

Appendices

Appendix A: Prototype Fujitsu Silicon Microdosimeter, Packaging and Processing

A.1. Device Packaging

- The IC is packaged in a 28 pin DIL package.
- 4 diode arrays are on each IC. The arrays and pin-outs are summarised below
- The devices are fabricated on 4 different wafers SOI (2 μ m, 5 μ m 10 μ m)+ bulk
- Substrate is p-type($1.5 \times 10^{15} \text{cm}^{-3}$)

Array	Diode Size	Array size	Pin(p side)	Pin(n+ side)	Comments
1	100x100um	30x50=150 diodes	1	4	Note 1
2	100x100um	10x5=50	2	3	
3	10x10um	120x120=14400	25	28	Faulty all devices
4	10x10um	40x120=4800	26	27	Note 1

NOTE 1: To reverse bias diode connect +Vdd to Pin(n+ side) and earth to Pin(p side)

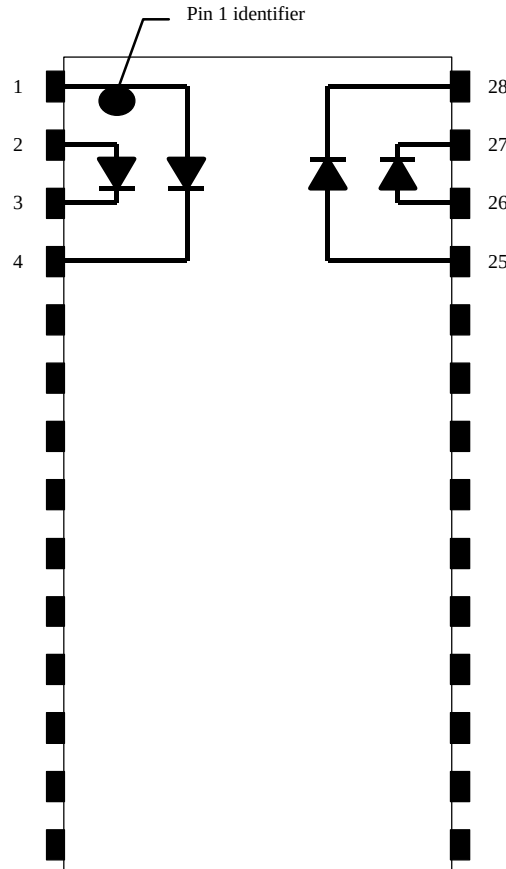


Figure A.1. Package pin-out diagram

A.2. Device Processing

The following pages contain mask details at various scales. The processing steps are summarized in the table below and the mask details are provided in the following figures.

Table A.1. Processing steps for microdosimeter device construction

	Step	Pre-process	Parameters	Post-process	Comments
1.	Crystallization	Czochralski Crystal growth	SOI wafer bonding		SOI formed by bonding wafers in oven with O ₂
2.	Pad Oxidize		50A, 800°C, dry O ₂		To reduce thermal expansion stress during oxidation
3.	SiN CVD		1150 A		
4.	<FL>	HMDS	Oxide Mask Photoresist		
5.	FL etch		SiN (1150A), TEL580	RS	
6.	Field Oxidation		3500A, 900°C, Wet O ₂		
7.	SiN Washout			RS	
8.	Thin Oxide		50A, 800°C, Wet O ₂		
9.	<FN>	HMDS	n+ Mask Photoresist		
10.	Ion Implant n+		As+, 30keV, 5E15 /cm ²	RS	
11.	<FP>	HMDS	P+ Mask Photoresist		
12.	Ion Implant p+		B+, 30keV, 5E15 /cm ²	RS	
13.	LTO CVD		4000A		
14.	Anneal		1000°C, 10s, RTA		Removes ion-induced lattice damage
15.	<NA>	HMDS	Mask Photoresist		
16.	SiO ₂ Wet Etch			RS	
17.	Ti/TiN Sputtering		Ti(200A)/TiN(1000A)		Radio Frequency sputtering
18.	Barrier Anneal		450°C, 30min, N ₂		
19.	Al Sputtering		6000A		
20.	<LA>	HMDS	Mask Photoresist		
21.	AL RIE				
22.	Sinter		450°C, 30min, N ₂ /H ₂		
23.	LTO CVD		2000A		
24.	<C>	HMDS	Mask Photoresist		
25.	SiO ₂ RIE			RS	
26.	Back Process		Process back side		Includes 2000A Au deposit

Acronyms: SOI = Silicon On Insulator
 CVD = Chemical Vapor Deposition
 LPCVD = Low Pressure CVD
 HMDS = Hexamethyldisilazene (primer for photoresist)
 RS = Resist Strip
 LTOCVD = Low Temperature Oxide CVD
 RTA = Rapid Thermal Anneal
 RIE = Reactive Ion Etching

Mask codes: <FL> = Field oxide mask
 <FN> = n+ ion-implant mask
 <FP> = p+ ion-implant mask
 <NA> = Ohmic contact mask
 <LA> = Aluminium metal mask
 <C> = Pad Contact mask

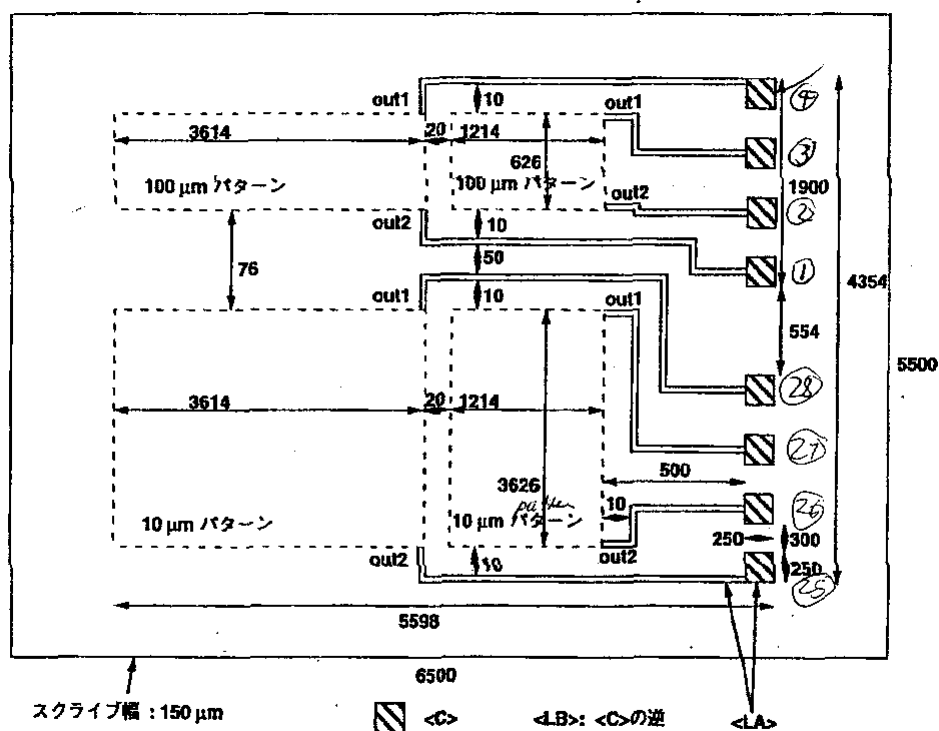
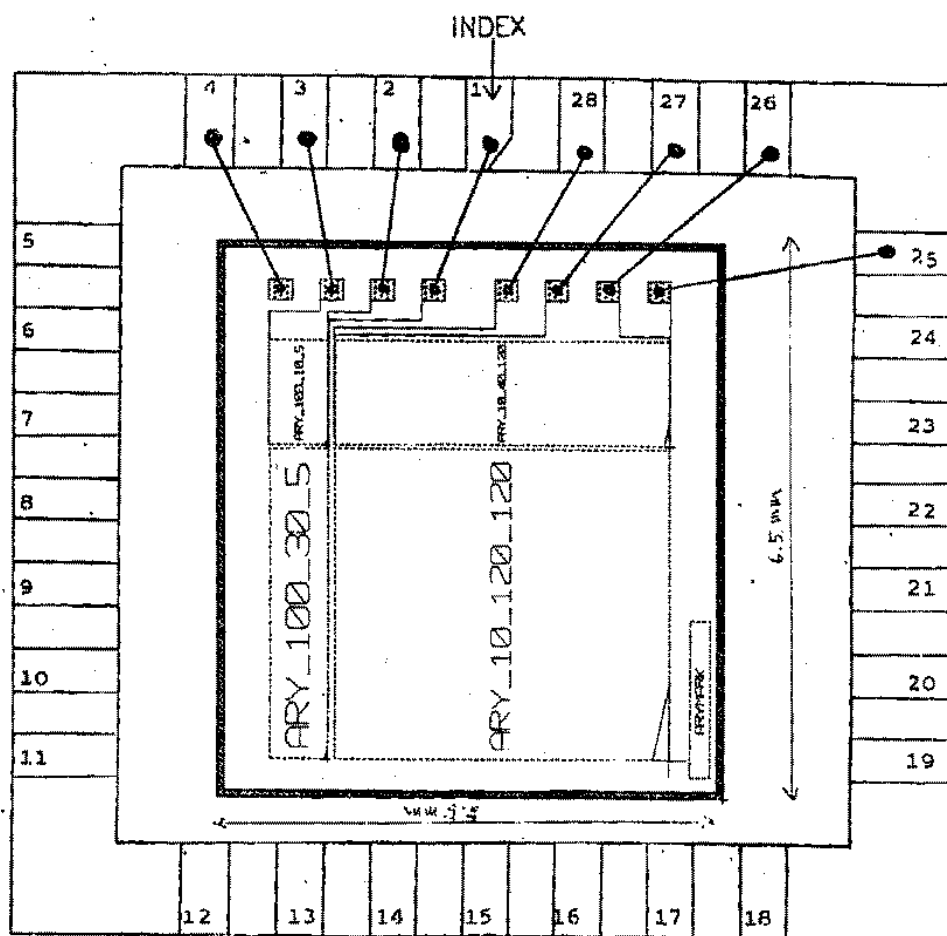
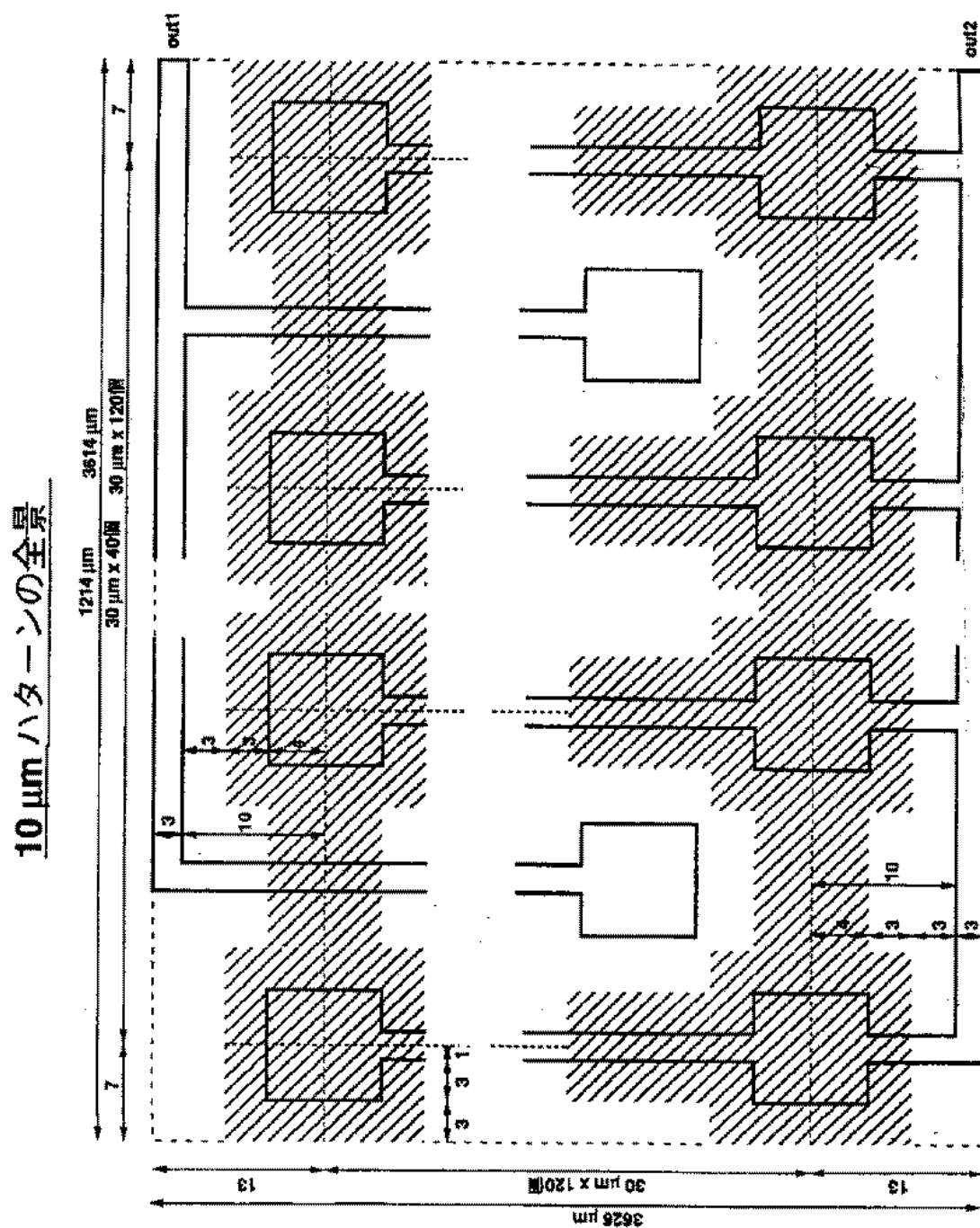
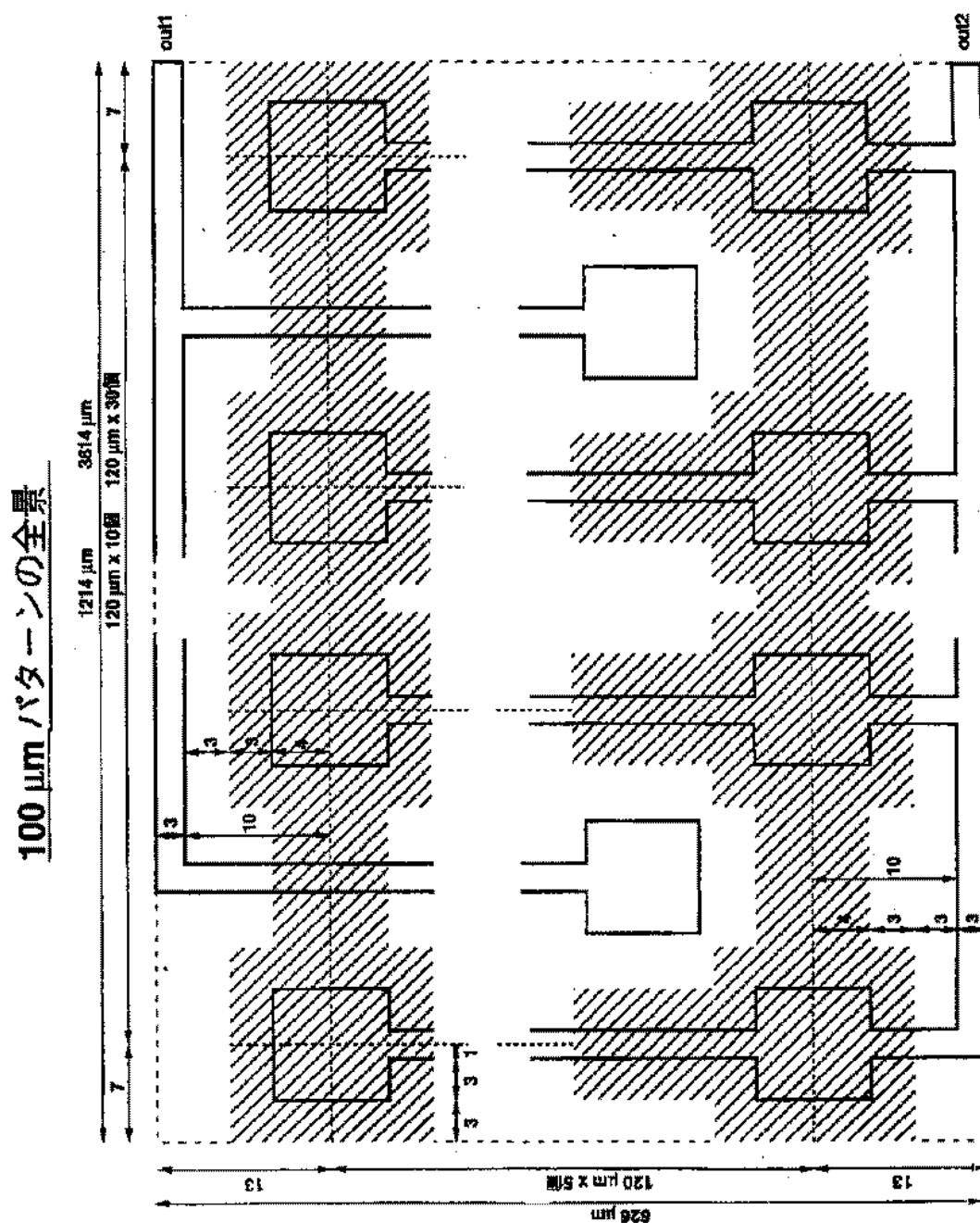
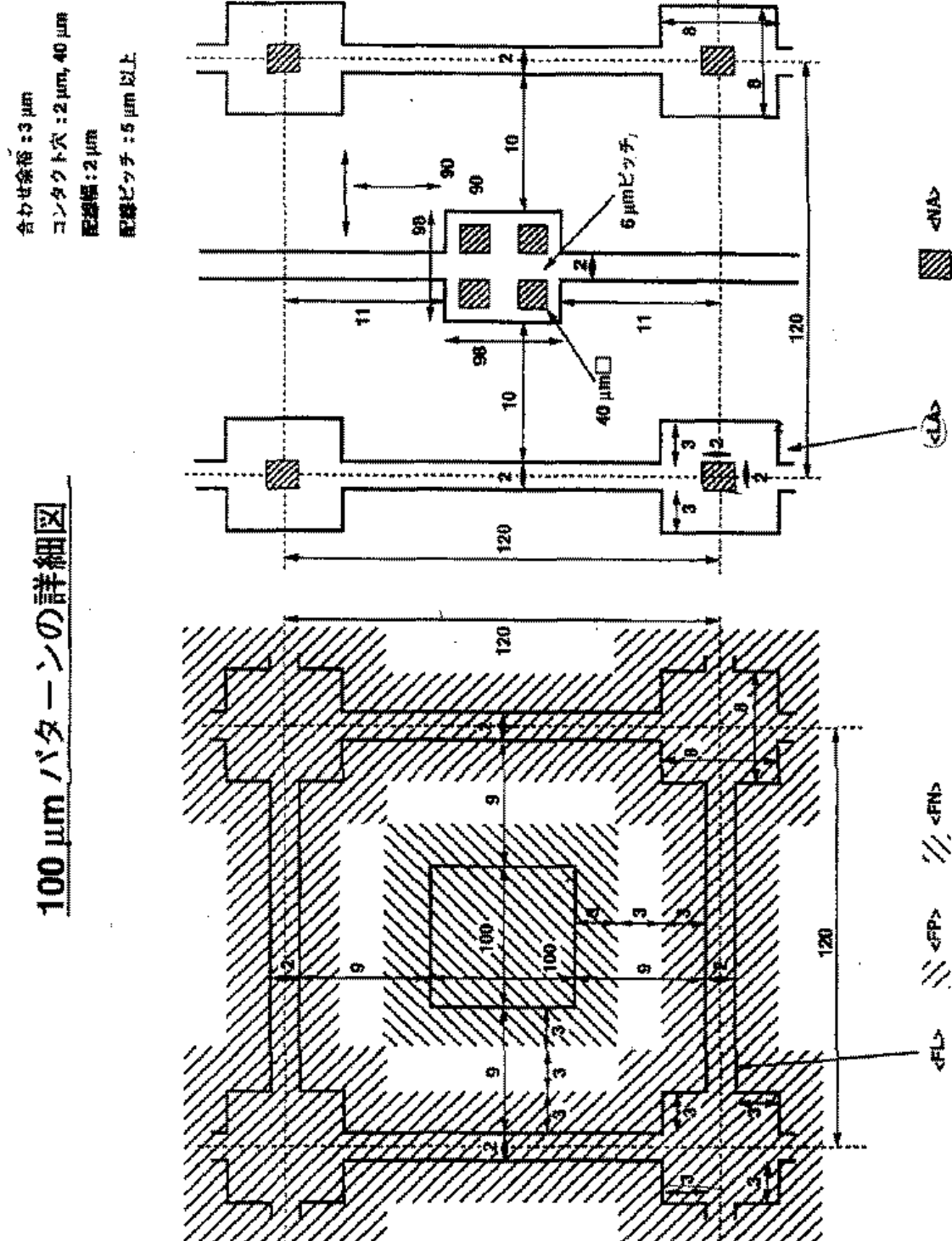


Figure A.2. Layout of arrays and silicon die.



Figure A.5. Large scale layout of 100 $\times$ 100 μm^2 junction arrays

Figure A.6. Small scale layout of 100×100 μm^2 individual cell

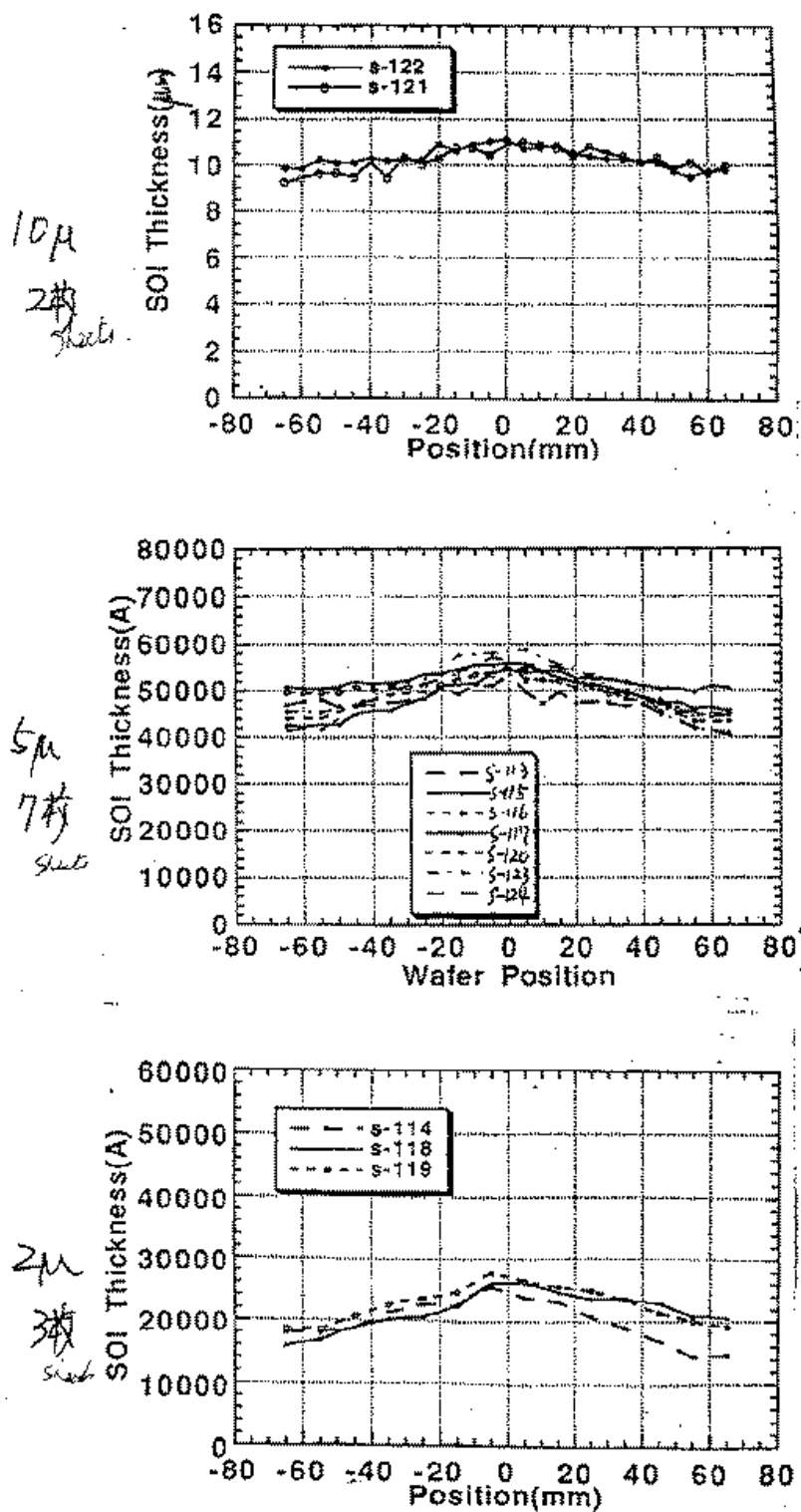
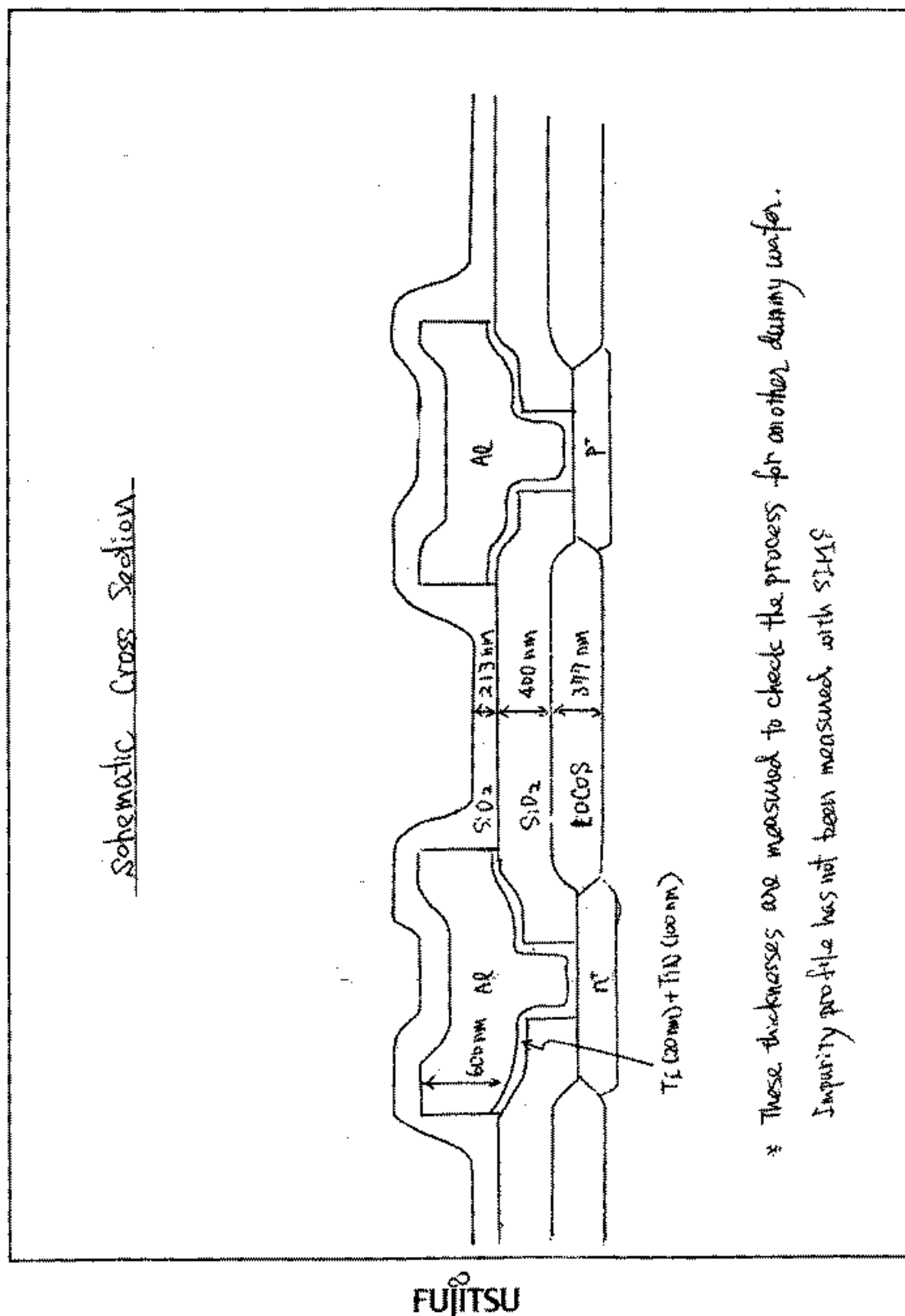


Figure A.7. Thickness of SOI substrates measured by Fujitsu as a function of wafer position and processed wafer



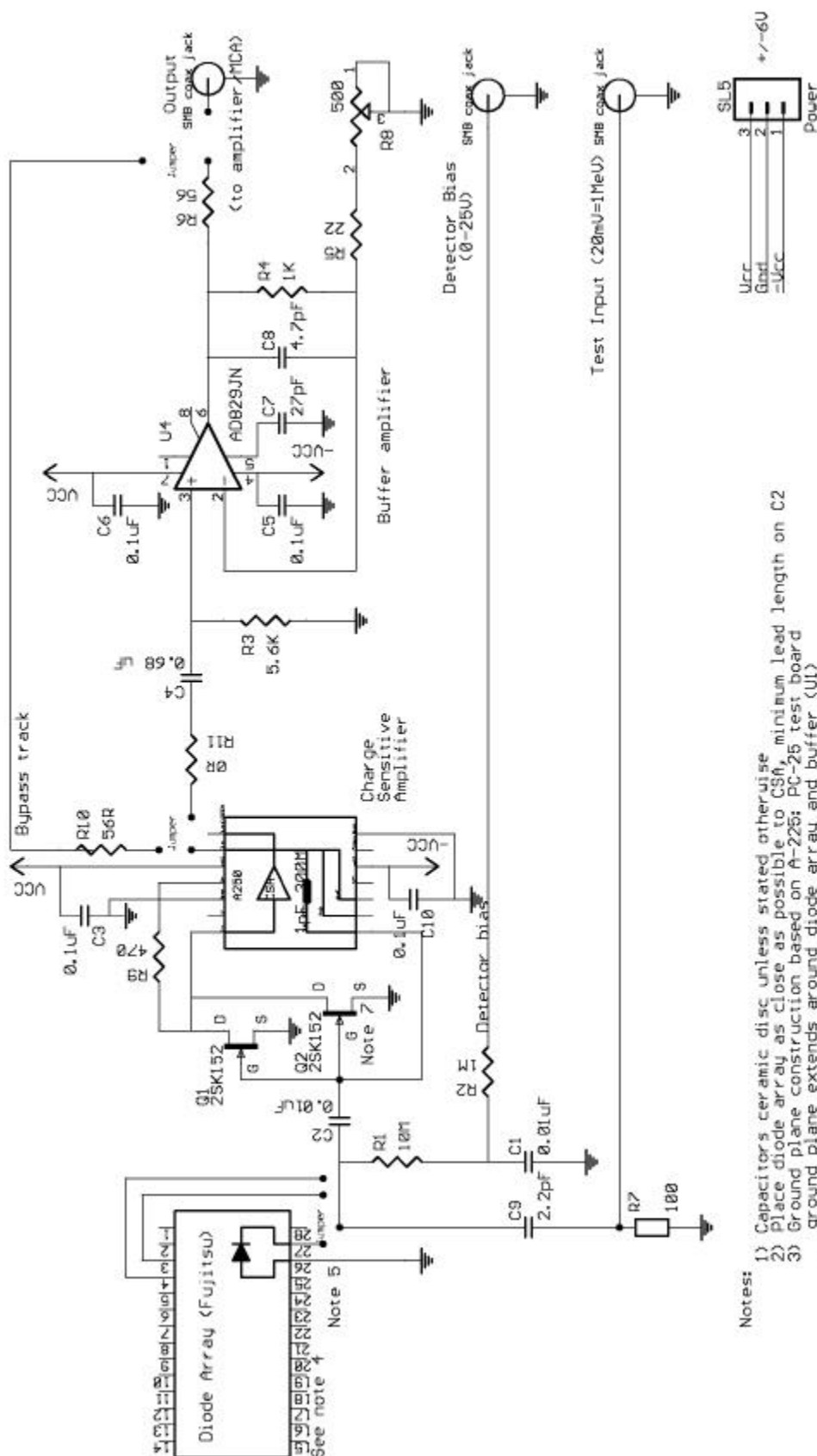
Appendix B: Mathematica Notebook - Analytical and Monte-Carlo Calculations of Chord and Segment Length Distributions in Various Shapes

This is an outline of the Mathematica [141] based notebook constructed to analyse and compare the SLD and CLD of various shapes. The entire notebook contents are too lengthy to present. The file (and other useful microdosimetric material) along with this thesis document will be available at the Radiation Physics Group (University of Wollongong) web site:

URL: <http://www.uow.edu.au/eng/phys/rpg/rpghome.htm>

- 1 Introduction
- 2 Chord Length Distributions under u-randomness
 - 2.1 CLD for Sphere
 - 2.2 CLD for Hemisphere
 - 2.3 CLD for Spheroid
 - 2.4 CLD for Cylinder
 - 2.5 CLD for Infinite slab
 - 2.6 CLD for Cube
 - 2.7 CLD for Rectangular parallelepiped (RPP)
 - 2.8 Plot Chord Length Distributions
 - 2.9 Plot CLD for 2 um SOI device and 10 um SOI device compared with a 2 um diameter proportional counter
 - 2.10 Plot distributions for literature review
 - 2.11 Calculate Relative Variance
- 3 Segment length distributions (u-randomness with finite range)
 - 3.1 SLD for Sphere
 - 3.2 SLD for Cube
 - 3.3 SLD for Rectangular parallelepiped (RPP)
 - 3.4 SLD for Infinite Slab with overlayer and converter
- 4 Comparison of Dose Average Lineal Energy (yd)
 - 4.1 Section Introduction
 - 4.2 yd and geometric reduction factor for a sphere
 - 4.3 yd and geometric reduction factor for a cylinder
 - 4.4 yd and geometric reduction factor for a RPP and cube
 - 4.5 yd calculation for infinite slab with overlayer and converter
 - 4.6 yd calculation for RPP (cube in particular) with overlayer and converter
- 5 Comparison of spectrum including straggling
 - 5.1 Chord length distributions under u-randomness with straggling
 - 5.2 Segment length distributions under u-randomness(finite range) with straggling
 - 5.3 Segment length distributions under c-randomness with straggling
- 6 Monte-Carlo Simulation of segment length distribution for RPPs (Analysis of Converter/Overlayer/RPP sensitive volume geometry)
 - 6.1 3D display of simulation geometry set-up
 - 6.2 CLD Monte Carlo simulation using Link to C routine
 - 6.3 Basic Software Verification Tests
 - 6.4 Calculate $\bar{y}_d$ and spectra for converter/overlayer/sensitive volume(50x50x2)

Appendix C: Low Noise Microdosimeter Probe Design (Prototype #2)



Notes:

- 1) Capacitors ceramic disc unless stated otherwise
- 2) Place diode array as close as possible to CSA, minimum lead length on C2
- 3) Ground plane construction based on A-225; PC-25 test board
- 4) Ground plane extends around diode array and buffer (U1)
- 5) Unused pins of diode array connected to gnd
- 6) Design needs to minimize capacitance between gnd and node at output of detector
- 7) Noise performance degrades with capacitance at this node
- 8) For off-probe buffer C4 may have to be increased (for A250) and R6 should be 75 ohm for R058 cable, 50ohm for R0174
- 9) Only one FET installed for most experiments