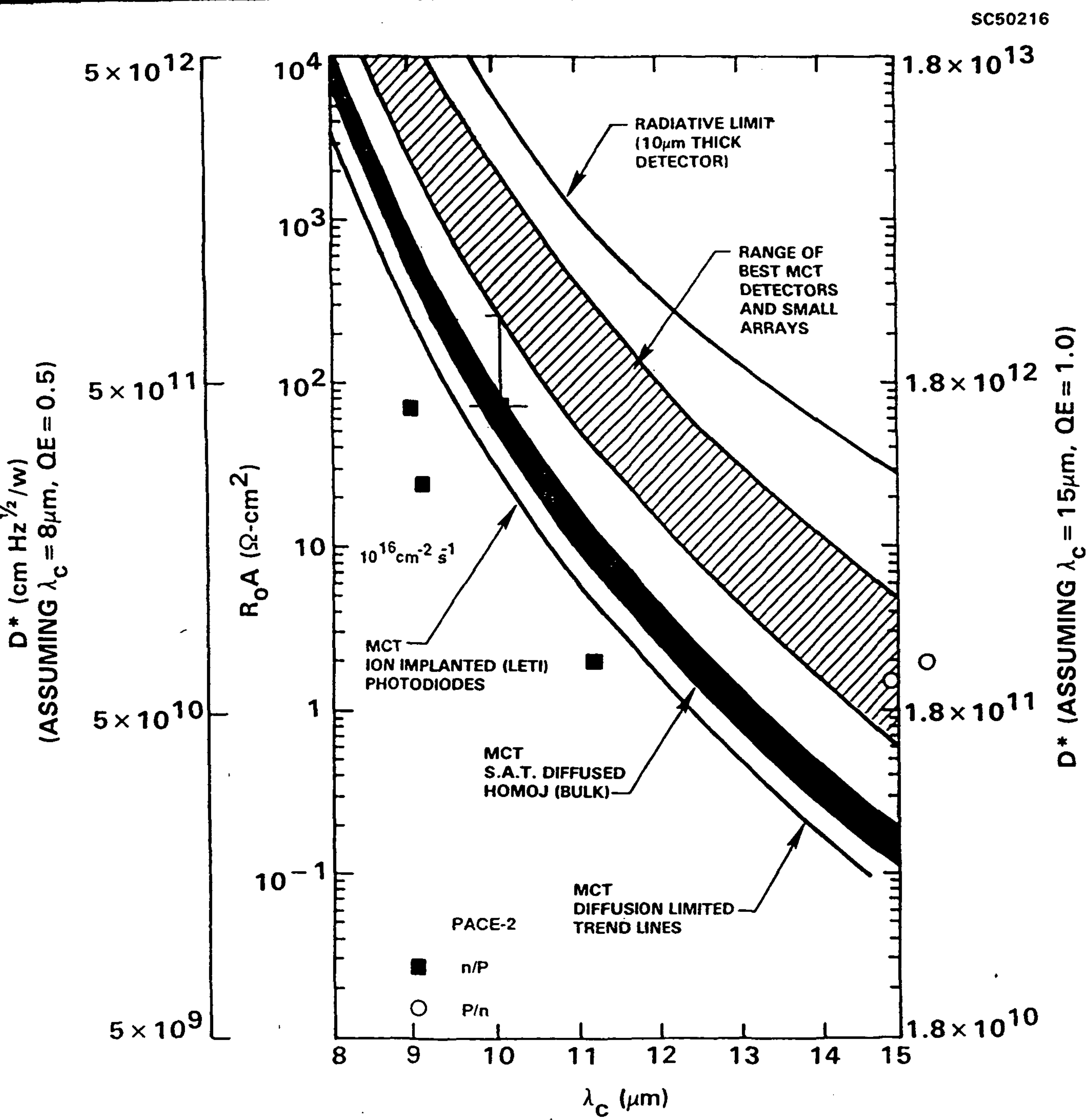
LWIR TACTICAL MCT DETECTOR PERFORMANCE



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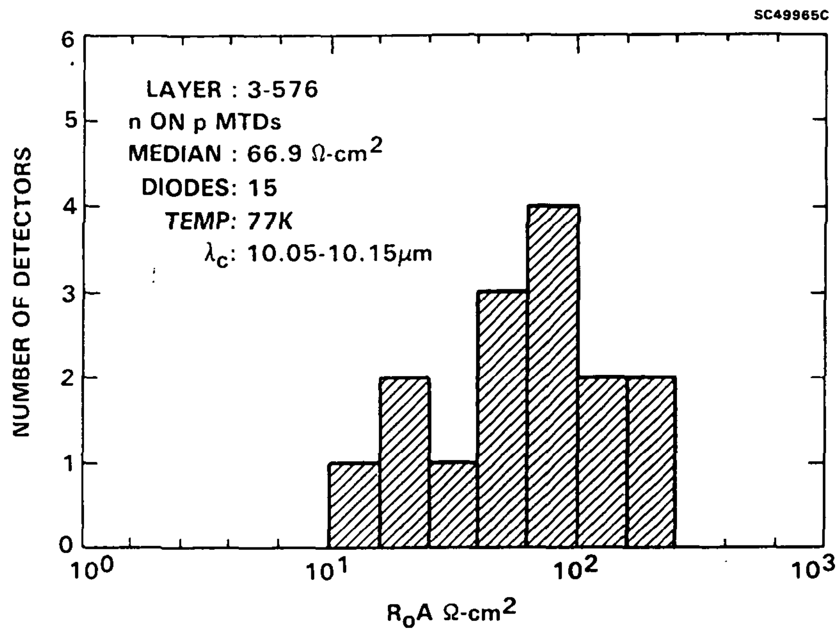
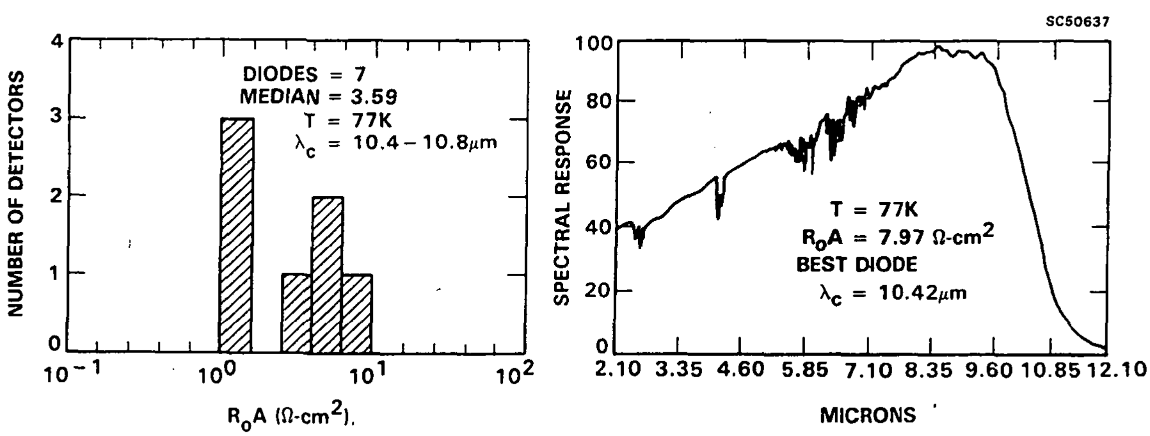
n^+/p TEST DIODES IN HgCdTe/GaAs (PACE-2)



MTD DATA FOR 3-623 BASELINE LAYER n ON p DEVICES, ION IMPLANTED



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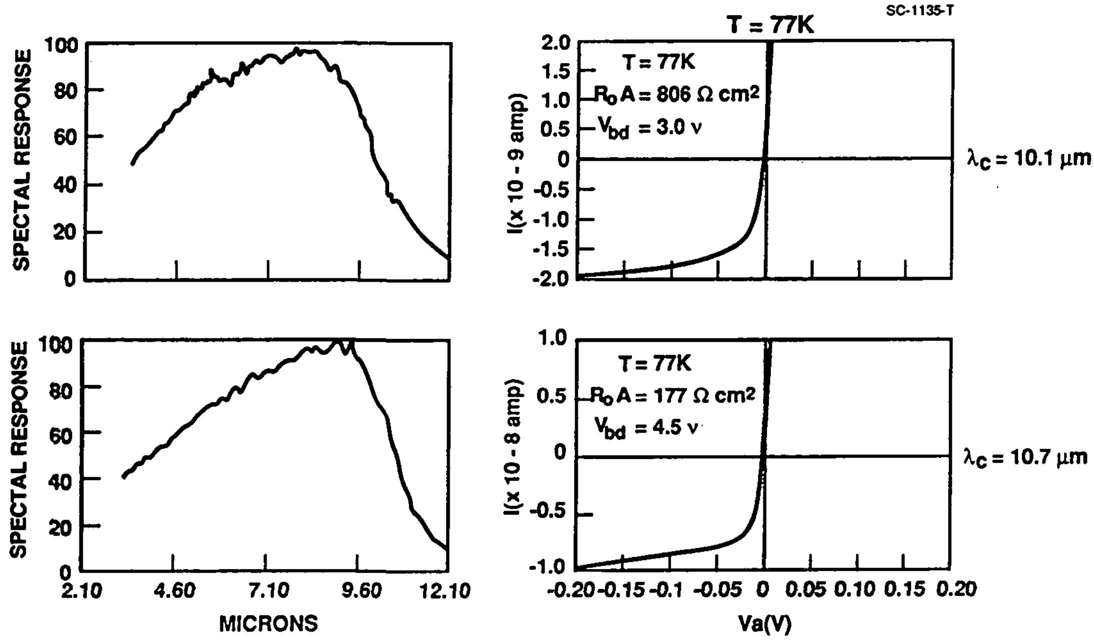
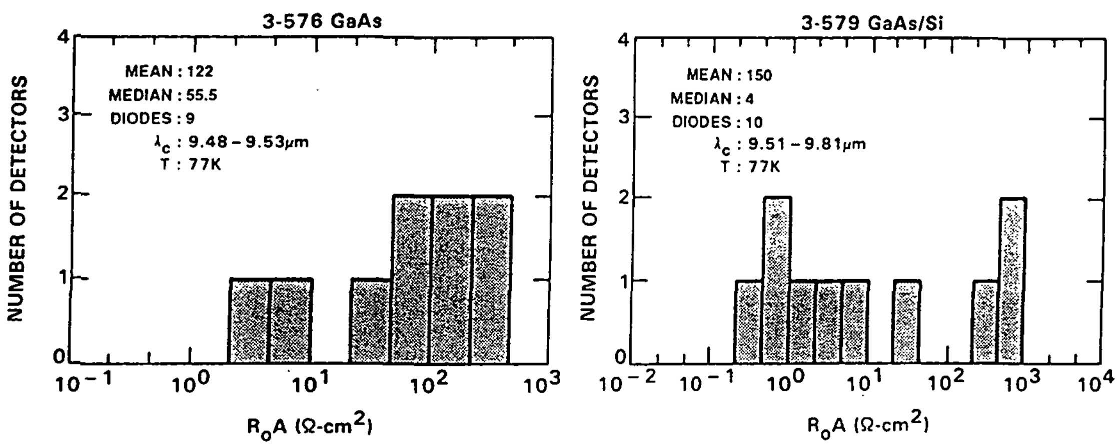
LWIR HgCdTe/Pace-2 p/n Devices Show Higher Performance Than LPE Devices



- ARSENIC IMPLANATATION
- OMVPE HgCdTe ON GaAs

RECENT p ON n MTD PERFORMANCE CONFIRM EARLIER RESULTS

ARSENIC IMPLANT/DIFFUSION IN DOUBLE LAYER HETEROSTRUCTURE



BEST DIODE
R_oA = 308 Ω-cm^2
AT 9.48µm

BEST DIODE
R_oA = 544 Ω-cm^2
AT 9.73µm

- n ON p DIODES HAVE BETTER UNIFORMITY

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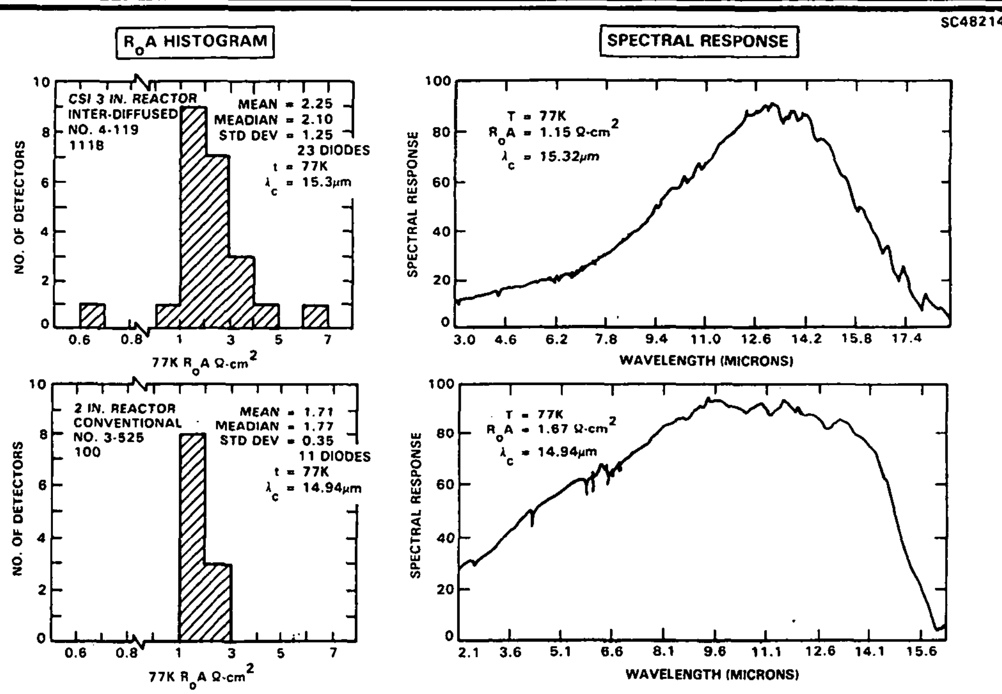
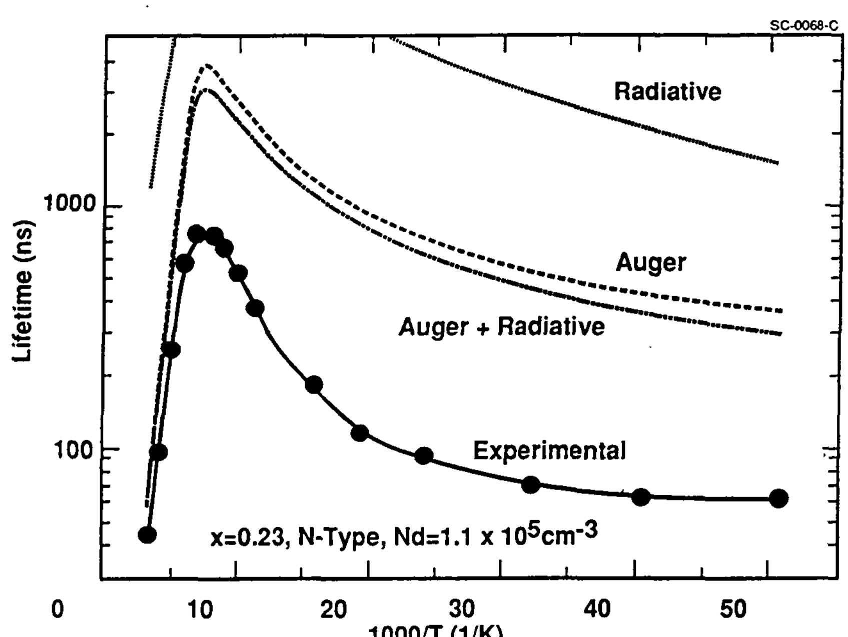
EXCELLENT DIODE PERFORMANCE IN VLWIR MOCVD MCT/GaAs p ON n DIODES



Minority Carrier Lifetime

4-334, N-Type, Undoped, x=0.235, Nd=1.1 x 10^{15}cm^{-3}



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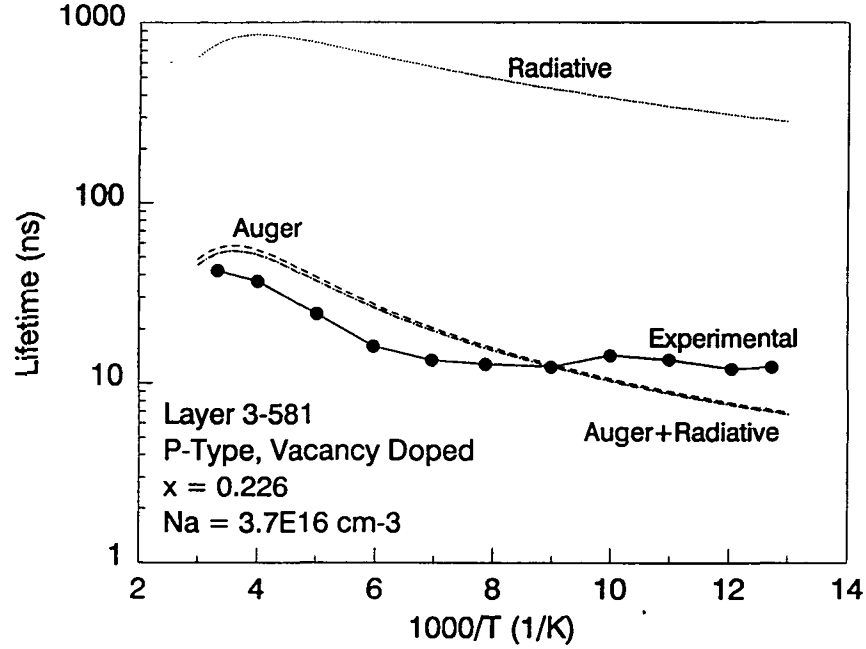
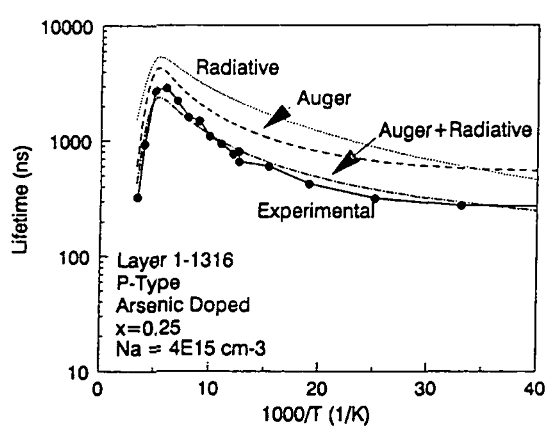
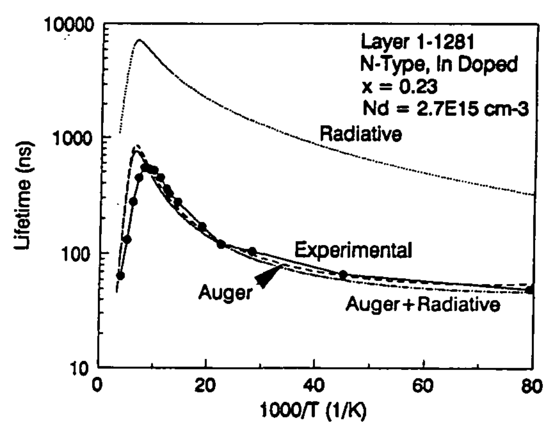
LIFETIMES IN SOME VACANCY DOPED PACE-2 APPROXIMATE THEORY



BEST IMPURITY DOPED PACE-2 SAMPLES SHOW THEORETICAL LIFETIMES





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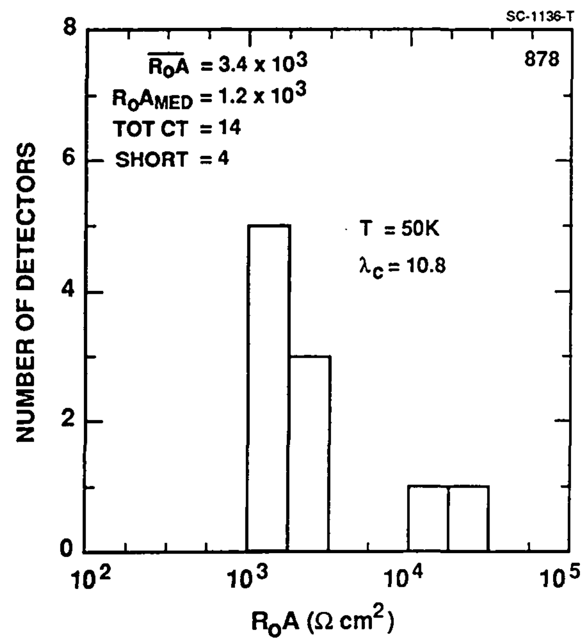
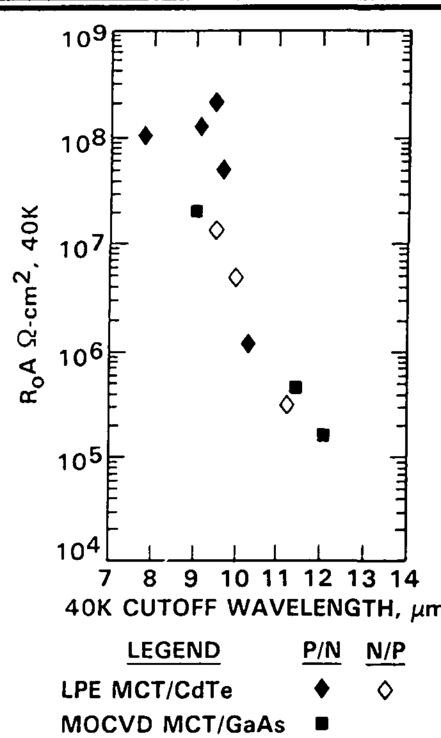
Performance of an LWIR MCT/GaAs Array at 50K



LWIR MOCVD HgCdTe/GaAs DIODES BEST PERFORMANCE IS AT TOP LPE LEVELS FOR 77 AND 40K



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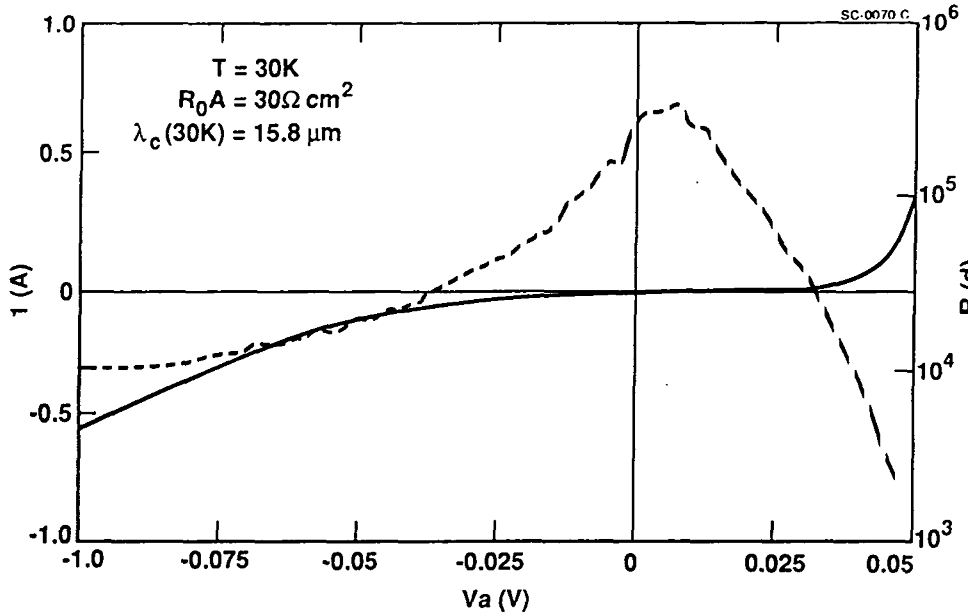
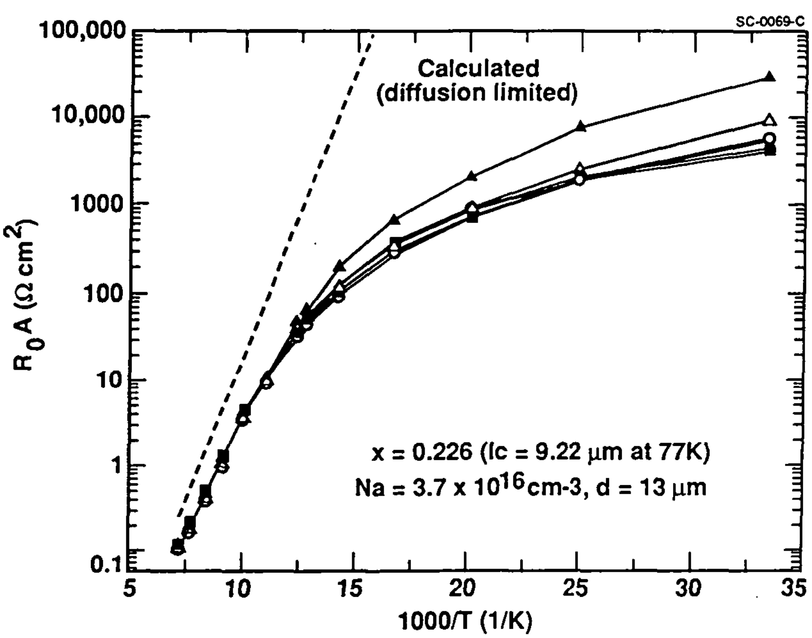
VLWIR I-V Characteristics for MOCVD Grown MCT/GaAs Detector



R_0A vs 1/T

Layer 3-581, L-134, Planar Ion Implanted



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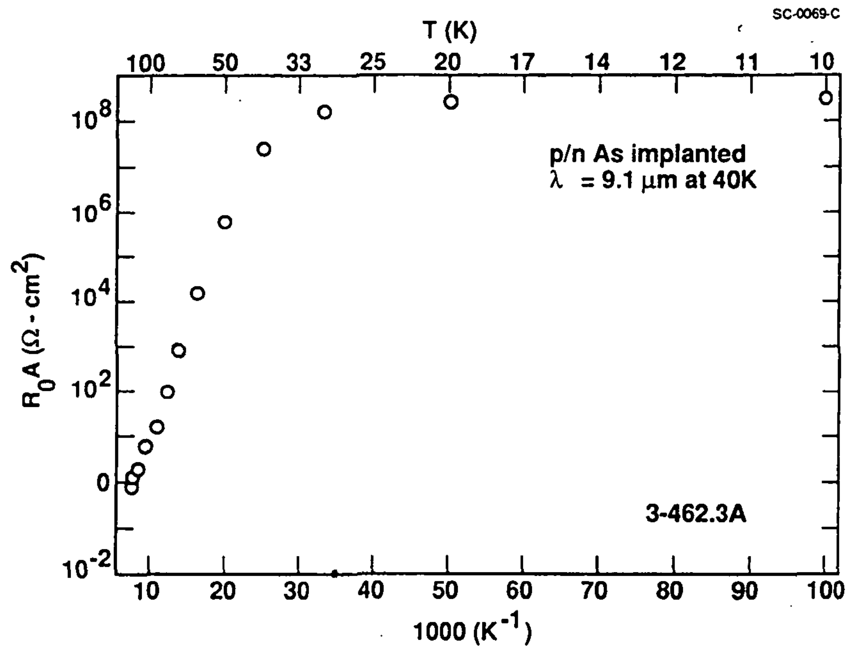
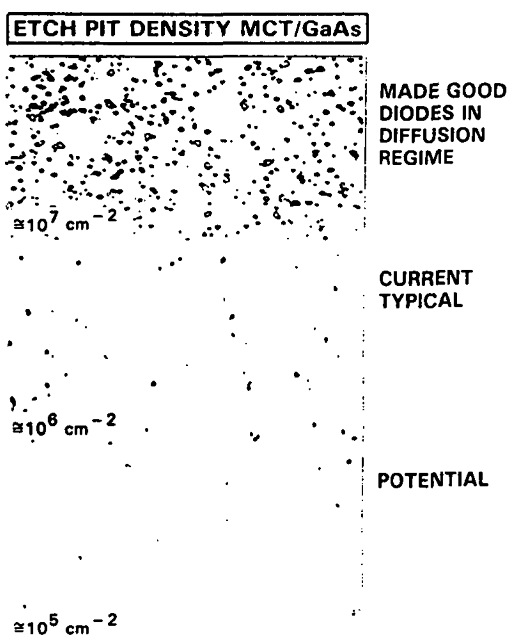
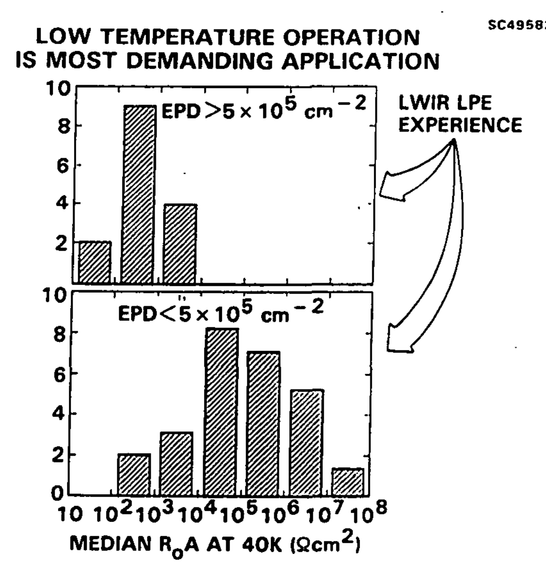
Temperature Dependence of the R_0A Product of a P/N Diode Fabricated from PACE-2 Material



STRATEGIC APPLICATIONS REQUIRE CONTROL OF DISLOCATION DENSITY





$\lambda_c \geq 9.1$-$10.3 \mu m$ AT 40K FOR 38 LAYERS

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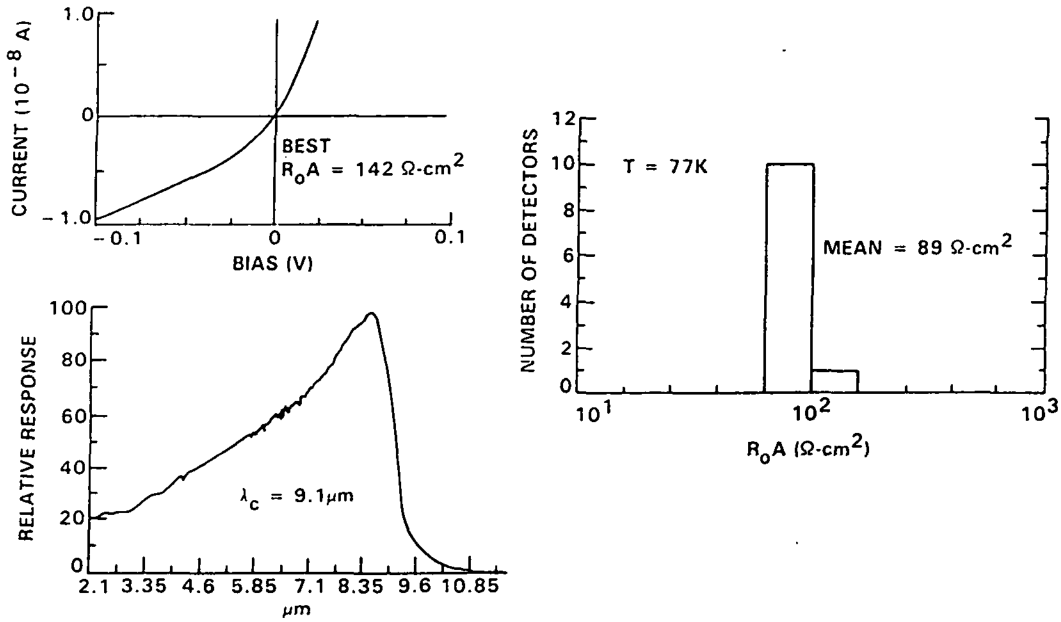
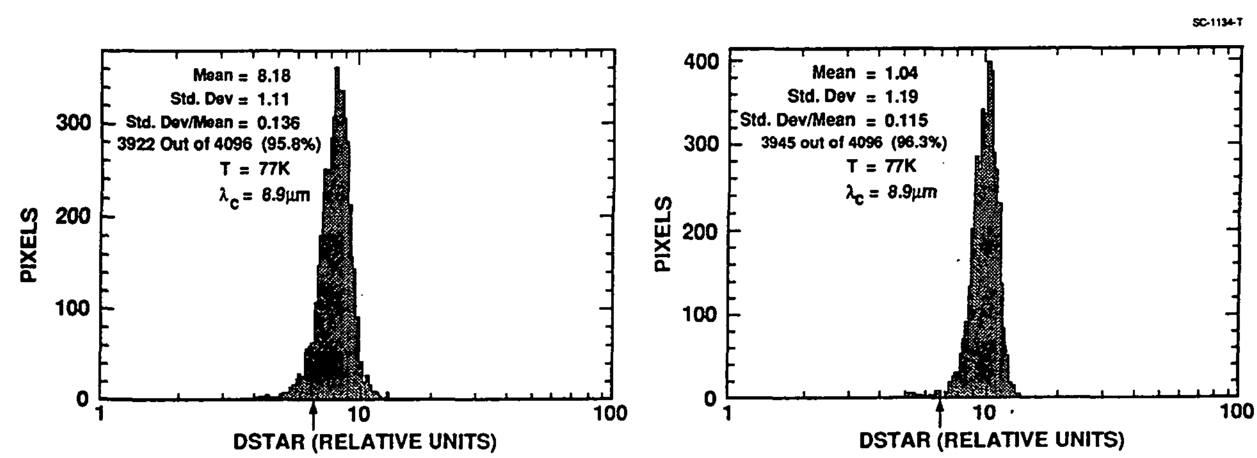
SAMPLE DIODES FROM PACE II 128 x 128 WAFER (ROCKWELL IR&D)

FULL PLANAR PROCESS: n/p, B-IMPLANTED, ZnS/SiO_2 PASSIVATED



Pace-2 Shows D* Uniformity and Operability of LWIR Hybrid



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CONCLUSIONS

- MCT HAS DEMONSTRATED THE HIGHEST PERFORMANCE OF ANY INTRINSIC AT ALL IR WAVELENGTHS
- NOVEL, ALTERNATIVE-SUBSTRATE, VPE APPROACHES CAN MEET PROGRAM GOALS WHILE ENHANCING PRODUCIBILITY AND MAKING POSSIBLE ADVANCED ARCHITECTURES
- THE PRESENT LIMITATIONS OF THE TECHNOLOGY ARE NOT FUNDAMENTAL BUT DUE TO IMMATURITY
- WE EXPECT LWIR/PACE-2 (GaAs)OR 3 (Si) TO FOLLOW A SIMILAR PATH TO PRODUCIBILITY AS THAT OF MWIR PACE-1 WHICH HAS RESULTED IN THE LARGEST (256X256) INSTRINSIC IR FPA TO DATE

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