Base dose
and
Proximity correction

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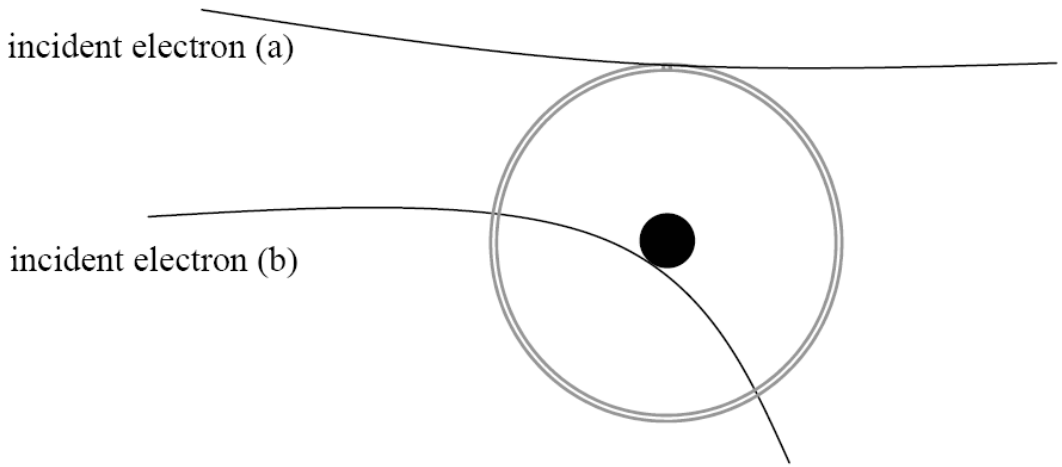
Electron Solid Interactions

- electrons forward scatter in resist (alpha)
- electrons backscatter off substrate (beta)
- Causes dose to spread away from where you want it to go, and expose areas you don’t want to be exposed


incident electron (a)
incident electron (b)

Forward Scattering (α)

- as electrons enter resist, they experience small angle scattering, effectively broadening the initial beam diameter
- forward scattering is minimized by using the thinnest possible resist and highest accelerating voltage

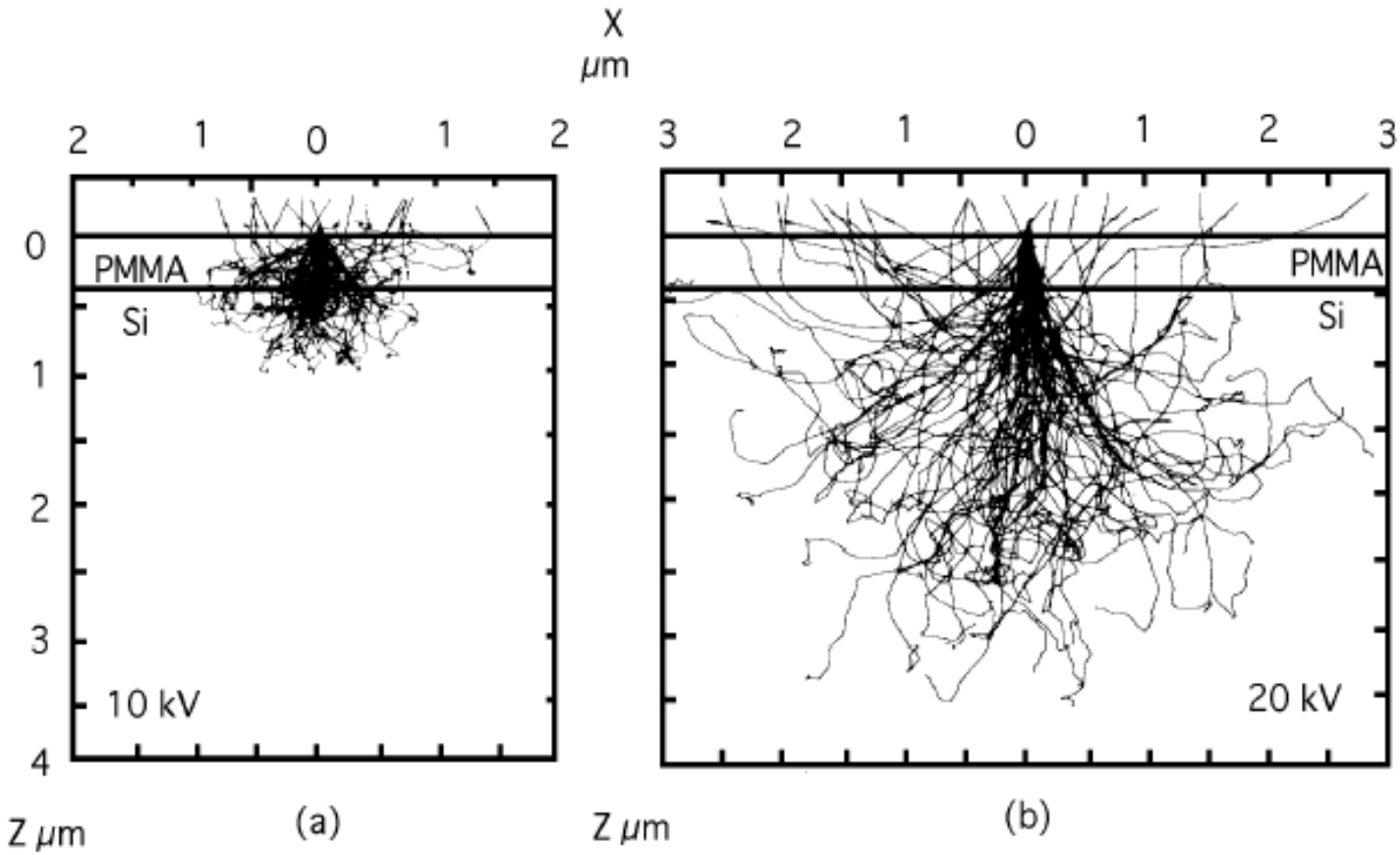
$$d_f = 0.9(R_t / V_b)^{1.5}$$

df = effective beam diameter (nm)
Rt = resist thickness (nm)
Vb = acceleration voltage (kV)

Backscattering (β)

- as electrons pass thru resist and enter substrate, many will undergo large angle scattering events
- these electrons may return back into the resist at a significant distance from the incident beam, causing additional resist exposure → this is called the proximity effect

Electron Solid Interaction



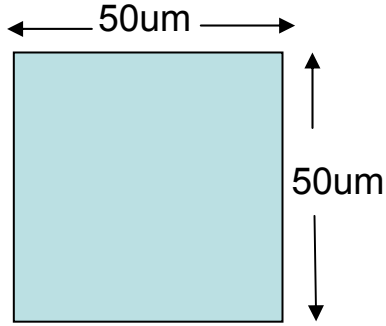
Source: SPIE Handbook of Microlithography, Section 2.3 Electron-Solid Interactions

Questions

- What exactly is “base dose” and how do I find it?
- What proximity parameters do I use?

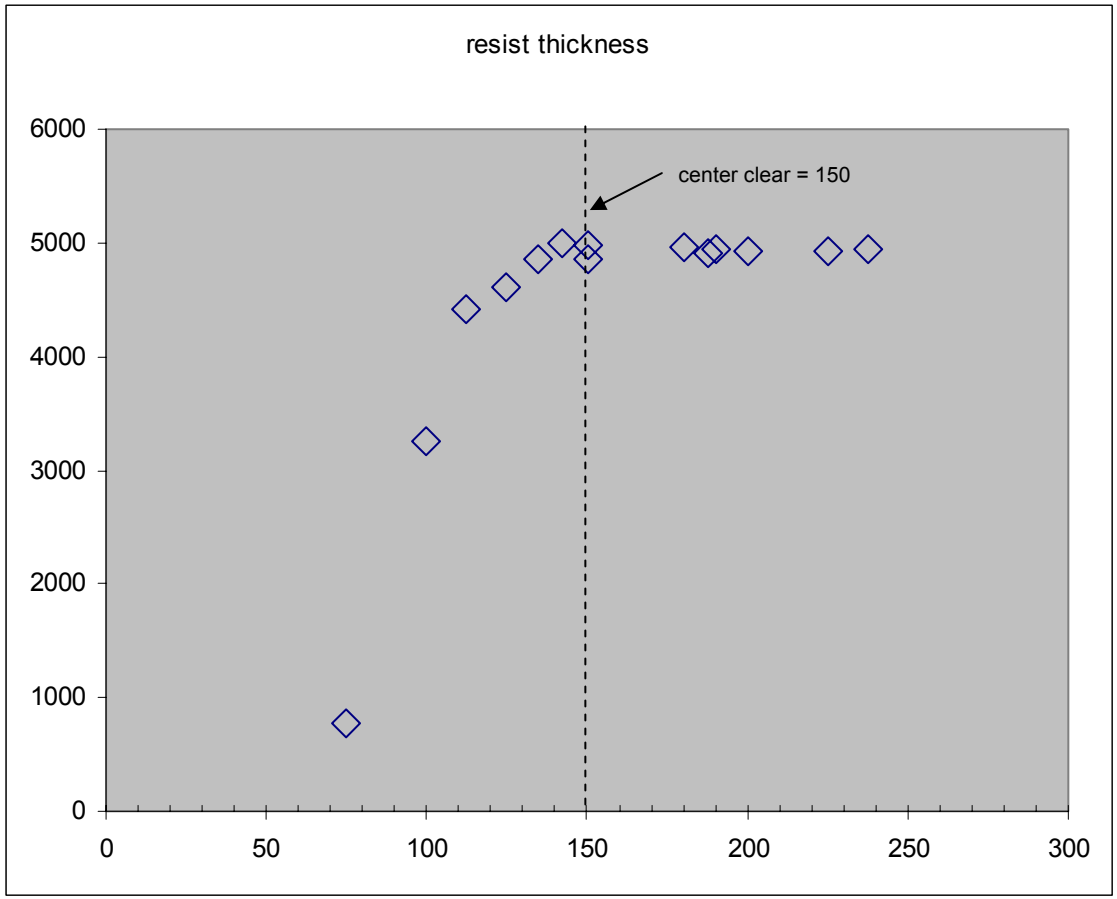
Process example

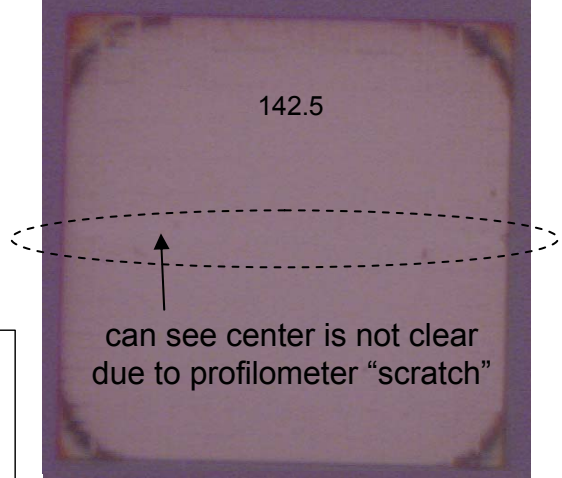
- substrate: black LiNbO3
- resist: ZEP520A 495nm thick
- expose 50um squares in resist
- develop n-Amyl Acetate 2min
- measure thickness with P15 (some difficulty with softness of resist)

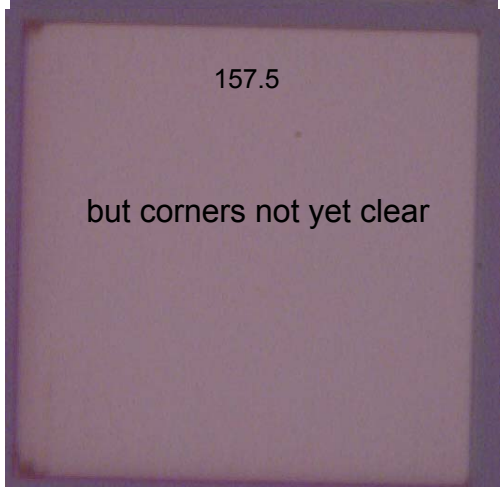



75
100
112.5
125
135
142.5
150
157.5
165
180
187.5
190
200
210
220
225
237.5
250
262.5
275
300
312.5
375
400
500

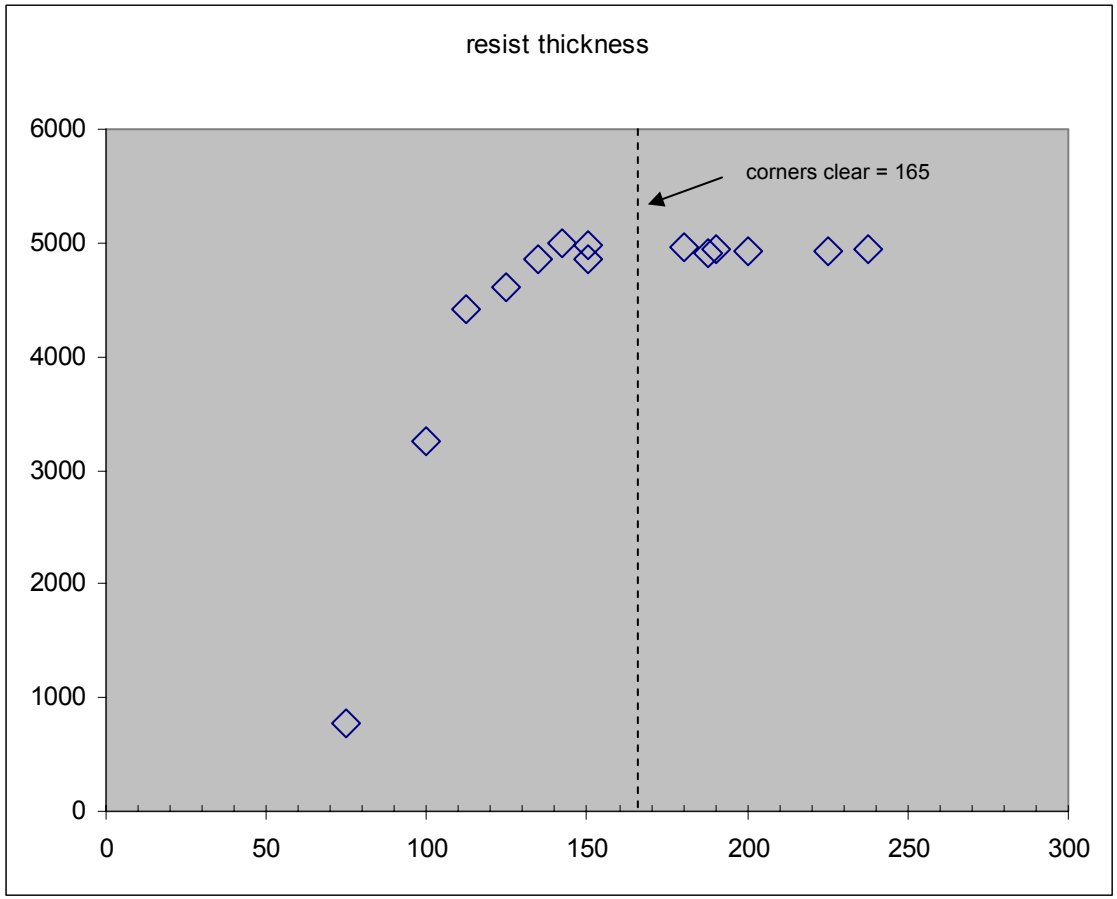
Center clear

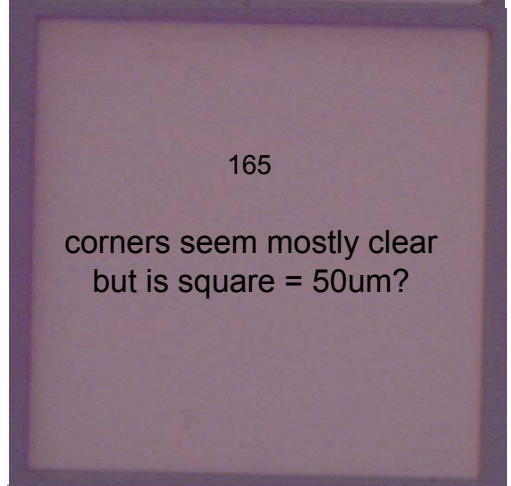


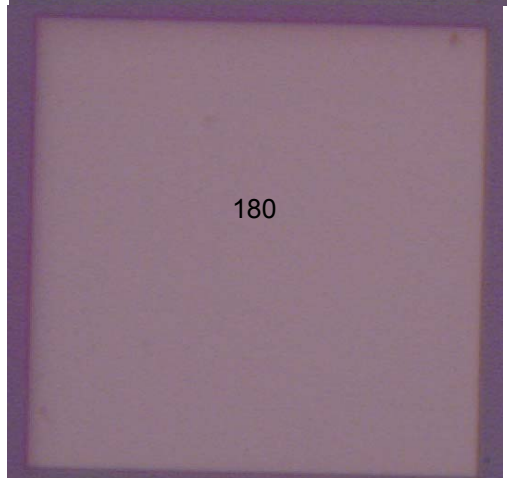


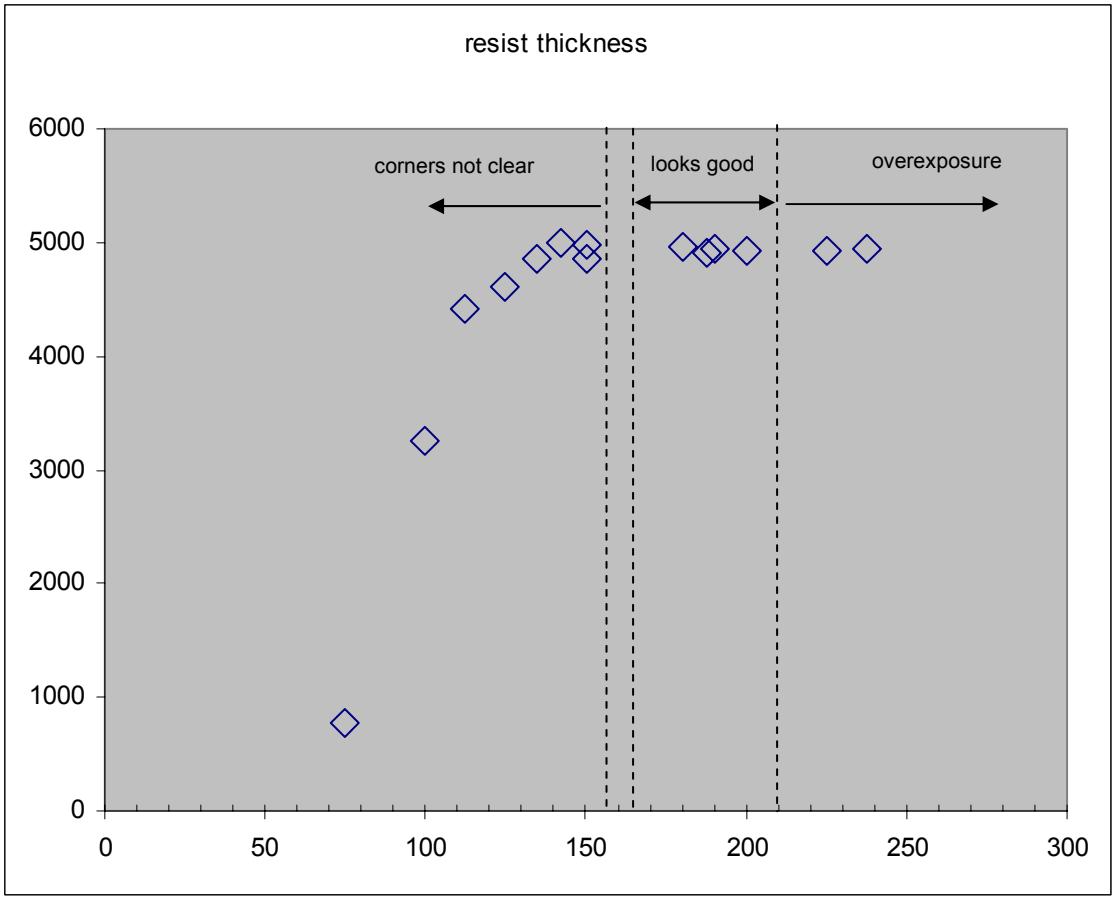


Corners clear



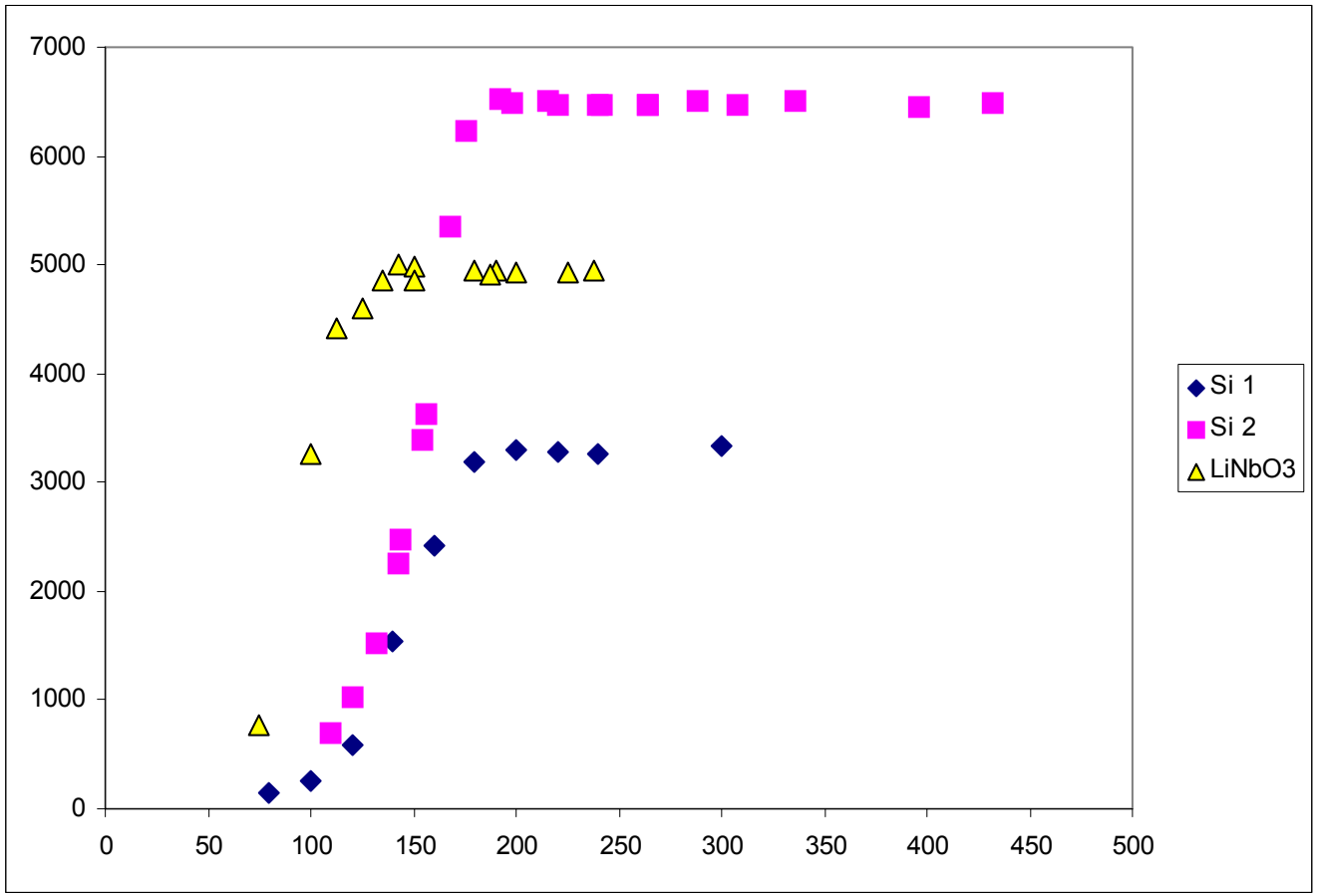




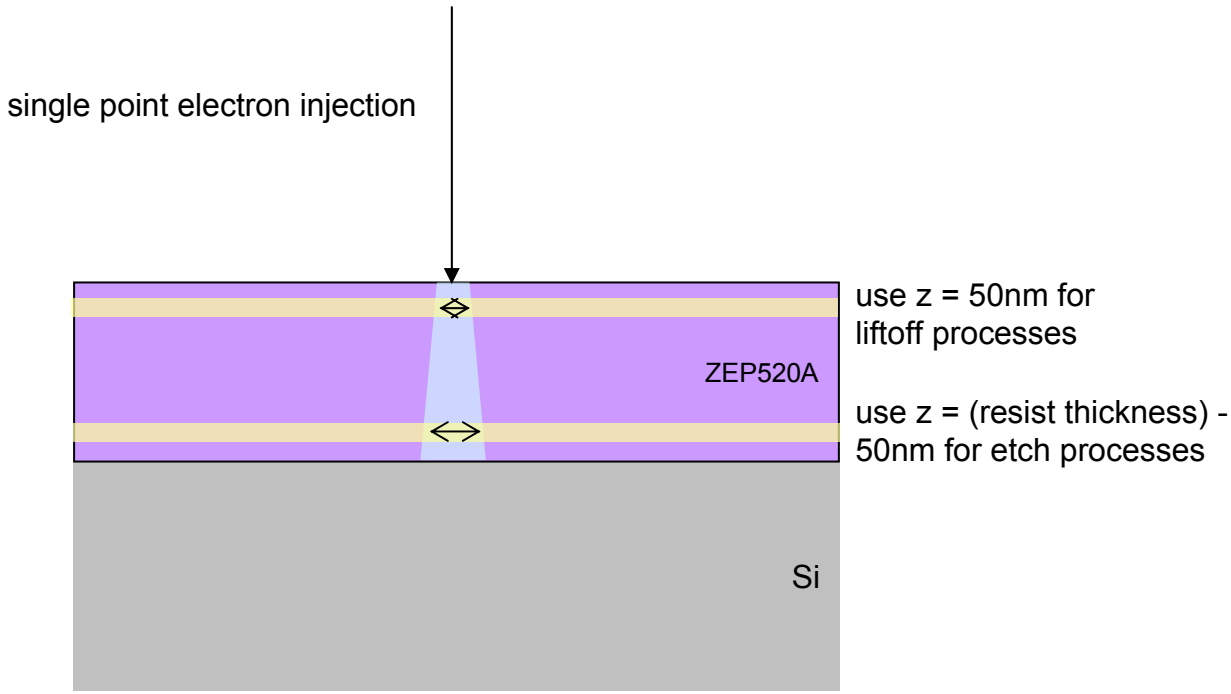


Does overexposure begin at 210uC/cm2? (see slide 4)

Comparison to silicon

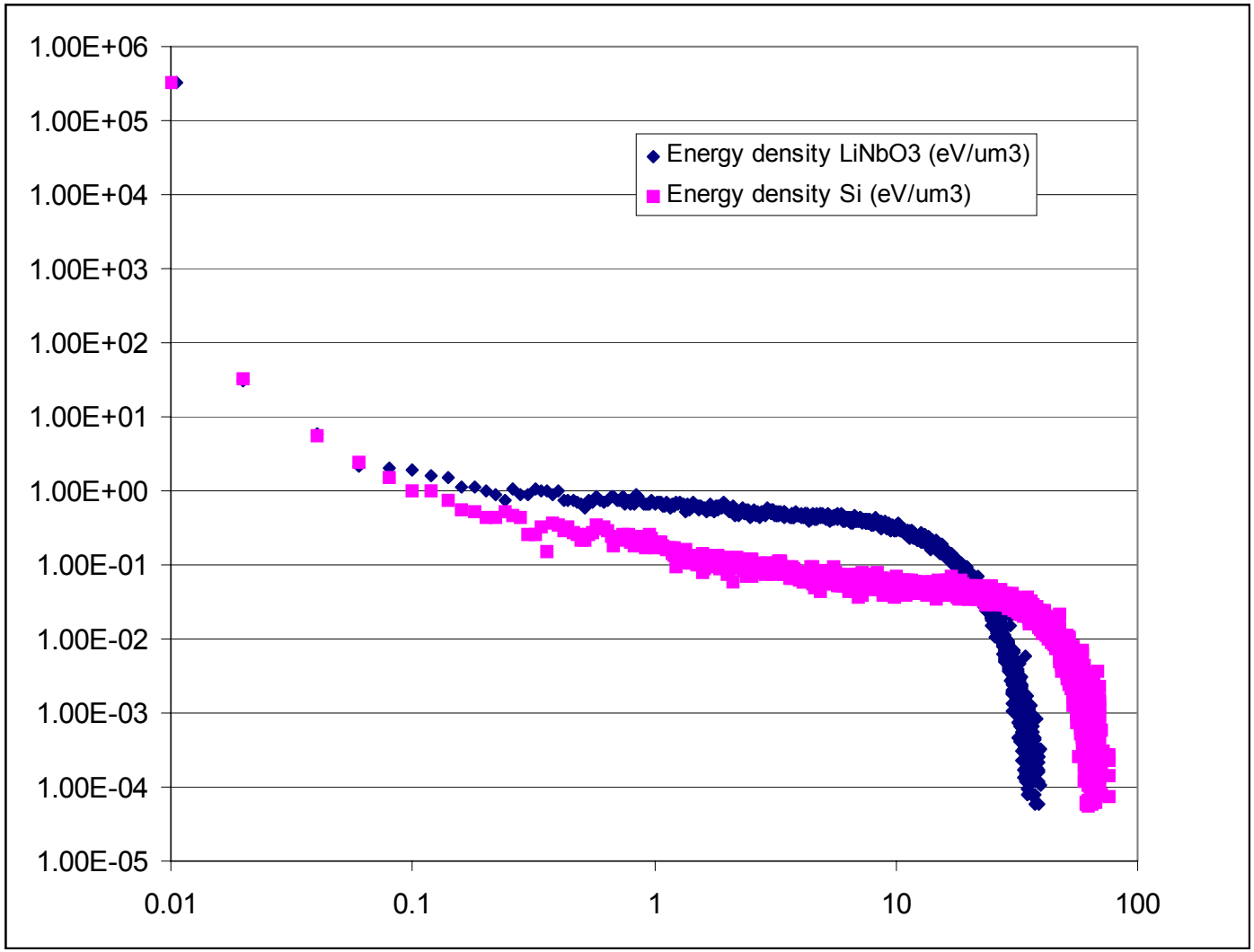


Double Gaussian fit of SCELETON



SCELETON simulation

(495nm ZEP520A, z = 50nm below resist surface)

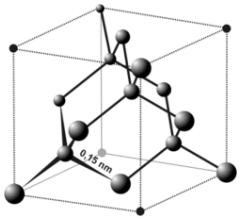


z = 45 - 60nm
ZEP520 = 495nm

substrate = Si
alpha = 0.0070um
beta = 35.0498um
eta = 0.5962

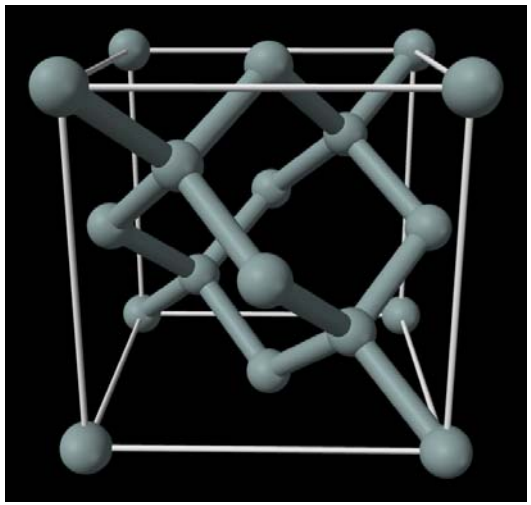
substrate = LiNbO3
alpha = 0.0070um
beta = 14.7635um
eta = 0.9152

Material properties



diamond cubic system

a = 5.4A

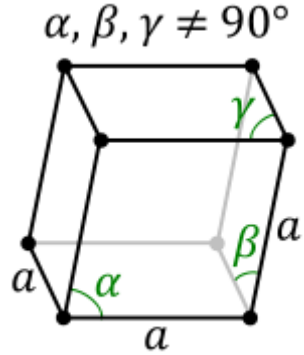


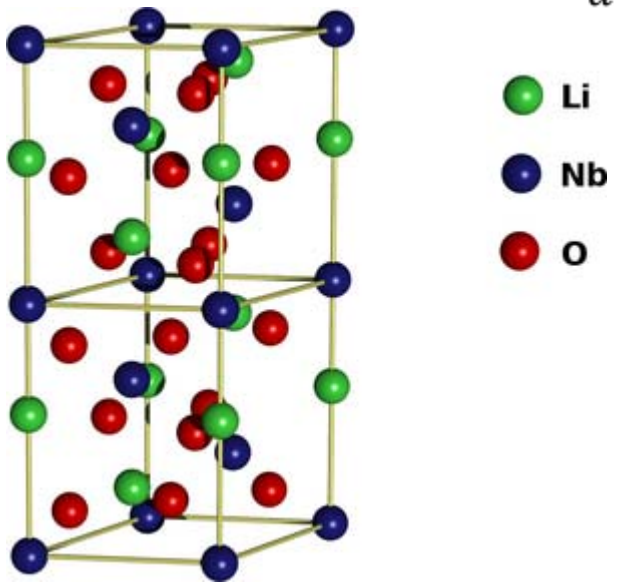
http://en.wikipedia.org/wiki/Silicon

Si density = 2.3290 g/cm³

trigonal crystal system

a=5.148 c= 13.863



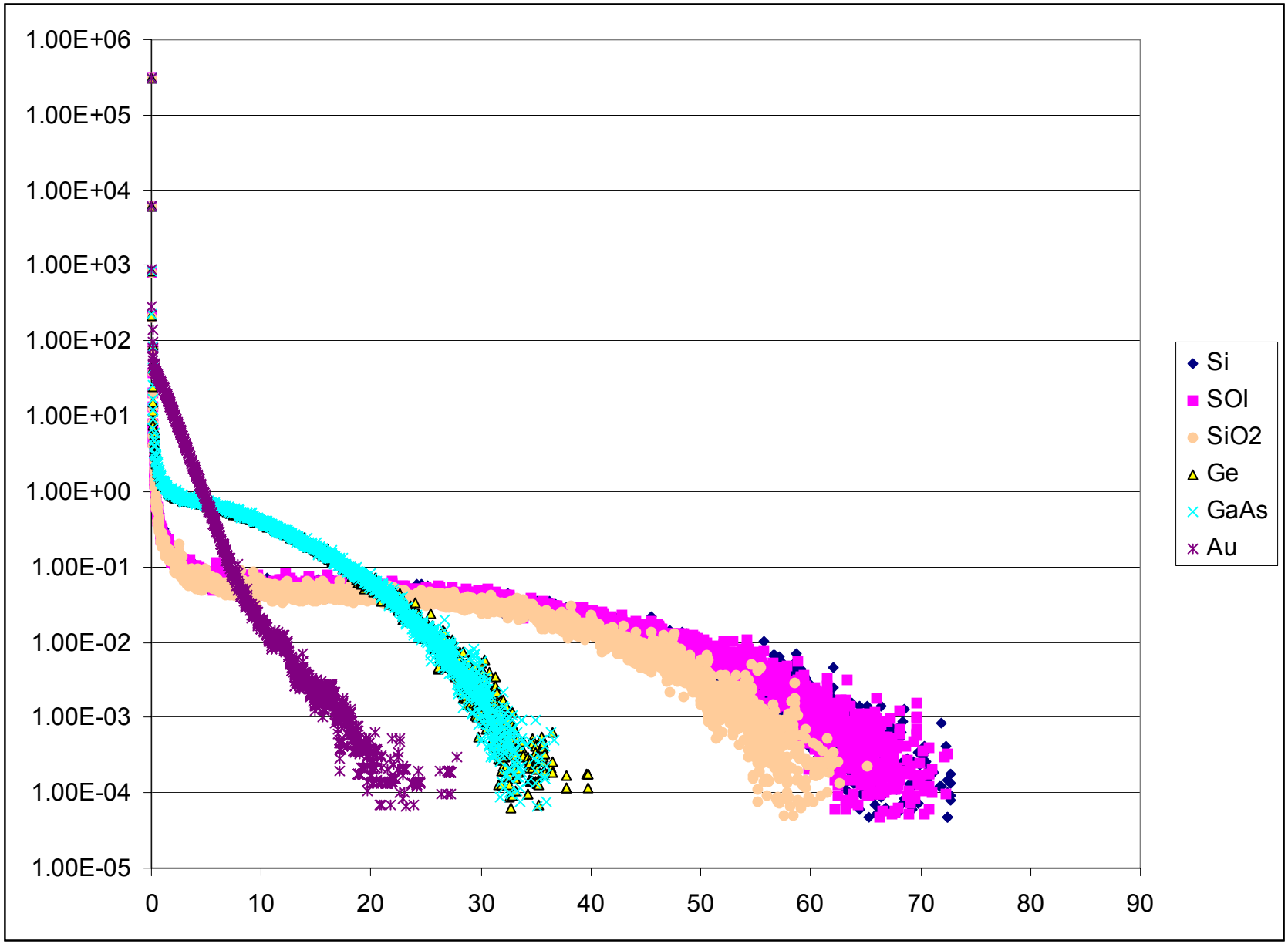


http://en.wikipedia.org/wiki/Lithium_niobate

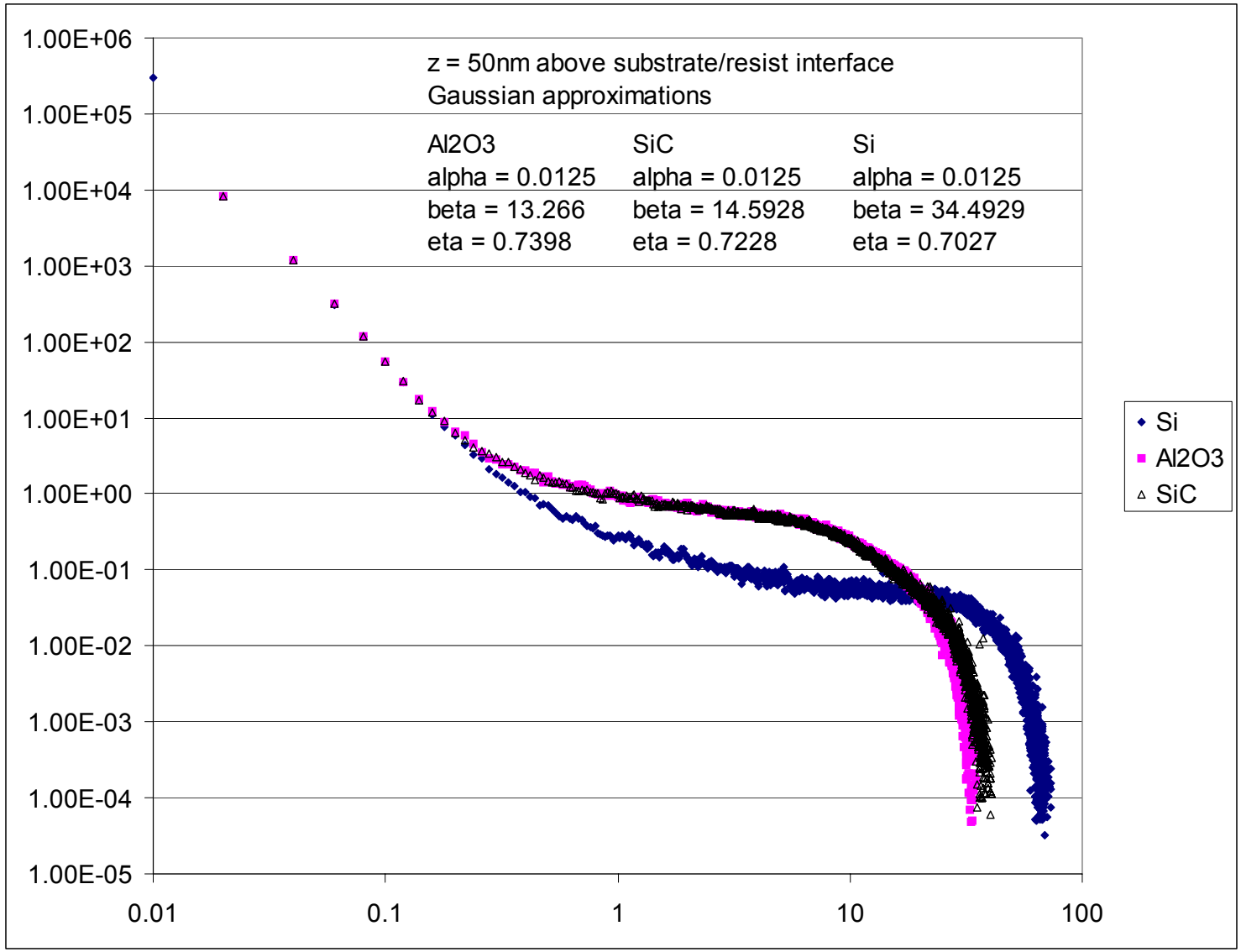
LiNbO3 density = 4.65 g/cm³

$$\frac{\text{LiNbO3 density}}{\text{Si density}} \sim 2$$

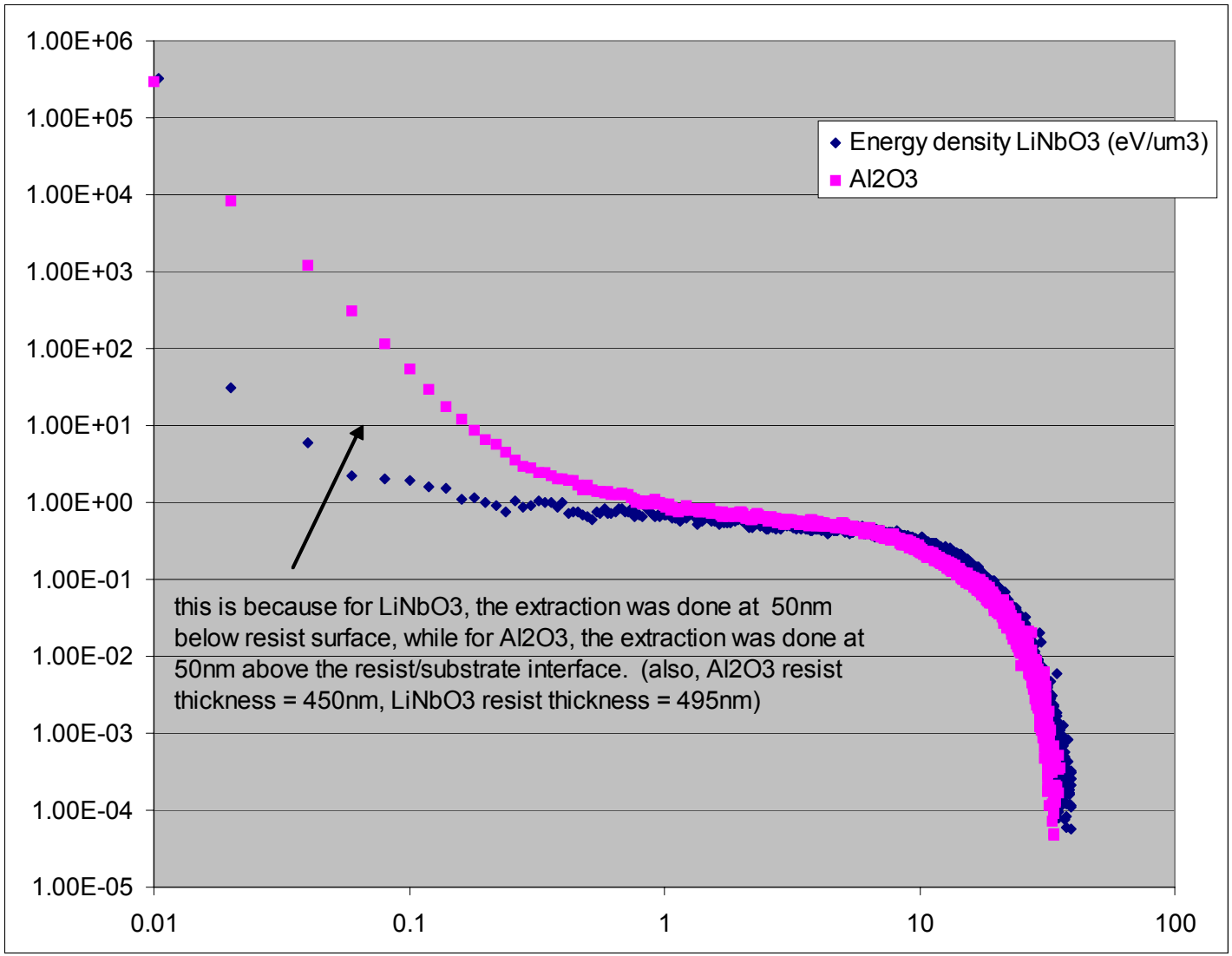
SCELETON simulation

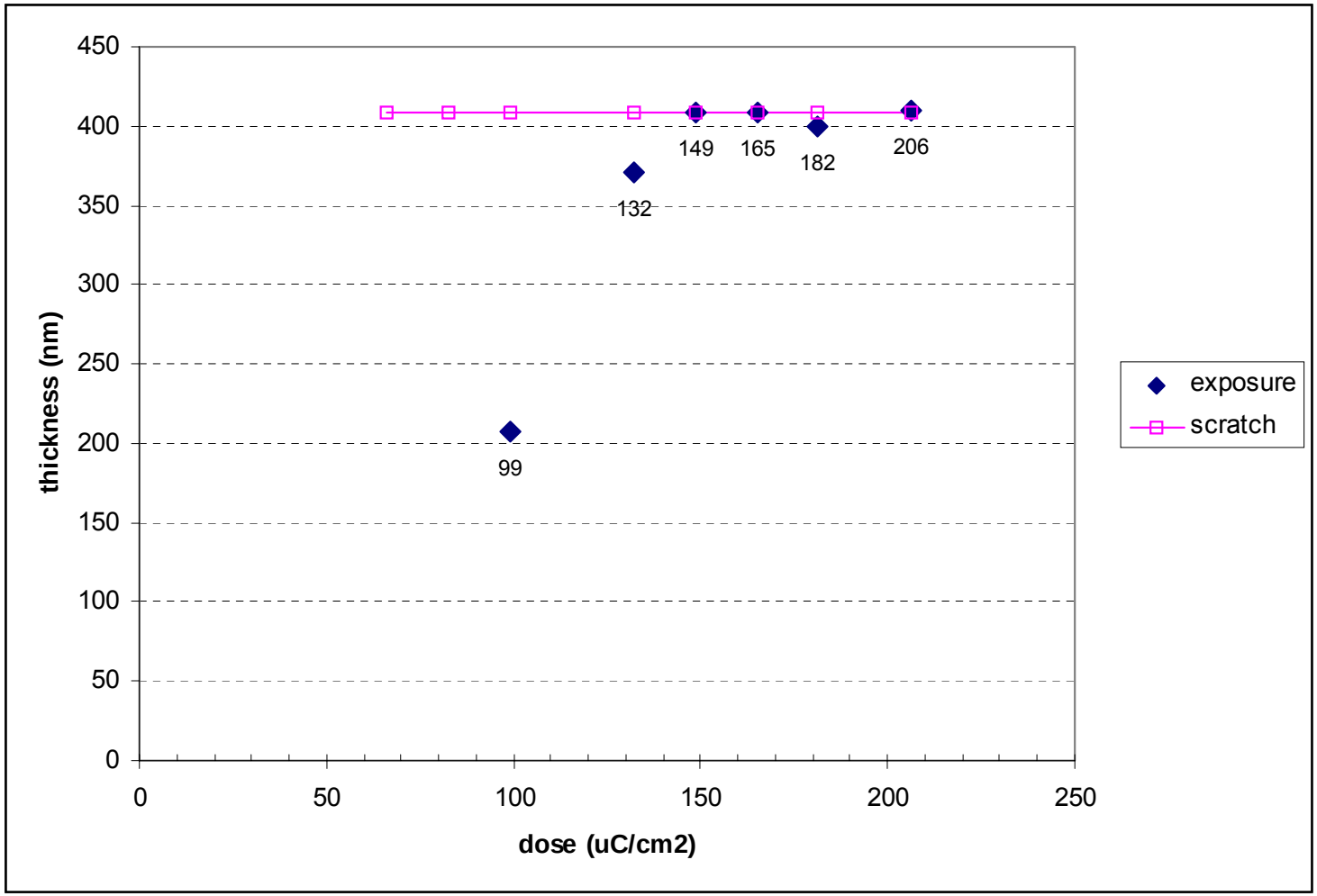


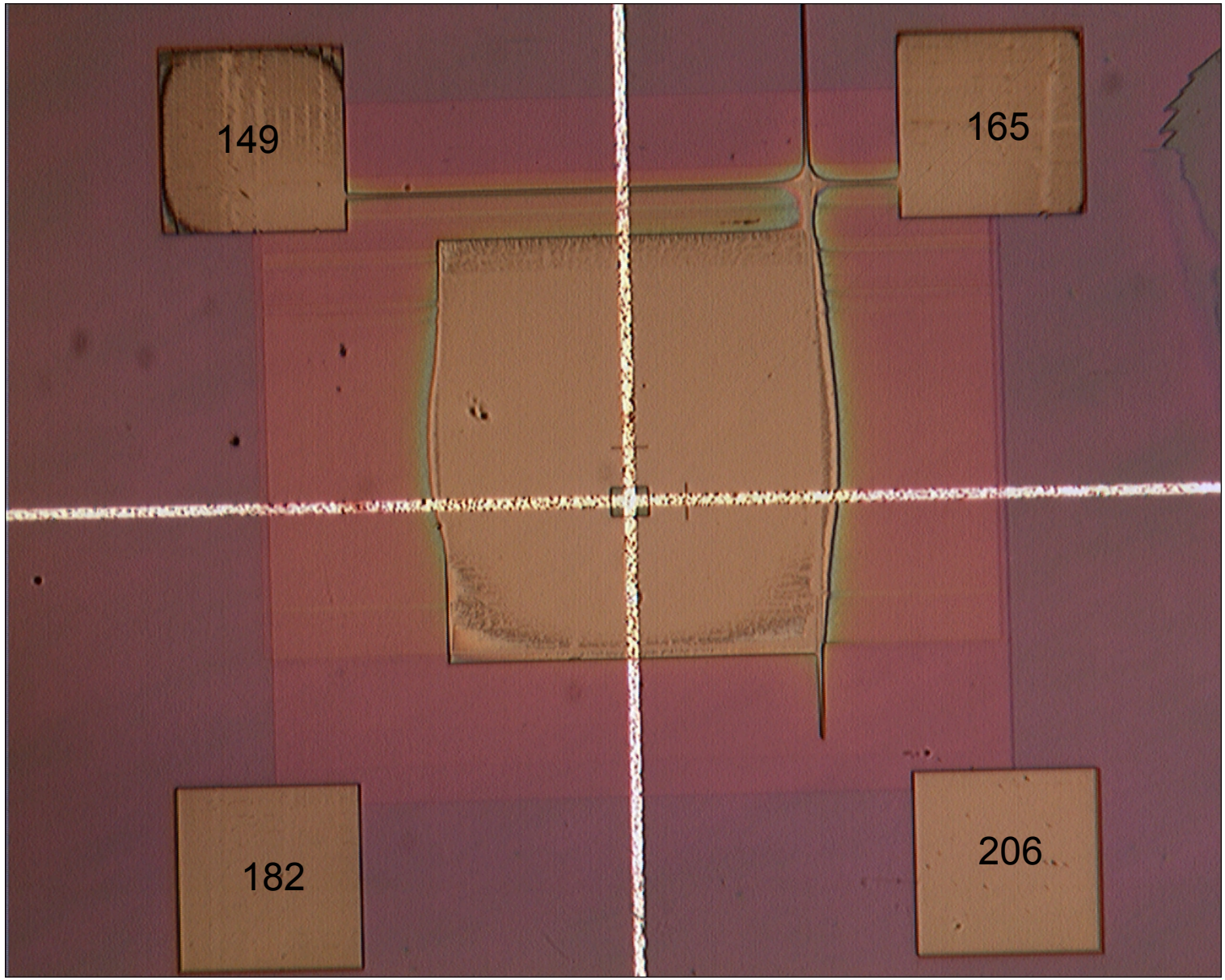
SCELETON simulation

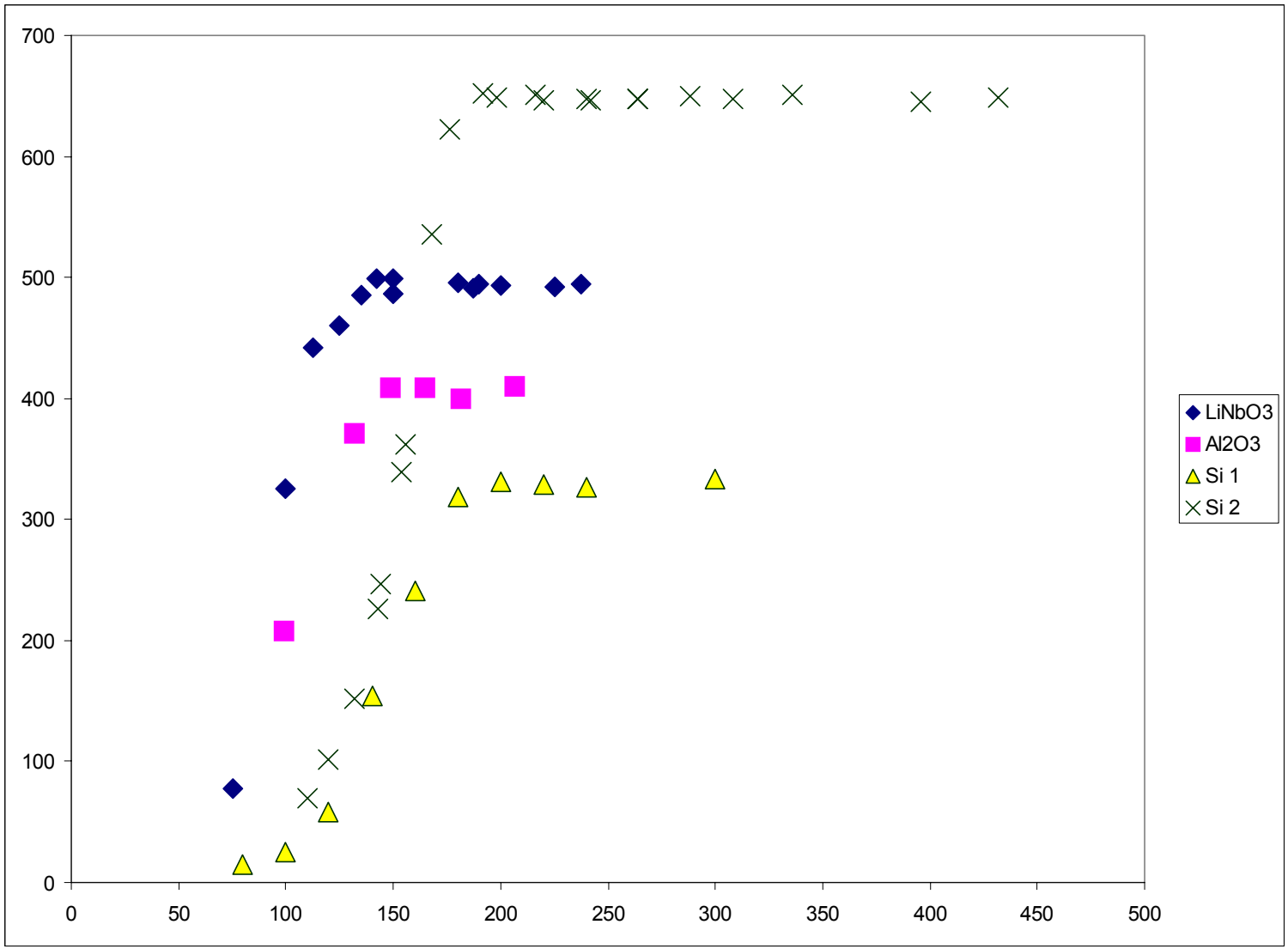


	Si	SOI	SiO_2	GaAs	Ge	Au
alpha	0.0118	0.0118	0.0118	0.0118	0.0118	0.0118
beta	33.3003	33.5357	31.7935	13.078	12.9845	2.3217
eta	0.6137	0.6748	0.5248	1.0942	1.0621	1.1596


1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
0.01
0.1
1
10
100
Energy density LiNbO3 (eV/um3)
Al2O3
this is because for LiNbO3, the extraction was done at 50nm below resist surface, while for Al2O3, the extraction was done at 50nm above the resist/substrate interface. (also, Al2O3 resist thickness = 450nm, LiNbO3 resist thickness = 495nm)


450
400
350
300
250
200
150
100
50
0
thickness (nm)
0
50
100
150
200
250
dose (uC/cm2)
149
165
182
206
132
99
exposure
scratch


149
165
182
206


700
600
500
400
300
200
100
0
0
50
100
150
200
250
300
350
400
450
500
LiNbO3
Al2O3
Si 1
Si 2