Precision Alignment of the GSD End Station

John Schuur, CTO

INNOViON, Inc.

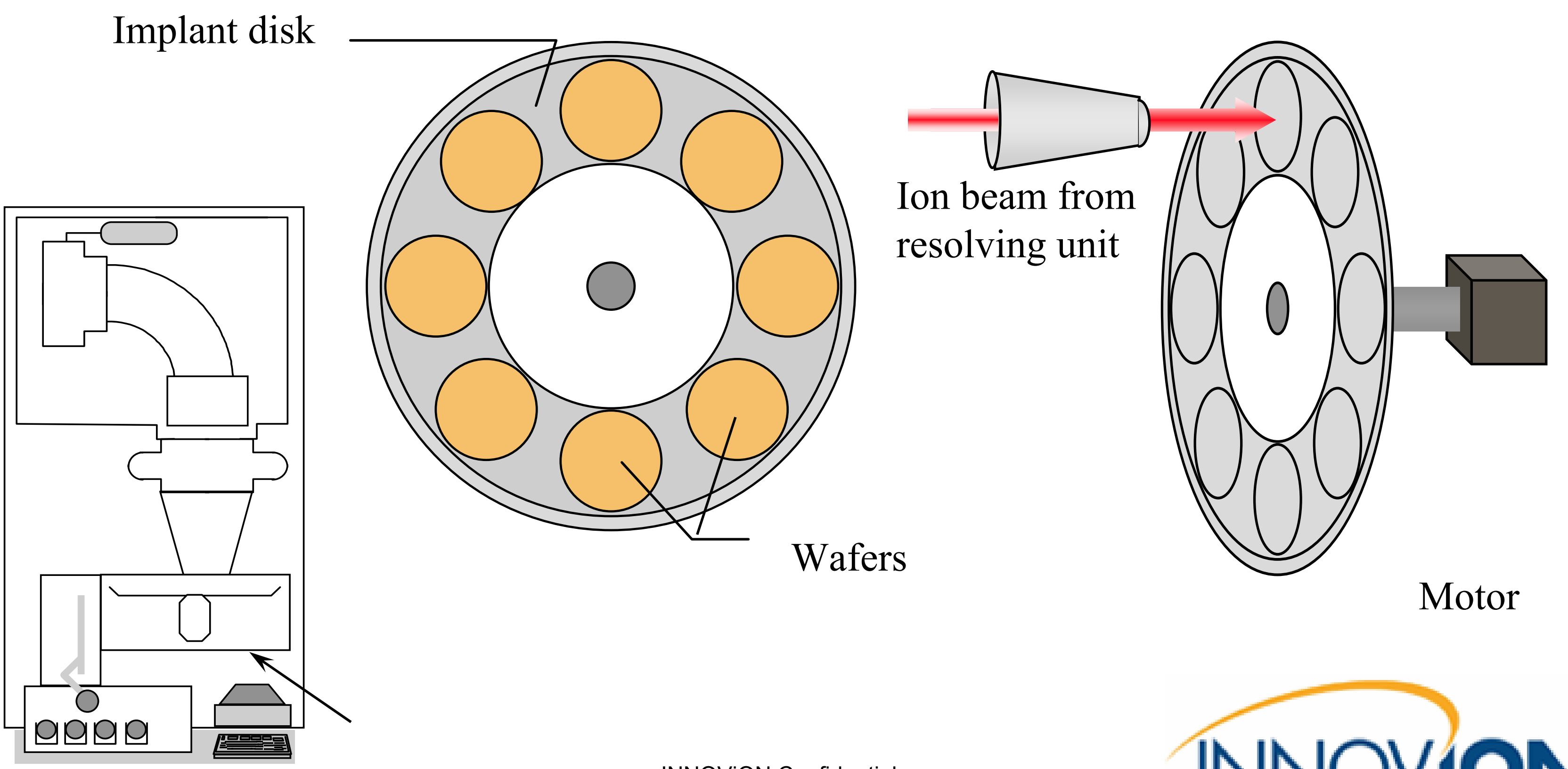
PASSS, 4/23/04

Precision Alignment of GSD End Stations

- The Incident Angle of the ion beam in batch ion implanters is determined by geometric design and the mechanical set-up of the End Station.
- This work focuses on the INNOViON method used on our Axcelis GSD-200E/E² and GSD-HE implanters but can be extended to other spinning disc batch implanters.

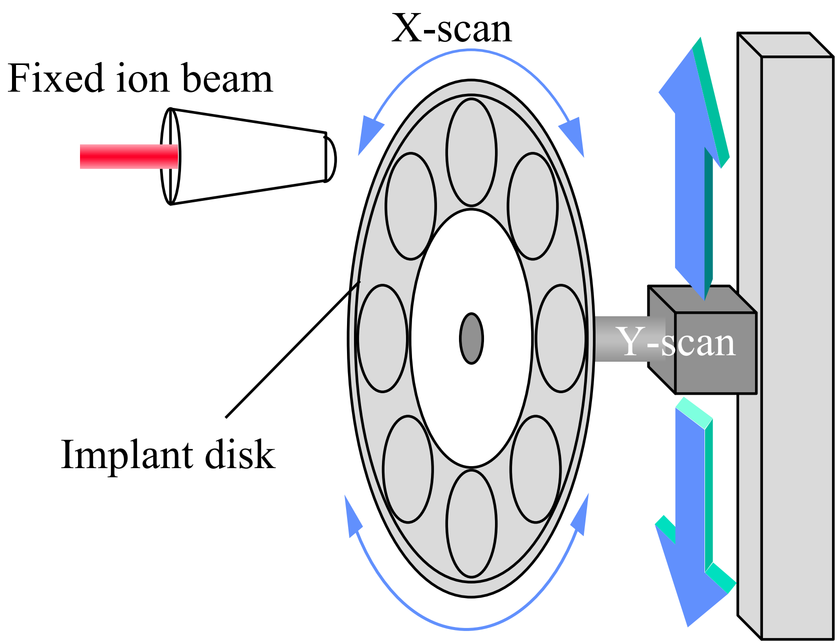
Process Chamber

- Background on the scanning system



Mechanical Scanning

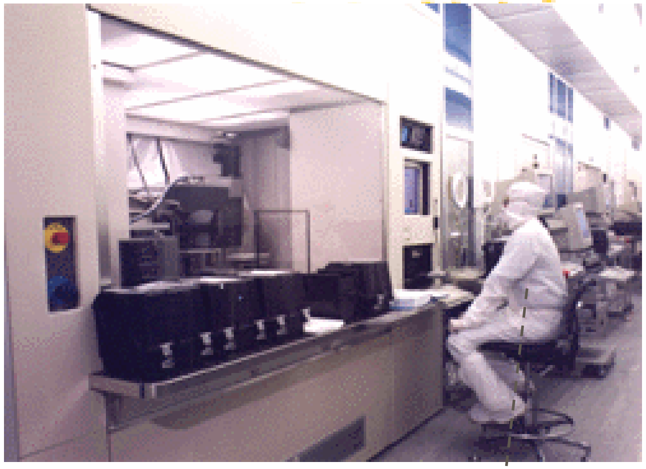
- The ion beam is fixed and the wafers are moved.



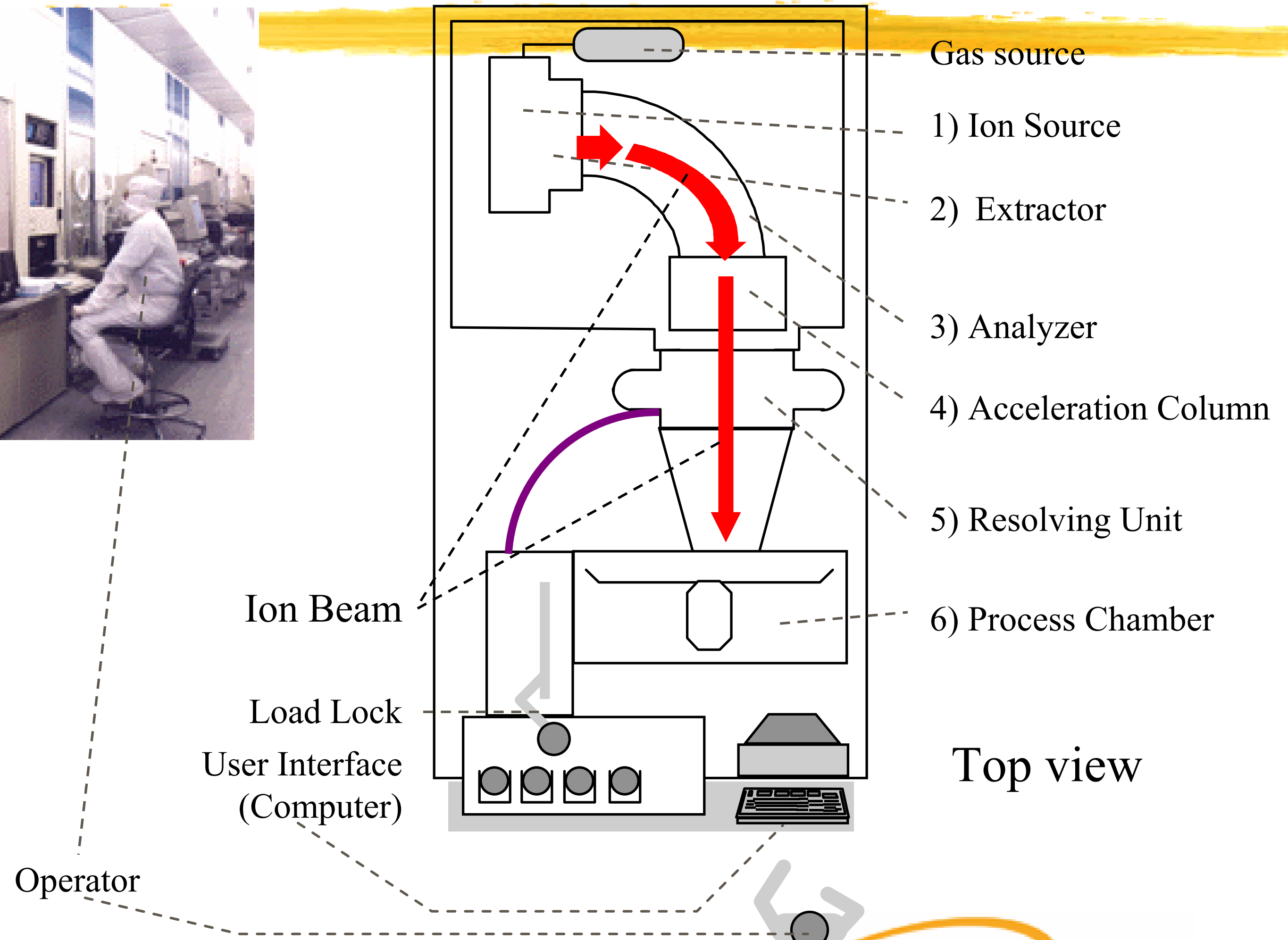
Precision Alignment of GSD End Stations

- Typical OEM tool assembly and set-up spec's assume mechanical alignment of the beamline to process chamber is sufficient to meet requirements.

The alignments in question



- Outside view



Precision Alignment of GSD End Stations

- The original OEM methods typically depend on the assumption that the ion beam is on-axis with the beamline cabinetry.
- A more accurate alignment method can be employed using test wafers and either sheet resistance or Thermawave measurement to determine and correct angle offsets in the End Station and the wafer crystal.

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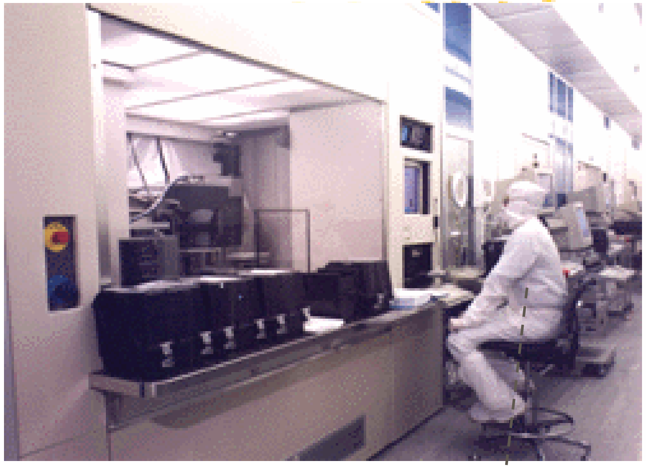
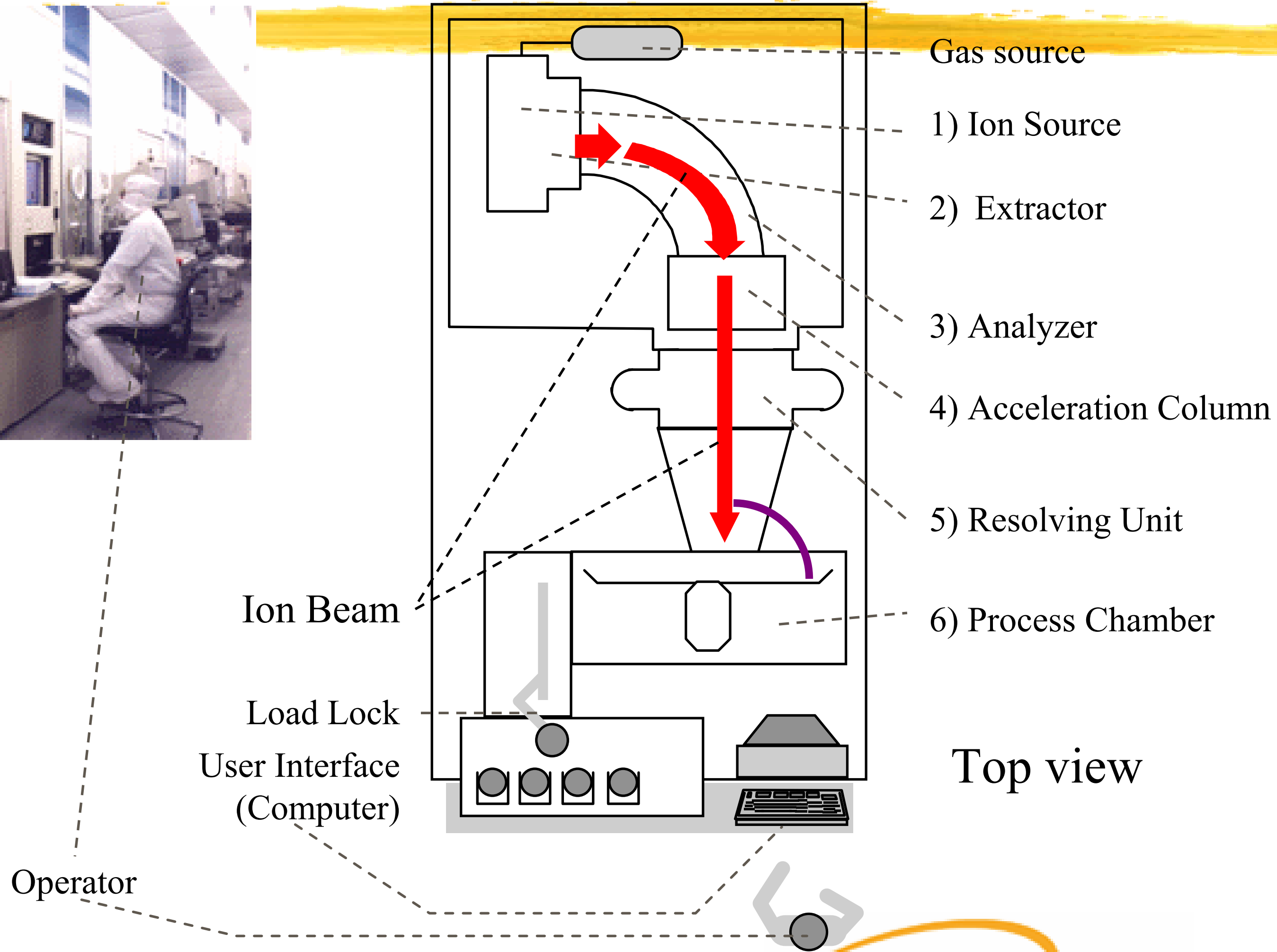
The alignments in question



- Outside view



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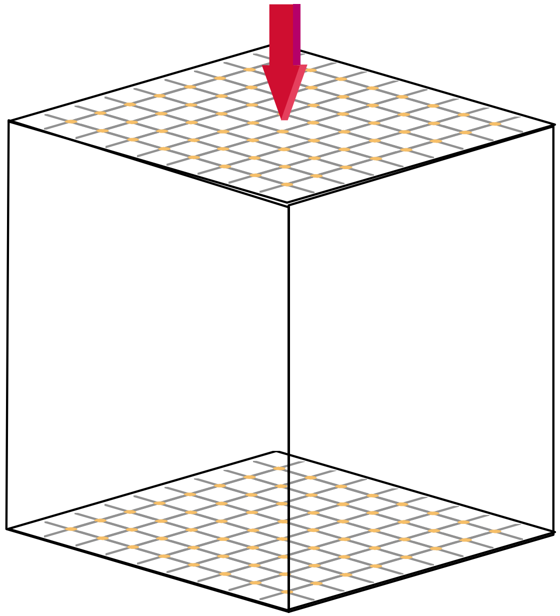
Precision Alignment of GSD End Stations

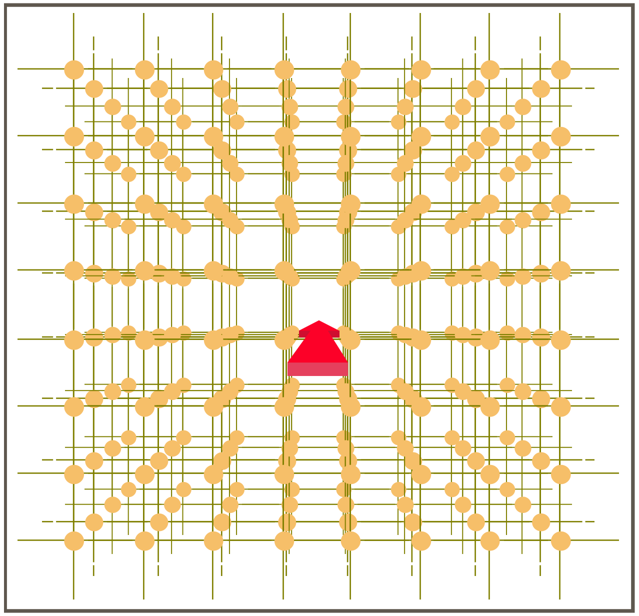
- For this purpose we actually capitalize on a small variation in angle of incidence known as cone angle. Essentially we turn what is normally a negative into an advantage for the characterization.

Channeling

- In single crystal lattices there are some directions in which the ions can go for long distances without hitting atoms in the lattice.

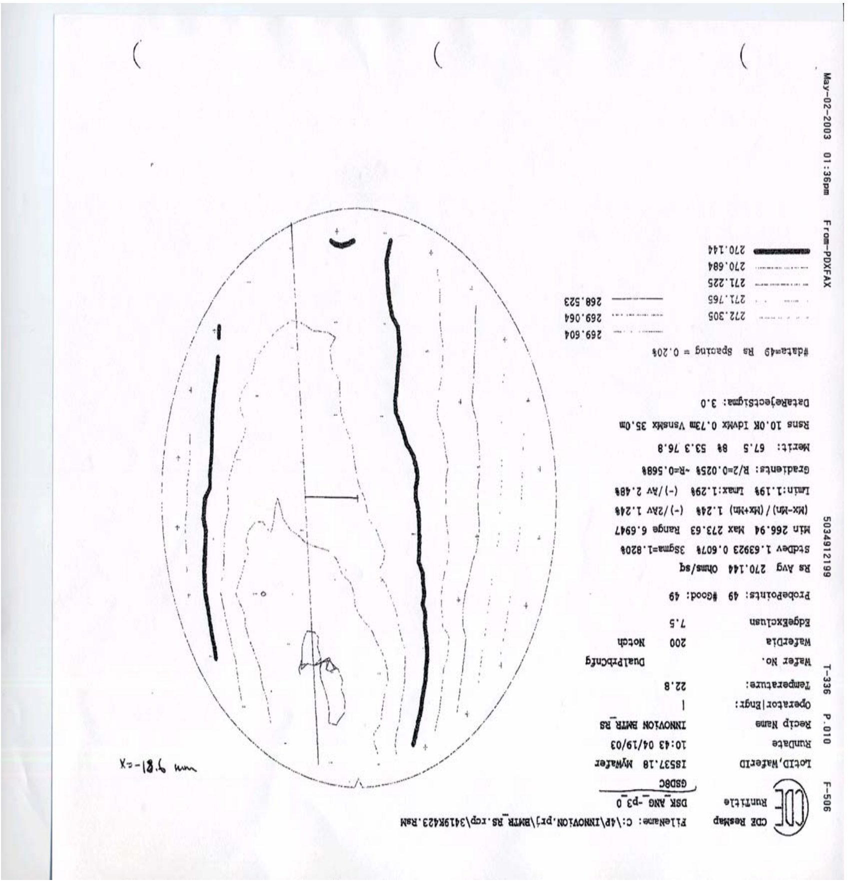


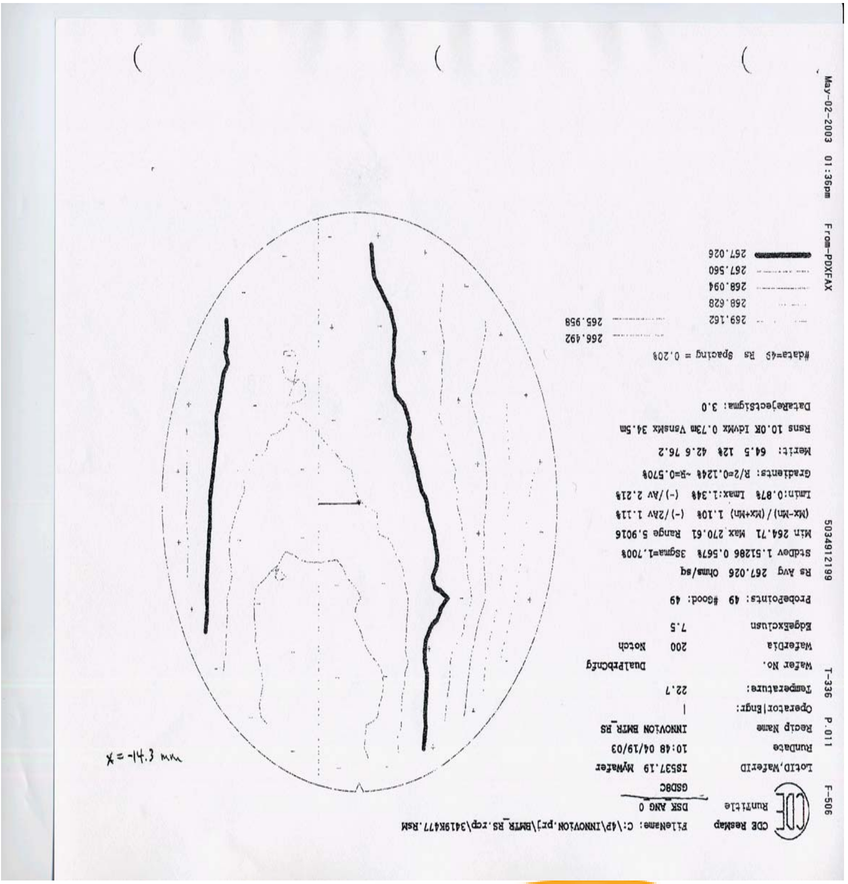
Single crystal



Top view

Channeling effect on sheet resistance (caused by cone angle)





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Statement of the problem

- A comparison of this method to the OEM (initial) alignment technique shows a large advantage.

PDX Tool Alignment Results

TOOL	α	β	Comments
HE8A			
Initial Reading	0.24	0.03	
1st post adjust	-0.10	0.40	Initial data is questionable
		0.30	Repeat measurement for B
2nd post adjust B only		-0.04	
FINAL	**-0.10**	**-0.04**	
HE8B			
Initial Reading	0.51	0.32	
1st post adjust	-0.30	-0.09	
	-0.12	-0.09	Repeat measurement for α & β
2nd post adjust a & b	0.13	0.03	
3rd post adjust a only	-0.07	0.03	
FINAL	**-0.07**	**0.03**	

Statement of the problem

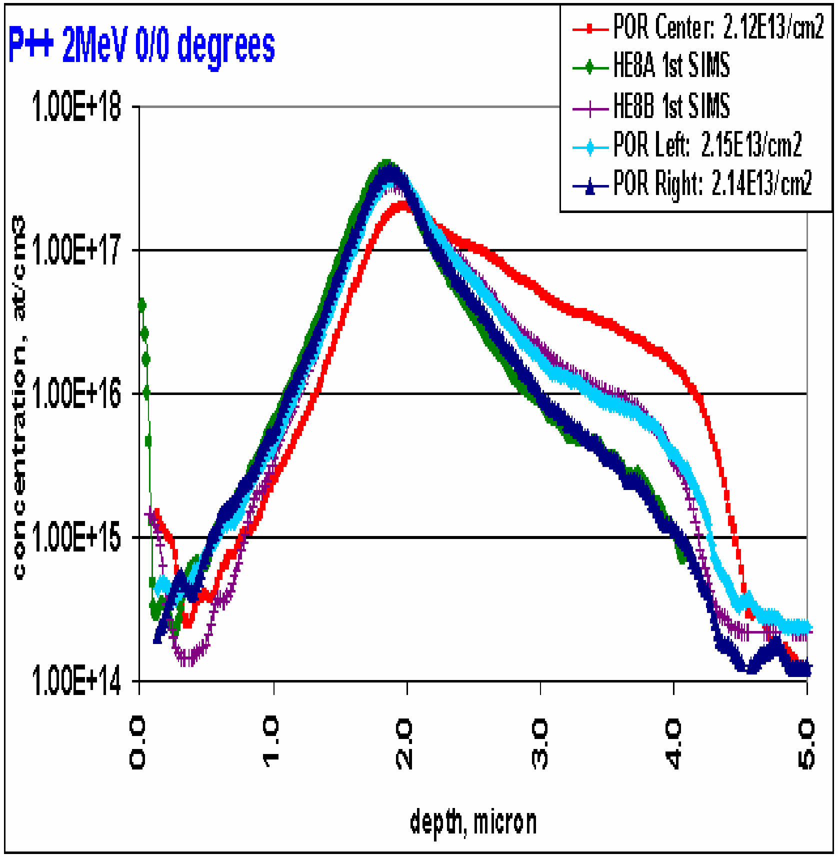
- Why Worry????
  - After all in a lot of cases one might not care.
    - Insensitive to channeling on all implants-
      - Pre-amorphized substrates
      - In-situ amorphization sufficient to control all effects
      - Screen oxide sufficient to control all effects
      - Proper selection of implant angle to minimize variation
      - Tolerant devices or implant conditions such as low KeV

Statement of the problem

- Why Worry????
  - Because cone angle effects force at least 1.1° angle of incidence variance at edges of 0° degree implants sometimes this variation makes tight control of limited value.
  - At other times cone angle effects can be worsened by "error stacking" and offsets can affect matching analyses etc.
  - What follows is an example of the profile changes caused by these small changes in angle that can in turn affect device parameters.

Statement of the problem

- A 2 MeV Phos implant showing misalignment of the end station as an uneven cone angle effect.
- The difference in profiles as a function of wafer position consumes parametric spec width, potentially decreasing yields.



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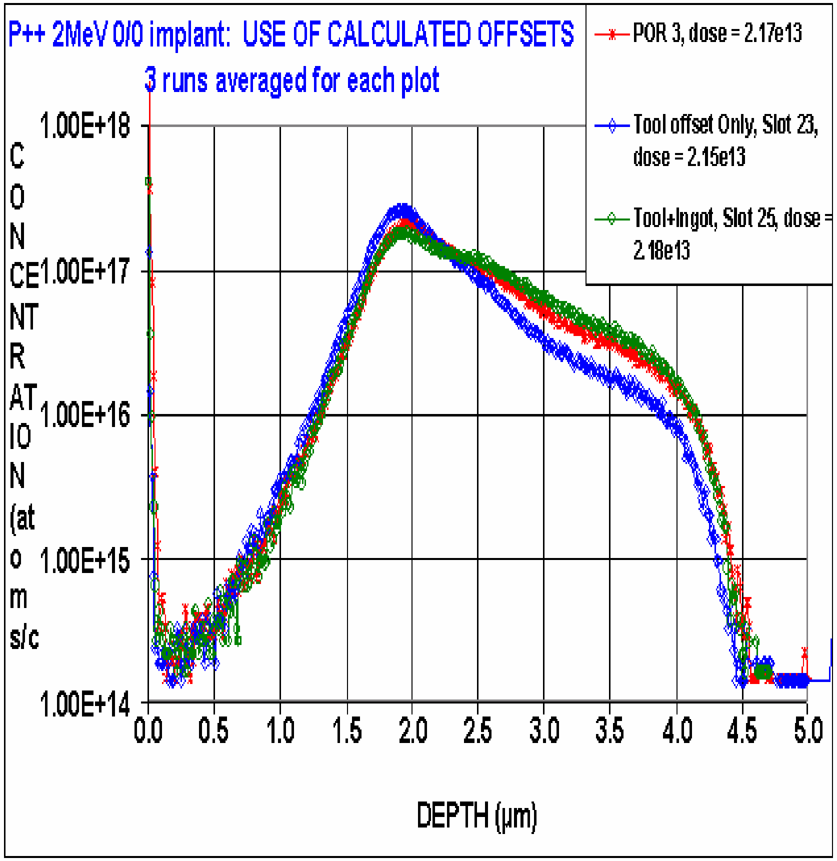
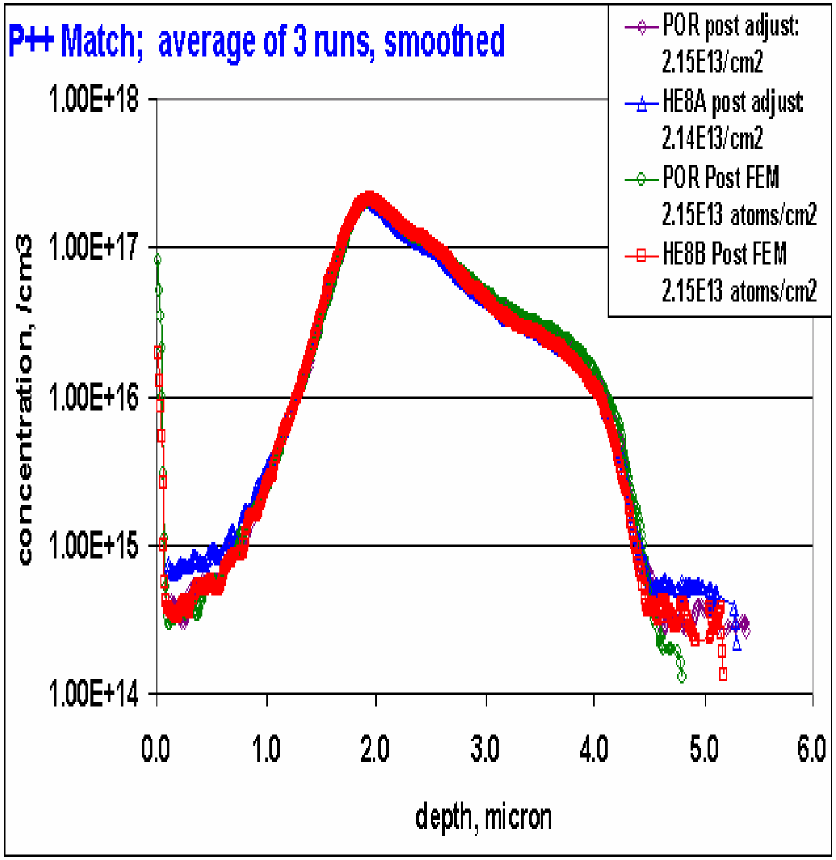
Statement of the problem





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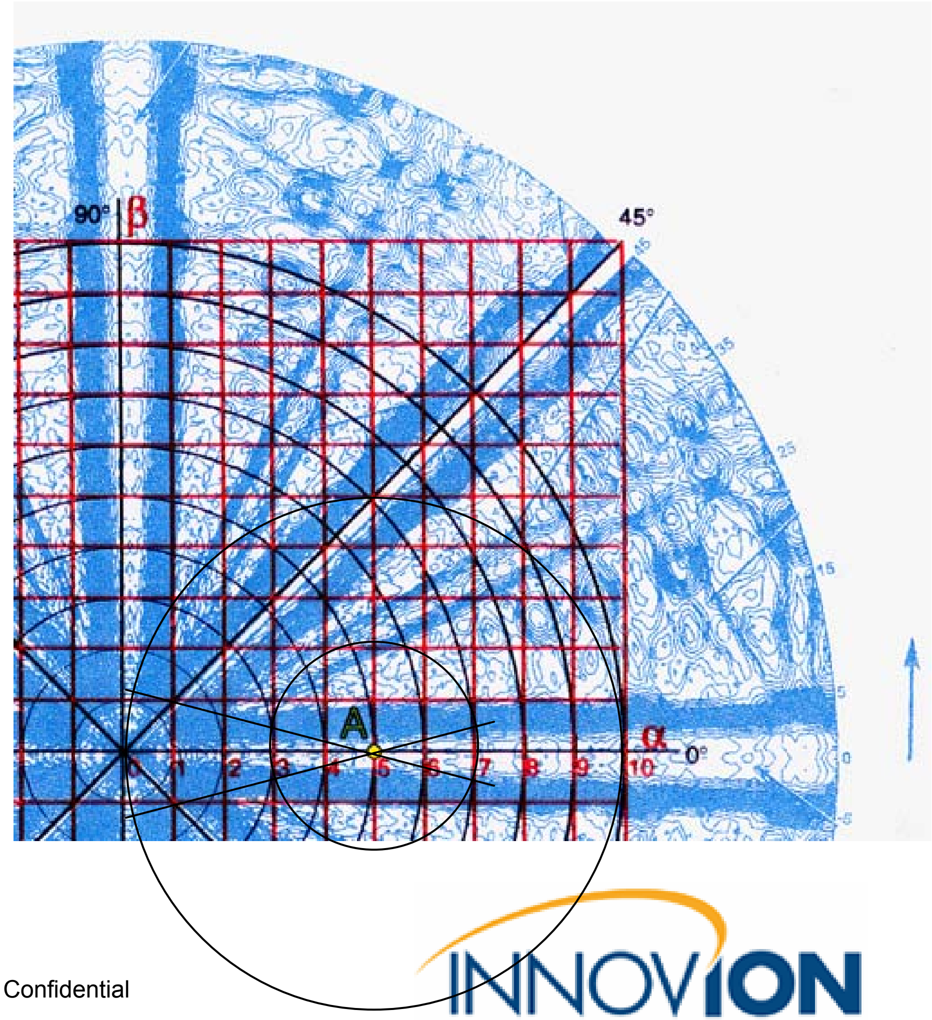
Statement of the problem

- A 0.5 degree Beta misalignment can be a significant influence on a simple 7/0 implant. The change in the position of either axis of the Ziegler channeling plot by +/- 0.5 deg. can bring a number of additional contour lines into one side of the wafer.



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Statement of the problem

- Besides, not worrying is never a real option.
  - Reasons that one might require more precise control:
    - There are devices that have particular sensitivity to features in implant profile that are affected by small changes in angle of incidence.
    - Improper alignment may affect understanding of results of matching studies of multiple implanters depending on conditions used.
    - Process integration issues-
      - may force otherwise undesirable angle choices
      - may preclude screen ox

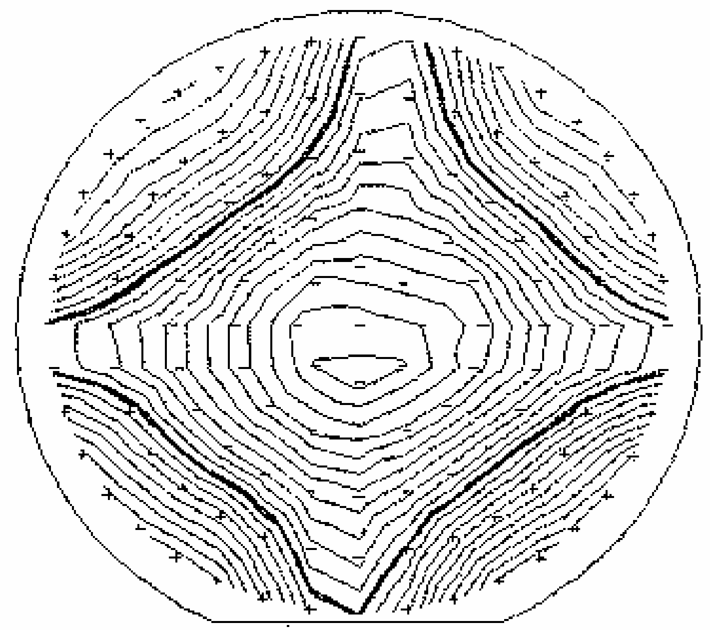
Statement of the problem

- What are the issues and their importance?
  - Generally the sawing of ingots is to a 0.5 degree crystal orientation spec for the bulk of 200mm and smaller wafers - “but” - there is a tighter spec for advanced processes.
  - Silicon vendors have been supplying material to advanced customers to specs as tight as 0.1 - 0.2 degree crystal orientation for some time.
  - VIISta 80 and SWIFT product designs were driven by customer requirements for incident angle control.
  - GSD movement is in 0.10 deg. Increments.

Statement of the problem

- Instead of worrying - be correct!!! (be happy!!!)
  - Matching of tooling is best achieved without the interference of confounding channeling effects.
  - Narrowed distributions of parametric values can improve the circuit manufacturer's profitability by allowing refined targeting of parametric values.
- This approach requires careful consideration of the silicon to be used.
  - Characterize both "alpha and beta" for crystal.
  - Understand saw lot vs. ingot & impact of inversion of the wafer before polish.

Origin of Method



- Medium Current alignment
- 0/0 Degree confirmation
- Principles extracted by Sing*
- and applied to GSD-HE
- Method requires either
- extremely accurate crystal
- or compensation for wafer orientation
- Our method uses sheet resistance vs. t-wave
- *(ICON '99)

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Basis of Method; Introduction

- GSD End Stations provide 2 orthogonal tilt axes for wafer orientation: alpha, beta
- The dual tilt axes provide a flexible and useful framework for exploring crystal alignments
- Alpha tilt corresponds closely to conventional tilt
- The beta tilt is a left-right motion relative to the wafer notch; notch normally points to disk center
- Manipulation of conventional wafer twist orientation coupled to alpha/beta allows for accurate determination of Crystal and End Station angle offsets.

Processing Conditions and Ingot Characterization

- Process 1 wafer at each of 90′, 180′, 270′ and 0′ with alpha = beta = 0. Anneal, probe and print contour map.
- Process: $^{31}P^+$, 120 keV, 1.34E14 (chosen for a known sensitivity to concentration effects on mobility)
- Maps are then oriented so that the notch is in same location as when wafer was implanted
  - notch down = 0′, notch up = 180′
  - notch right = 90′, notch left = 270′
- As is common with 0′/0′ implants, a channeling valley is evident in sheet resistance plots

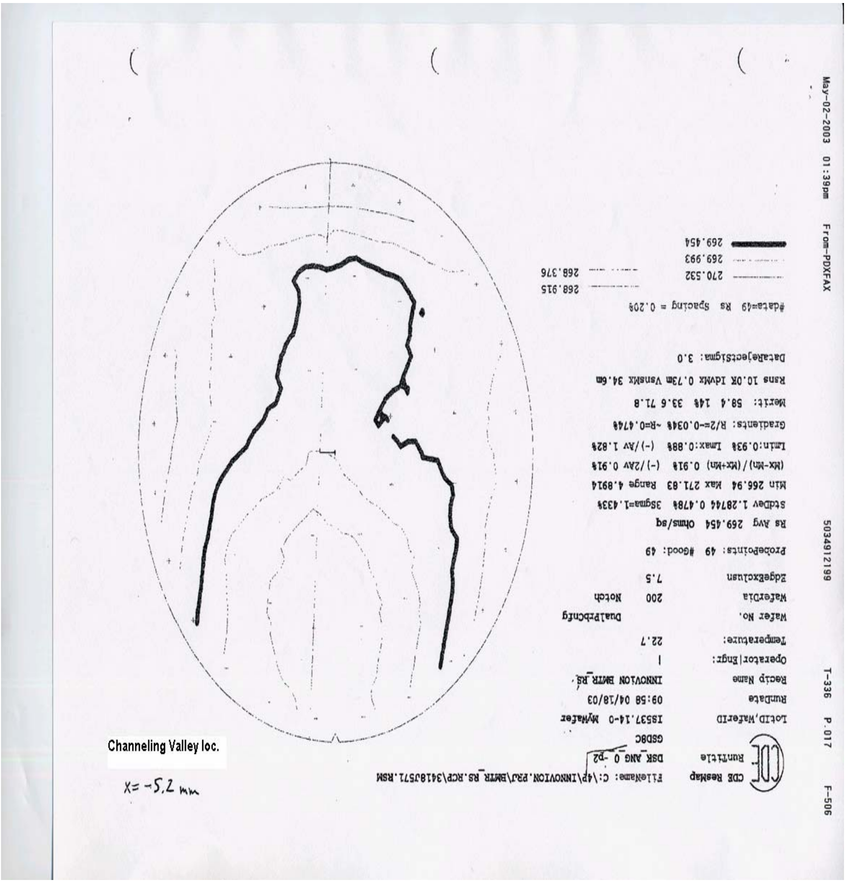
Basis of Method; Rs interpretation

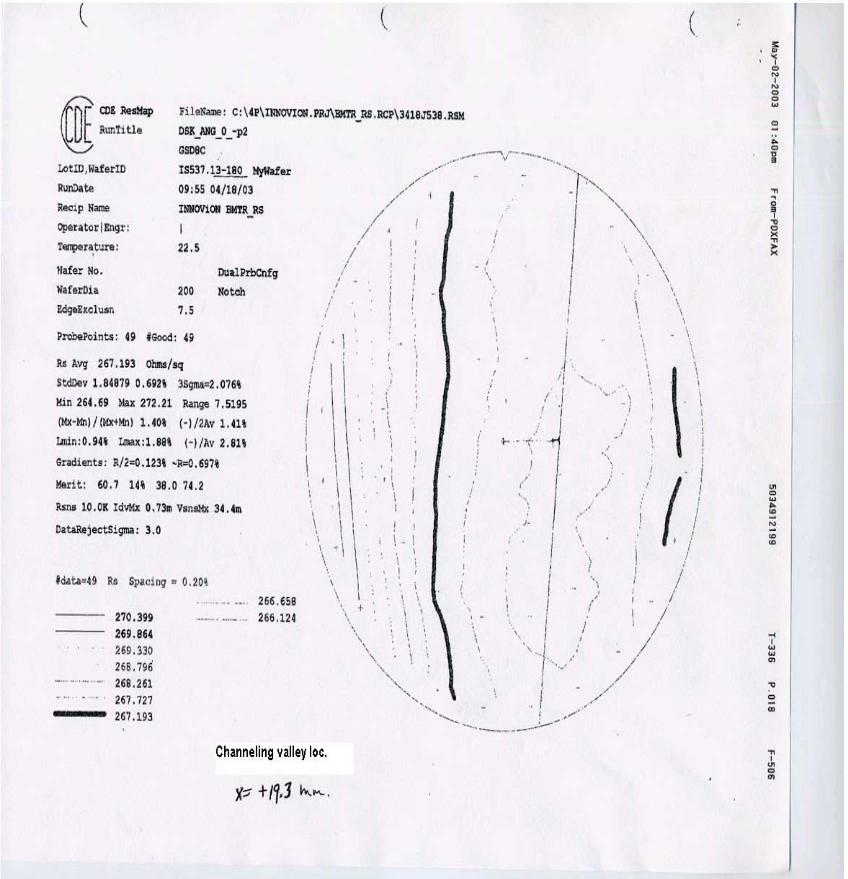
- The offset from the valley center to wafer center is measured
- Offsets to right of center are counted as positive and to the left as negative
- For a 200 mm wafer processed on a GSD End Station, the radius corresponds to 1.1° beta offset due to cone angle effect
- Angle offset = 1.1° * [measured offset(mm) / measured radius(mm)]
- Label the calculated offsets as: f(0°), f(90°), f(180°), f(270°)]

Basis of Method; Angle Relations

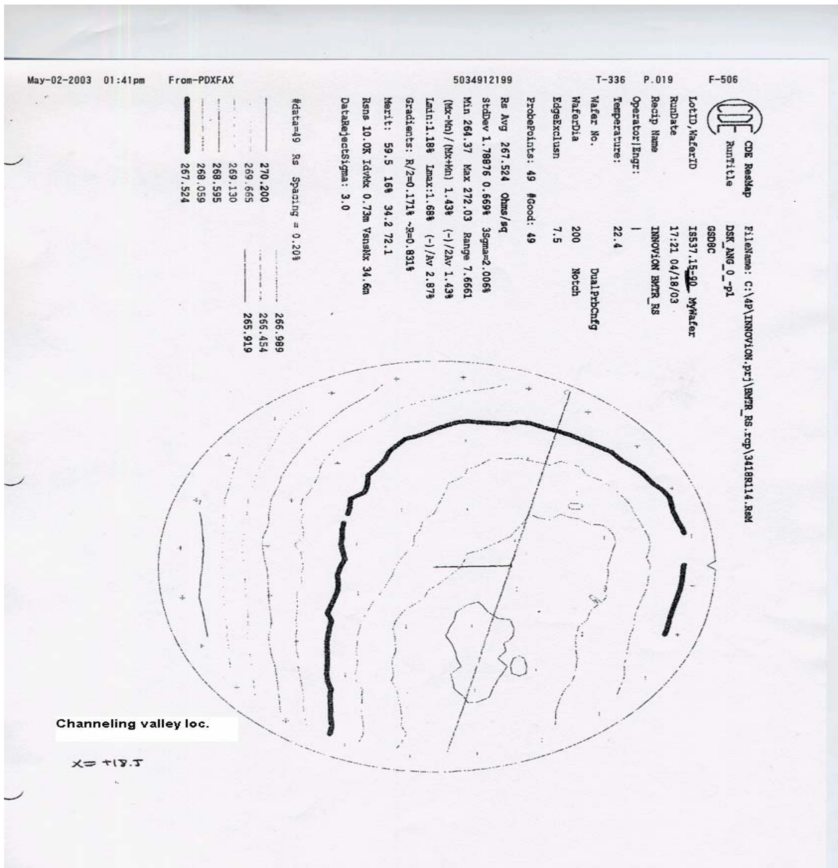
- Wafers see both End Station and crystal offsets in alpha and beta
- Data from the four wafers, arranged as wafer pairs allow for subtracting out and averaging the offsets
  - These four wafers can determine Crystal beta, Crystal alpha and End Station beta:
  - 0° wafer: $f(0°) = \beta_{ES} + \beta_C$, 180° wafer: $f(180°) = \beta_{ES} - \beta_C$
  - 90° wafer: $f(90°) = \beta_{ES} + \alpha_C$, 270° wafer: $f(270°) = \beta_{ES} - \alpha_C$
  - $\beta_C = ½ * [f(0°) - f(180°)]$, $\alpha_C = ½ * [f(90°) - f(270°)]$
  - β_{ES} = average $[f(0°) + f(180°) + f(90°) + f(270°)]$
- Determination of End Station alpha is accomplished with a series of wafers processed with alpha increments, employing adjustments from the first four wafers and interpolating angle for Rs minimum

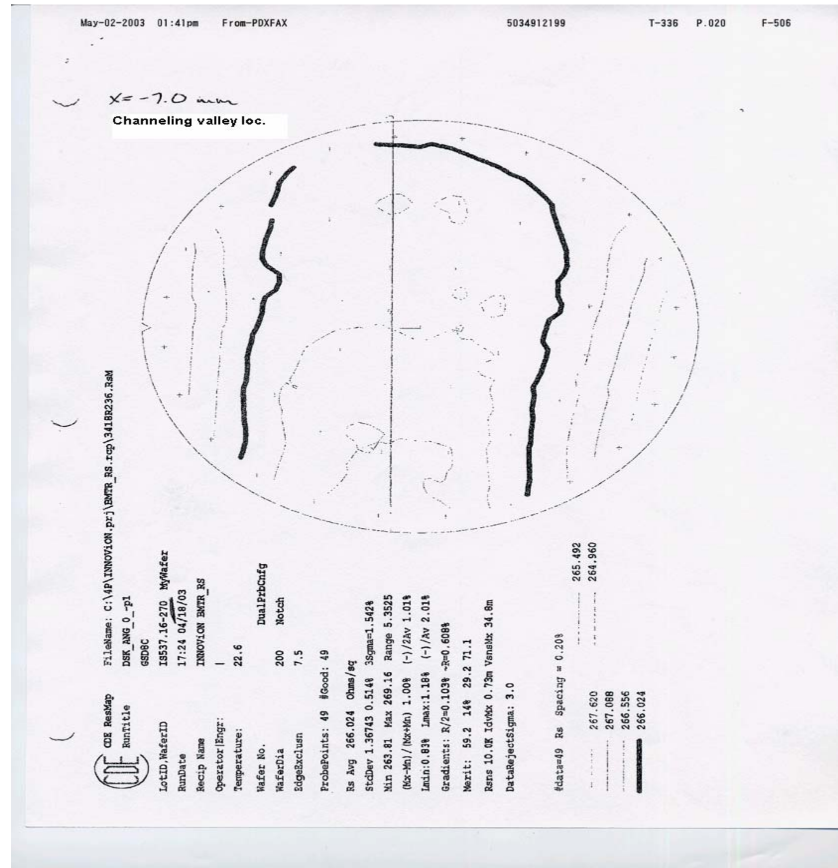
0 deg. & 180 deg. Ingot test and initial beta angle test samples





90 deg. & 270 deg. Ingot test and initial beta angle test samples





Ingot test and initial tool beta angle measurement

Initial Crystal and machine ß offset data

Equip ID: PDX GSD8C 4/18/2002 js

Method: (1) With (α,ß) set to (0,0), run a wafer at each of the following 4 twist (notch alignment) settings (0, 90, 180, 270).

(2) Anneal and measure wafer on the CDE (recipes: ENGR/ANGLE).

(3) Determine the Rs minimum contour and measure its distance from the wafer center (to be converted to units of radii later).

(4) Calculate $ß_C$ and α offsets using (0,180) and (90,270) pairs, respectively and the $ß_{ES}$ offset using the same pairing of data and formulae (a) and (b).

Formulae: (a) $ß_C$ offset = (x1-x2)/2
(b) $ß_{ES}$ offset = (x1+x2)/2
assuming x is in units of wafer radii and 1 wafer radius is approximately 1.1° of cone angle.

Calcs:

	α	ß	T	X, Rs min, mm	x, Rs min, °	$ß_C$ and $α_C$ offset, °	$ß_{ES}$ offset, °
x_0	0	0	0	-5.2	-0.08	-0.194	0.112
y_{90}	0	0	90	18.5	0.29	0.202	0.091
x_{180}	0	0	180	19.3	0.31		
y_{270}	0	0	270	-7.0	-0.11		

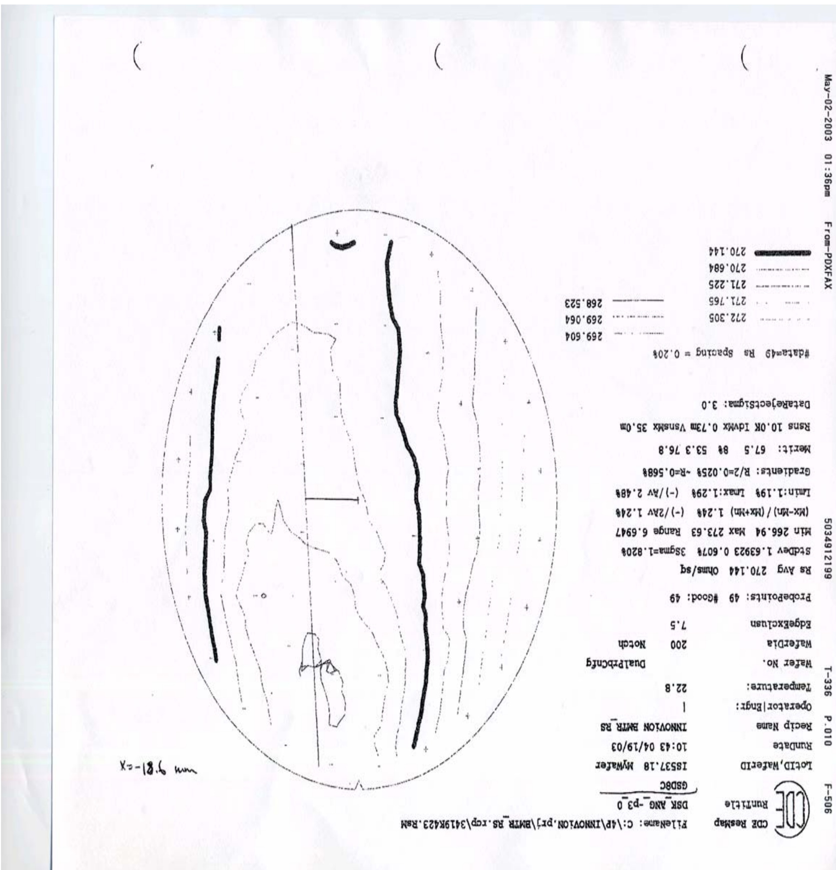
69.5 <==Measured radius of contour map, mm

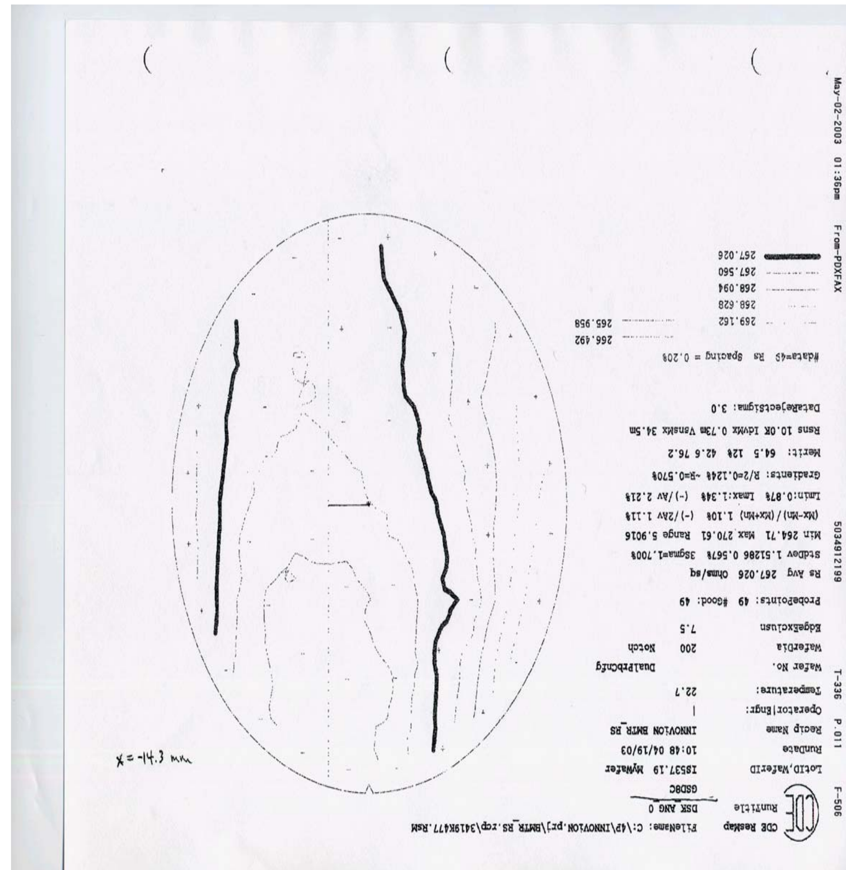
0.10 <== $ß_{ES}$

Conclusion: (1) Beta of 0.10 is acceptable.

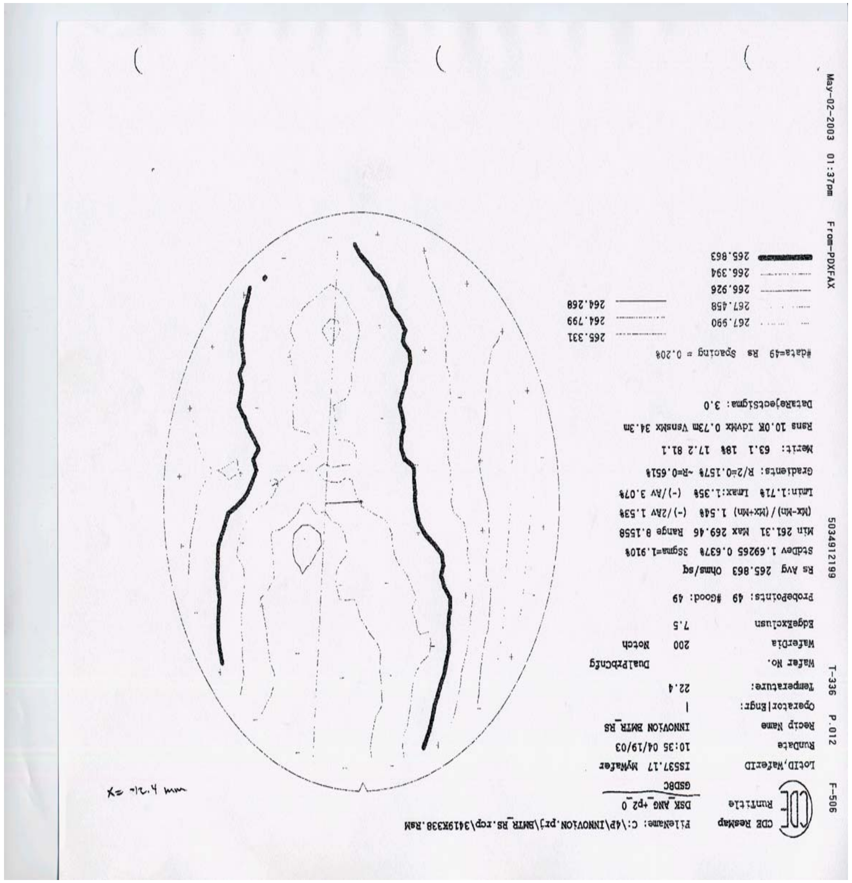
(2) Ingot offsets, $α_C$ and $ß_C$ are also acceptable.

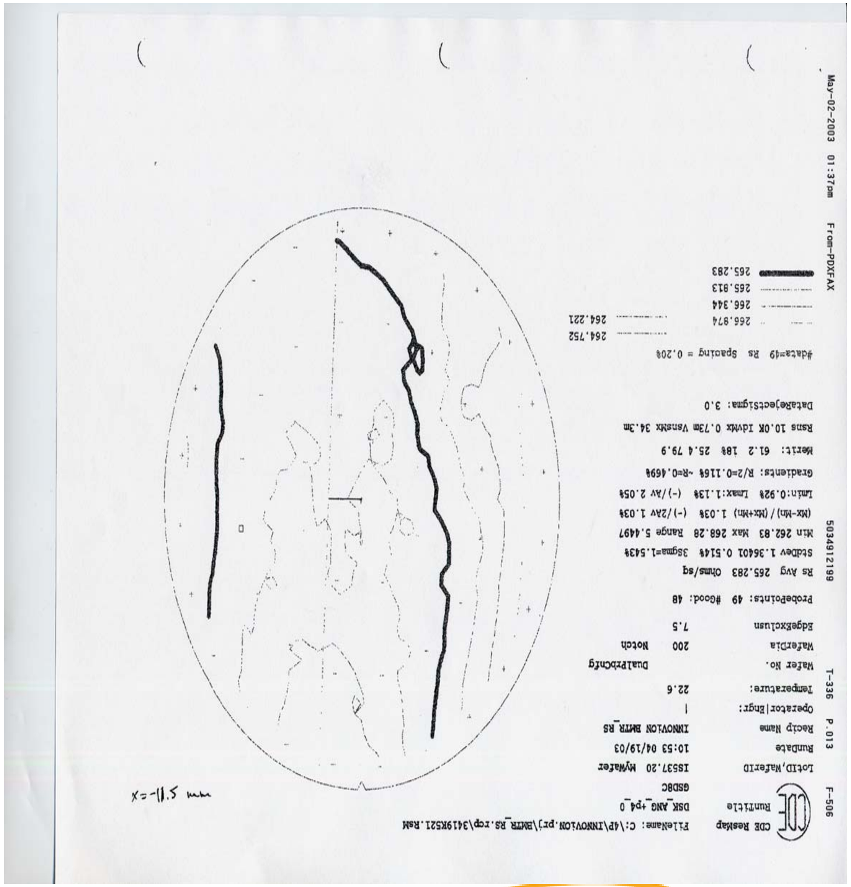
Initial E.S. Alpha characterization and post Beta adjustment data



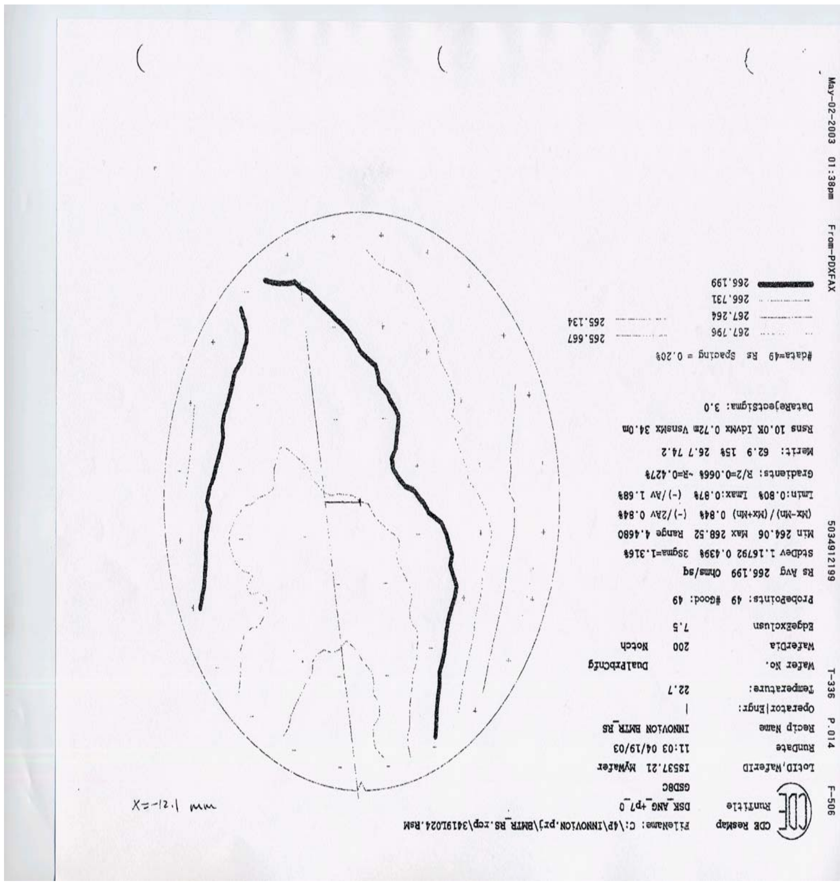


Initial E.S. Alpha characterization and post Beta adjustment data





Initial E.S. Alpha characterization and post Beta adjustment data

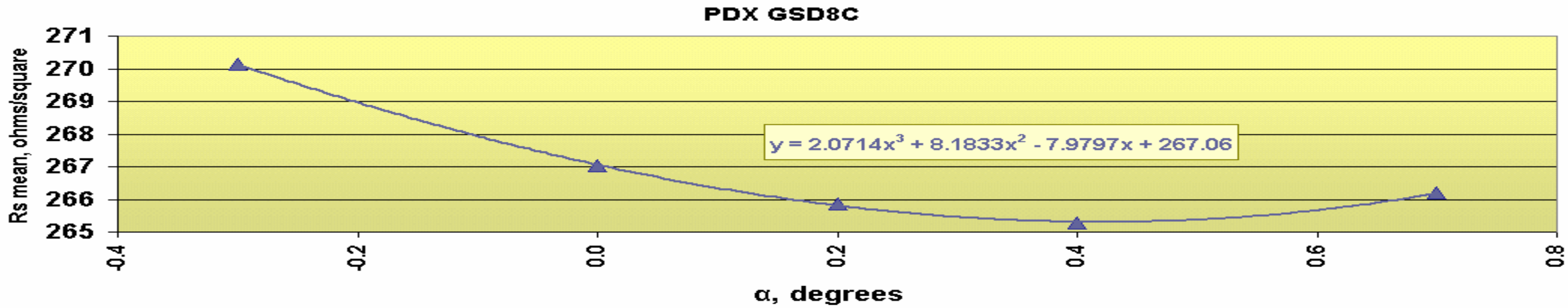


- Beta measurement consistent across the 5 separate wheels processed
- Adjustment successfully reduced incident angle
- Sheet res. trend for the 5 samples is well behaved and allows tool alpha offset determination

Initial E.S. Alpha characterization and post Beta adjustment data

α_{ES} **Determination** | PDX GSD8C | α ==> (α_C, ±0.4, ±0.8); β = (β_C+β_{ES}); T = 0 | {enter date here} | MSM

RECIPE	α	ß	T	Rs Mean	%SDev	X, Rs min, mm	x, Rs min, °	Implied β_{ES}
DSK_ANG_-p8_0	-0.3	0.0	0	270.14	0.61	-18.6	-0.29	-0.10
DSK_ANG_-p4_0	0.0	0.0	0	267.03	0.57	-14.3	-0.23	-0.03
DISK_ANGLE_0	0.2	0.0	0	265.86	0.64	-12.4	-0.20	0.00
DSK_ANG_+p4_0	0.4	0.0	0	265.28	0.51	-11.5	-0.18	0.01
DSK_ANG_+p8_0	0.7	0.0	0	266.20	0.44	-12.1	-0.19	0.00
Crystal offsets ==>	0.20	-0.19					Verified β_{ES}==>	-0.02



Enter coefficients of best 3rd order curve fit, then use SOLVER

x^3	x^2	x^1	x^0
2.0714	8.1833	-7.9797	267.06
0.1545	1.4499	-3.3589	267.06

to find MIN of this cell ==> 265.3

by varying this cell =====> 0.421

0.22 <== INITIAL α_{ES} offset

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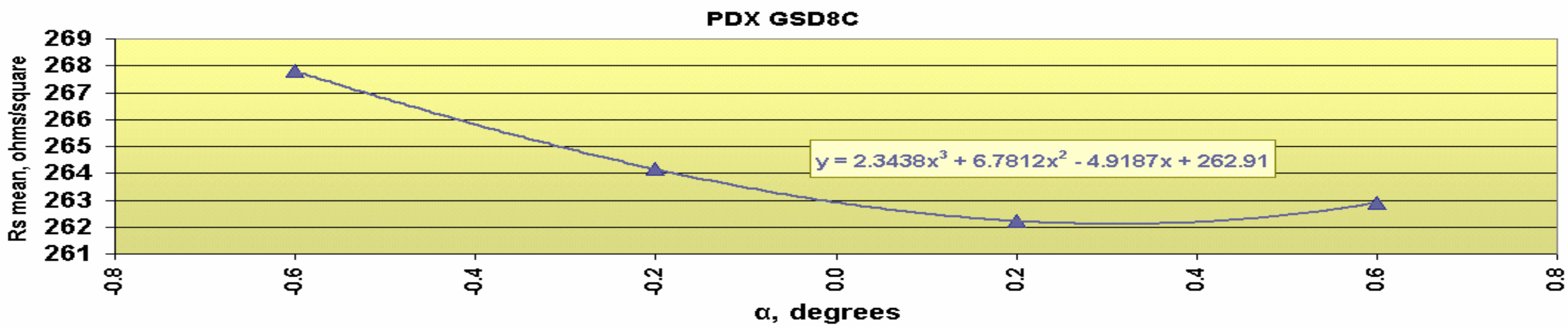
Final E.S. Alpha characterization

α_{ES} , β_{ES} **Verification** **PDX GSD8C** | α ==> (α_C, ±0.2, ±0.4); $\beta = \beta_C + \beta_{ES}$; T = 0 | {enter date here} | MSM

RECIPE	α	ß	T	Rs Mean	%SDev
DSK_ANG_-p4_0	-0.6	0.0	0	267.80	
DSK_ANG_-p2_0	-0.2	0.0	0	264.15	
DSK_ANG_+p2_0	0.2	0.0	0	262.22	
DSK_ANG_+p4_0	0.6	0.0	0	262.91	
Crystal offsets ==>	0.20	-0.19			



Enter coefficients of best 3rd order curve fit, then use SOLVER

	x^3	x^2	x^1	x^0
	2.3438	6.7812	-4.9187	262.91
	0.0726	0.6686	-1.5445	262.9100

to find MIN of this cell ==> 262.1

by varying this cell =====> 0.314

0.11 <== Final α_{ES} offset

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Conclusions

- Standard ES alignment procedures and initial crystal offset are large (±0.5°)
- This technique allows for ±0.1 degree accuracy for End Station alignment of HE's
- Additional work has shown the GSD's may require a more relaxed spec (0.15 degrees?) for at least the Beta axis as the ion beam is not as precisely positioned as in the HE
- Accuracy of results can be gauged by verifying maximum channeling at 0°/0° by compensating for the wafer offset or requiring that it be extremely small

Conclusions

- This technique can be applied to other end station types with appropriate understanding of angle determination.
  - Note that the pivoting arm of VIISion's and AMAT's make the motion more difficult to interpret as there is a varying twist component to the angle of incidence.
- This method is essential for High Energy processes where channeling can result in dramatic dopant distribution differences

Acknowledgements

- Motorola: David Sing
- INNOViON: Ray Pong, John Mayes, Karen Tan, Mike Murawski, Ron Johnson, Randy Tysinger, Ken Gorr
- Axcelis/Eaton: Mary Jones, Frank Sinclair, Bob Simonton,
- Univ. of Texas: Al Tasch
- IBM: Robert Ziegler