EPI-Hi Technology Development

Outline

- objective
- approach
- development strategy and status
- fidelity of test article
- test performed
- transition to flight

Objective

Develop new approach to fabricating multi-element ion-implanted silicon solid-state detectors thinner than ~30μm with the following features:

- thicknesses in the range ~10 to 30 μm
- good control of absolute thickness and detector-to-detector variation (±1 μm)
- good thickness uniformity (~0.2% or better rms variation) to allow good species resolution (e.g., He isotope separation)
- mechanical robustness to provide good manufacturing yield and to survive launch environment without breaking

Approach

• fabrication based on commercial silicon-on-insulator wafers (SOI)

• detector pn junctions produced on device layer of SOI using conventional ion-implantation technology

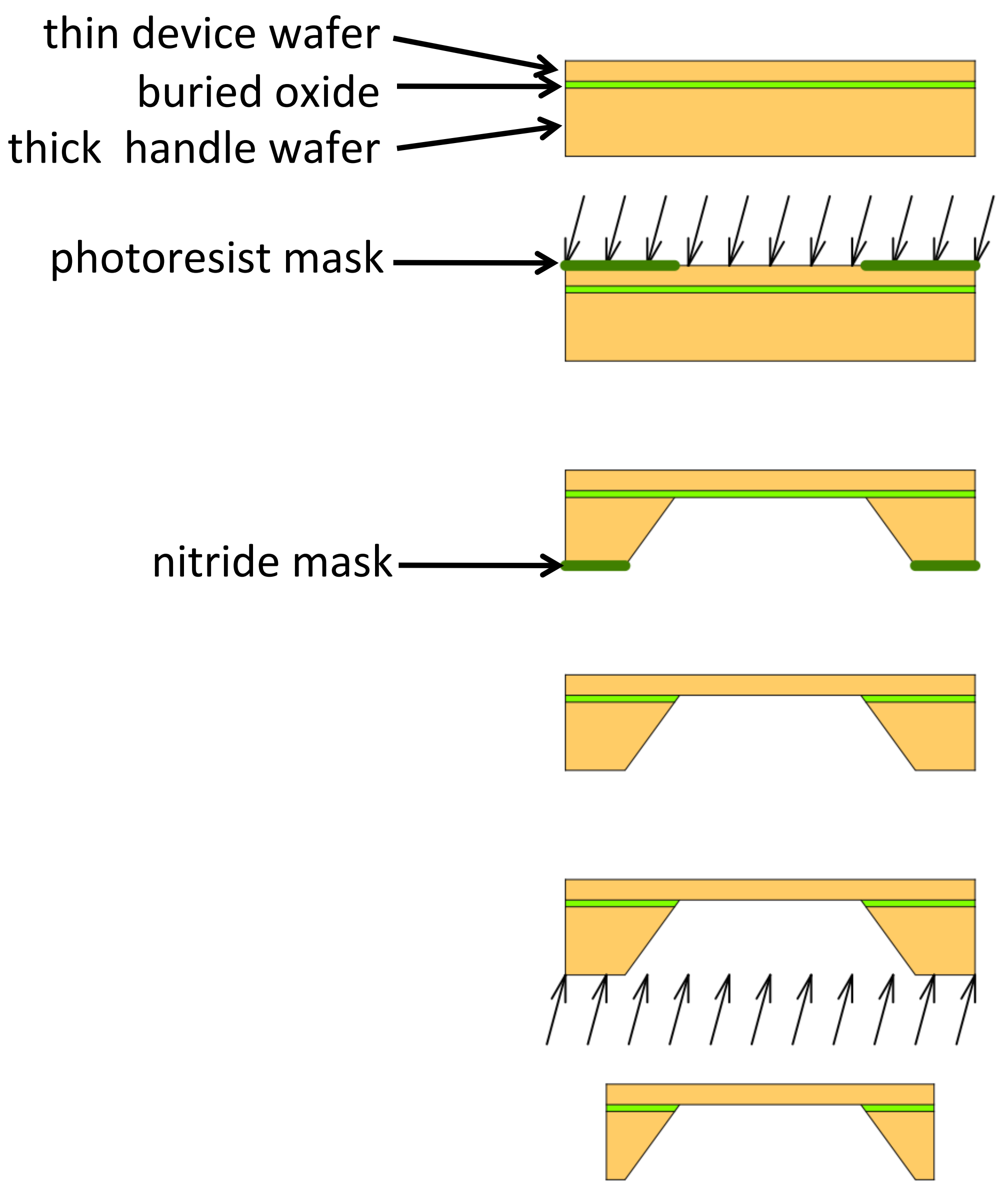
• supporting handle layer etched away under portion of the wafer containing detector active area

• thin SiO_2 interface between the two wafers acts as etch stop that makes thickness control and uniformity independent of etch rate variations

• remaining thick "picture frame" immediately outside the thinned region provides robust mechanical support and avoids the need to wirebond to the fragile thin membrane

• production of ohmic contact and dicing into individual detectors done after thinning

Thin Silicon Detector Fabrication Process Summary



silicon-on-insulator (SOI) wafer, commercial product

ion implant to produce diode pn junctions on device layer

wet etch to remove handle layer under active area—oxide acts as etch stop

etch away oxide from underneath active area

ion implant from back to produce detector's ohmic contact

dice wafer into individual thin detectors with thick supporting frames

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SOI THICKNESS CHARACTERISTICS:

- ***THICKNESS COMPARISON BETWEEN THINNED TEST SAMPLES OF SOI AND CONVENTIONAL (STEREO/LET) DETECTORS***
- ***MANUFACTURER DATA ON THICKNESS UNIFORMITY OF SOI PURCHASED FOR EPI-Hi THIN DETECTOR DEVELOPMENT***

Development Strategy and Status

<u>Background</u>

• prototyping studies carried out by a collaboration between LBNL (diode fabrication) and Caltech/JPL since 2003

• prior Caltech/JPL collaboration with Micron Semiconductor (Lancing, Sussex, England) allowed them to develop the capability for making thin, supported detectors from conventional silicon wafers; thickness control and uniformity were did not meet specifications

<u>Phase B Activity</u>

• efforts to prototype EPI-Hi thin detectors from SOI wafers has been funded during phase B both at Micron and LBNL

• testing and evaluation being carried out by the manufacturers and by Caltech/JPL and GSFC

<u>Flight Detectors</u>

• plan to down-select to a single source for flight detectors based on test results

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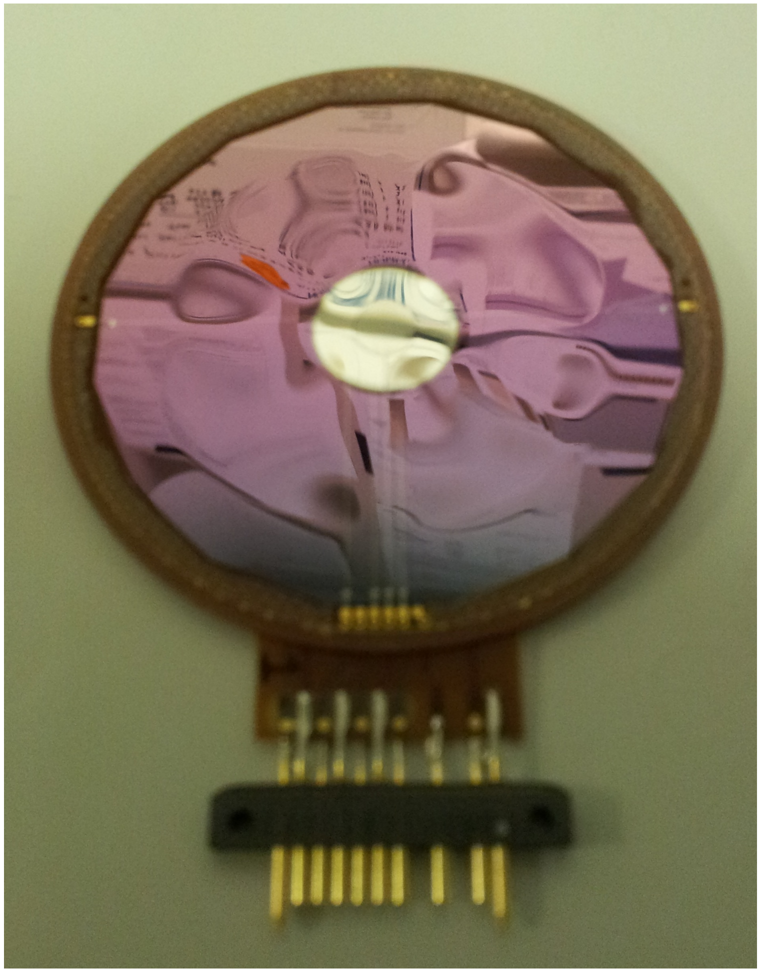
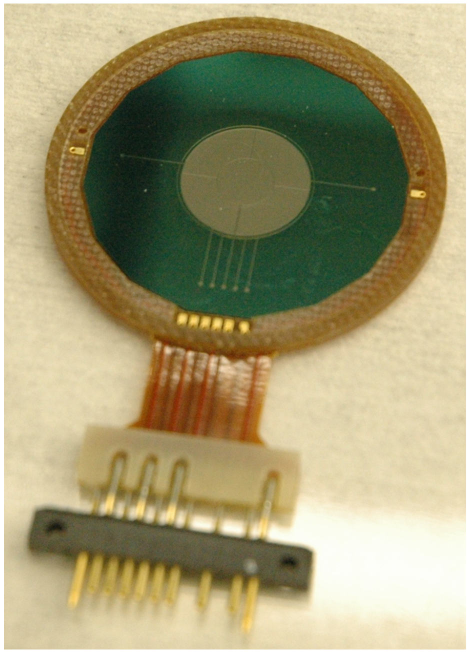
Photograph of Thin Detectors

L0 Detector from
MIcron Semiconductor



L1 Detector from LBNL



Labeling needed:

- ***dimension***
- ***location of active area***
- ***comment about waviness***

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Photograph of SOI wafer after thinning

Fidelity of the Test Article

flight detectors are expected to be identical to the prototypes

- the same photolithography masks will be used
- no changes are anticipated in process parameters (ion implantation energy, annealing temperature and time, etc.)
- it presently appears that a sufficient supply of SOI wafers may be left over from the phase B work to allow fabrication of all of the flight detectors and spares
- no changes are anticipated in the detector mounts (provided by GSFC to both LBNL and Micron)

possible exceptions

- if expected risk from dust impacts is judged to be excessive, a modest increase in detector thickness (e.g., 12µm —> 15µm) could be considered
- if LBNL is selected to make flight detectors, adhesive used for gluing detectors into mounts may be changed to that conventionally used by Micron

Tests Performed

electrical characteristics

- leakage current versus bias (IV) —> maximum operating voltage
- capacitance versus bias (CV) —> bias required for full depletion

particle response

- alpha particles from ^{244}Cm source (5.8 MeV —> 1.45 MeV/nuc)
- accelerator beams of heavy ions

thickness characteristics

- thickness and thickness uniformity inferred from particle response tests checked against expectations from SOI characteristics

stability in expected environment

- thermal-vacuum life test at GSFC—our standard test for flight qualification of all silicon detectors
- total dose testing using ^{60}Co gamma-ray source at JPL

mechanical robustness

- acoustic test of mechanical model made from thinned SOI

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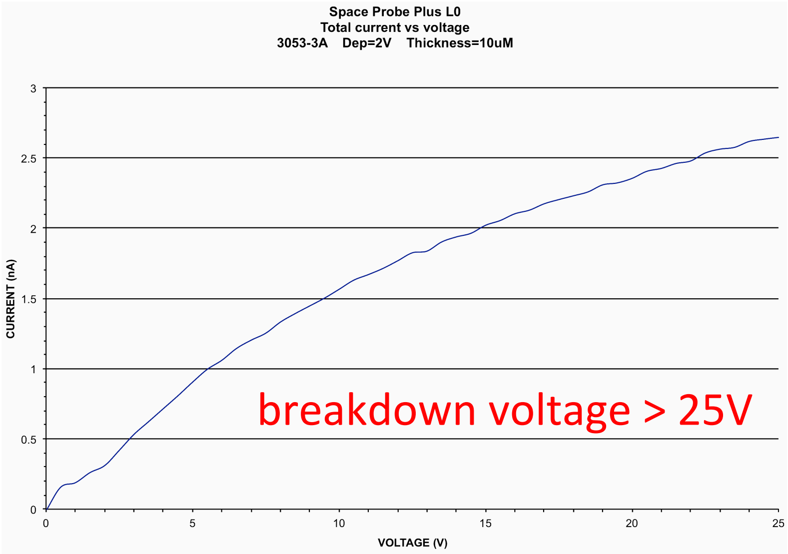
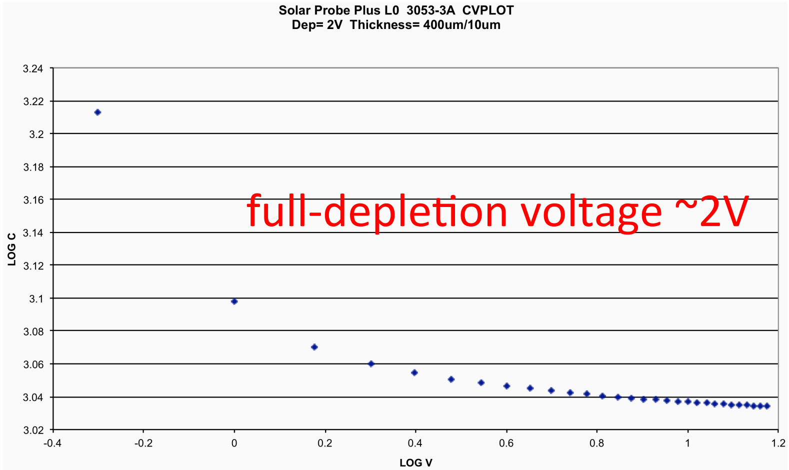
Plots of electrical characteristics

- IV curve(s)
- CV curve(s)





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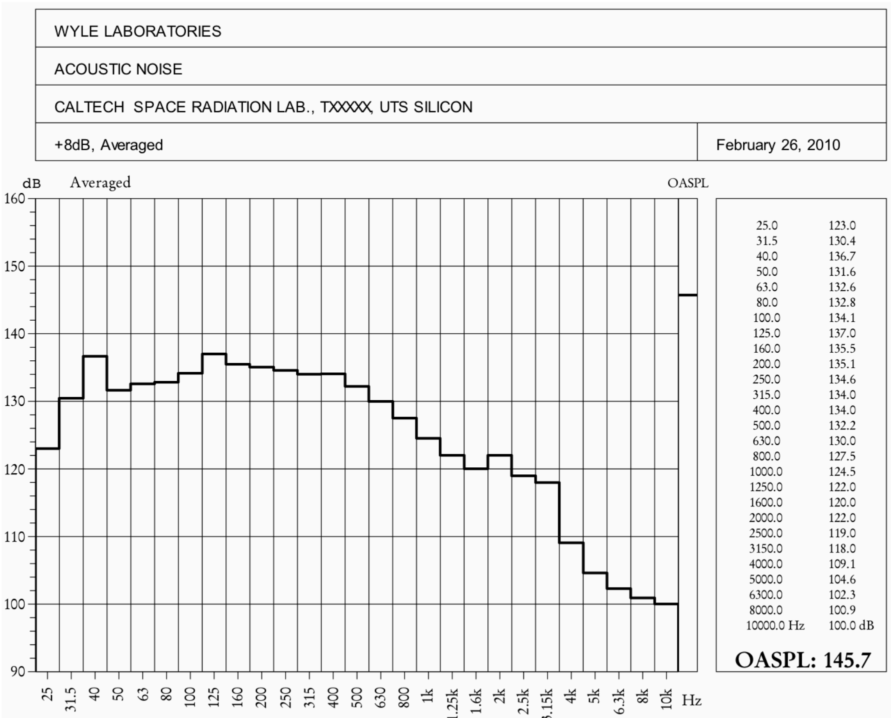
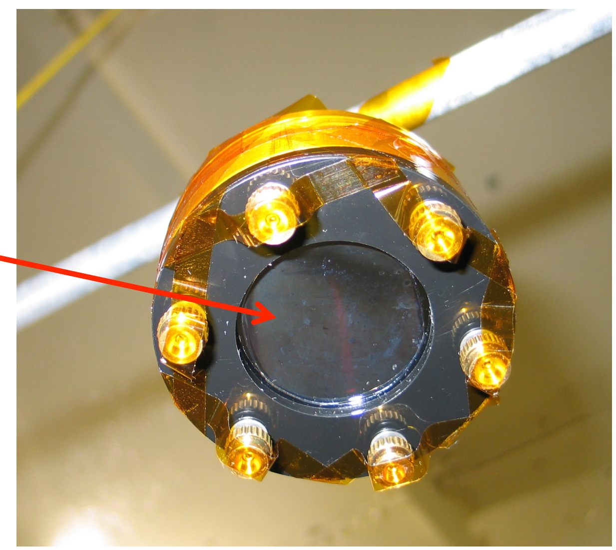
Acoustic Test of Mechanical Sample L0



highest test level: 145 dB = SPP spec + 8 dB

silicon membrane
10 μm thick
~3.4 cm diameter



POSSIBLE PLACE-HOLDER SLIDE

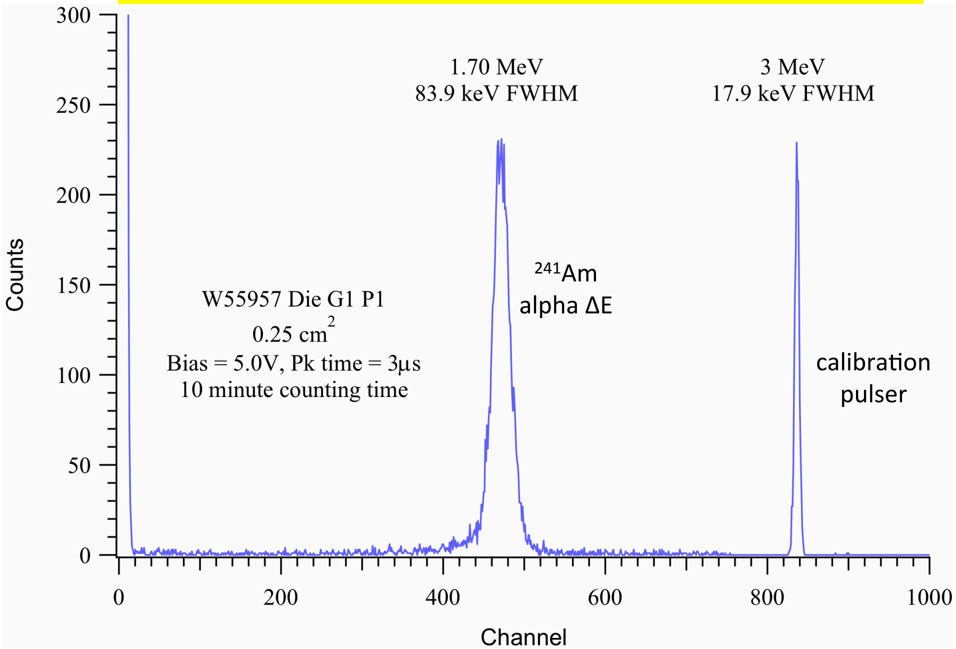
PLOTS OF PARTICLE TEST RESULTS—ALPHAS

He mass histogram made using alpha particles—comparison with expected resolution

Possibly easier alternative to consider:

- *mono-energetic alpha particle ΔE and E' distributions compared with expectations*

NOTE: these data are not from EPI-Hi detectors; they are from a LBNL pre-prototype detector (15µm thick, 1cm[2] active area, 4 pixels)



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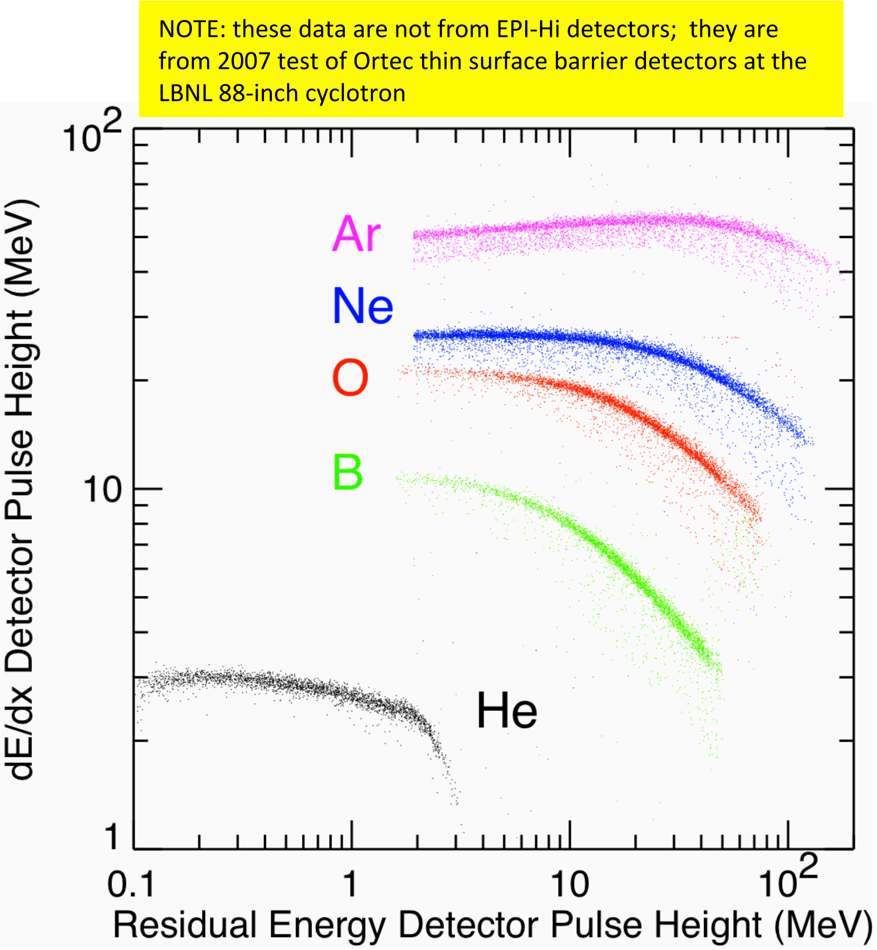
PLOTS OF PARTICLE TEST RESULTS— HEAVY IONS

- ***ΔE vs. E' cross plot showing element tracks***



Transition to Flight

- extend selected prototype tests to cover additional detectors that have been fabricated in phase B—determine whether there are any detector-to-detector differences that might affect
    - yield
    - selection of manufacturer for flight detectors
    - test program needed for flight devices
- select manufacturer for flight detectors