



Active Layer Parametrics, Inc.

Abhijeet “AJ” Joshi, PhD.



Outline

Current Techniques

Non-Electrical Data & Electrical Data

Resistance based: Scanning Spreading Resistance Microscopy (SSRM)

Charge based: Electro-Chemical CV (E-CV)

Is the Data Complete?

Analytical Process

Germanium Data

Techniques Currently Used

1. Microscopy: Optical, SEM, FIB-SEM
2. Transmission Electron Microscopy
3. Scanning Probe Techniques: SPM, SSRM
4. Secondary Ion Mass Spectroscopy (SIMS)
5. Electro-Chemical CV
6. X-Ray Photoelectron Spec. / Auger ES
7. Atom Probe Tomography (APT)
8. Low energy Electron induced X-ray Emission Spectrometry (LEXES)
9. X-Ray Diffraction Techniques



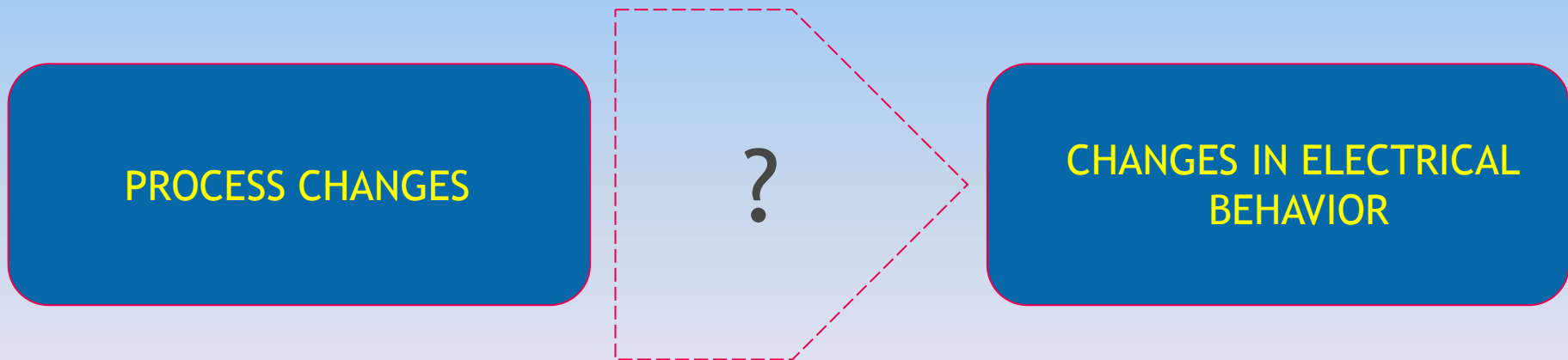
Electrical Techniques

FAaST (CV), 4-Point Probe, Bulk Hall - Single Point

Scanning Spreading Resistance Microscopy (SSRM)

Electro-Chemical CV (E-CV)

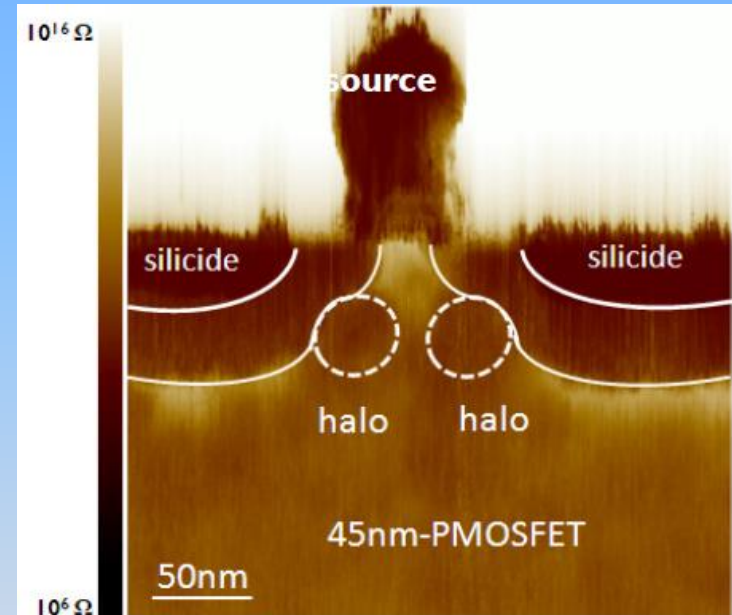
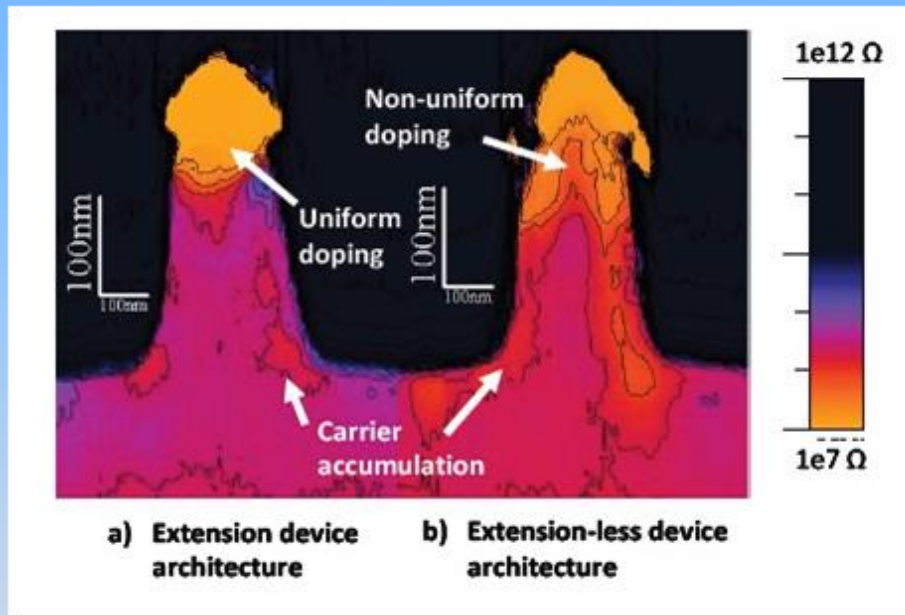
....and that's it!



SSRM

Provides Spreading Resistance *ONLY*

AFM based technique - 2D imaging



Applications: Local Assessment of *partial* electrical image

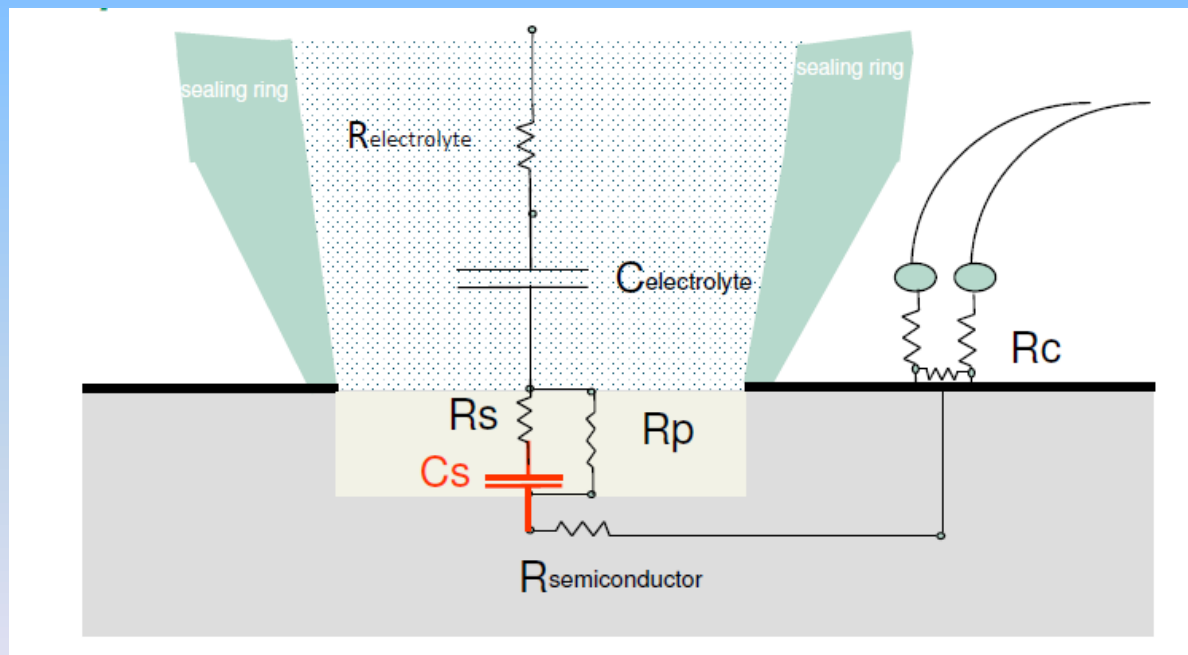
[1] J Mody et al. IEDM 2011

[2] Eyben et al. Mat. Sci. Engr B 124-125 (2005)

E-CV Technique

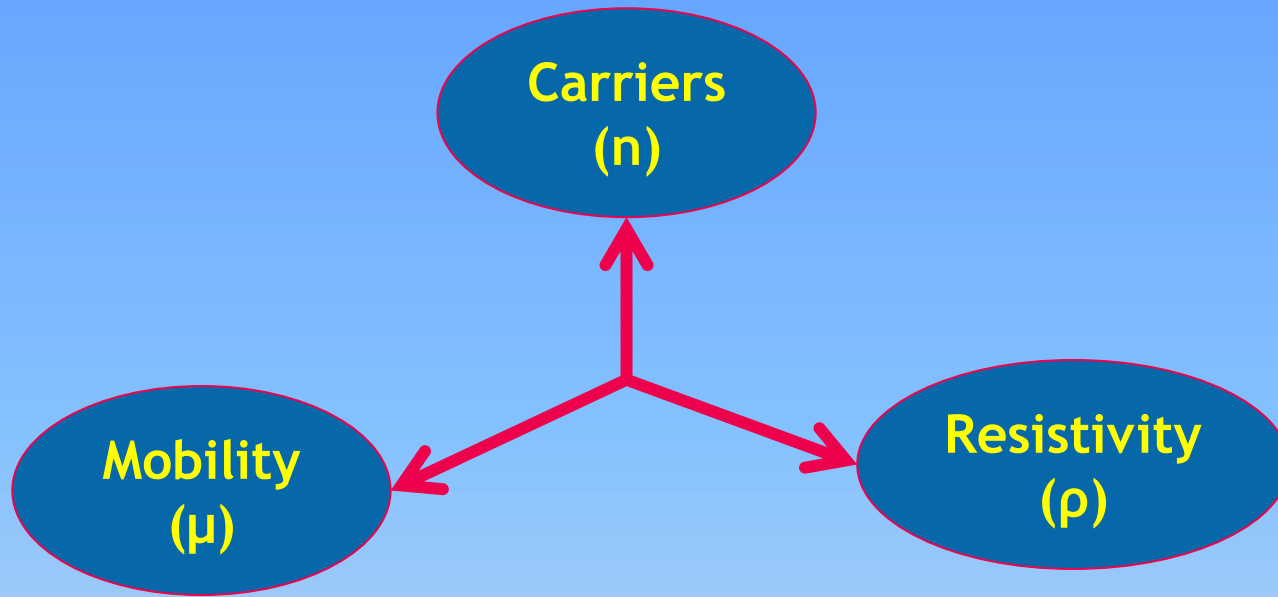
E-CV relies on measurement of both C_s and $C_{\text{electrolyte}}$

Nanometrics' E-CV Pro uses a 3-term model



C_s is very small and thus dominates

Is the Dataset Complete?



$$n(x) = \frac{1}{\mu(x) \rho(x) q_{electron}}$$

Resistance Profiles (Ω or ρ) : SSRM

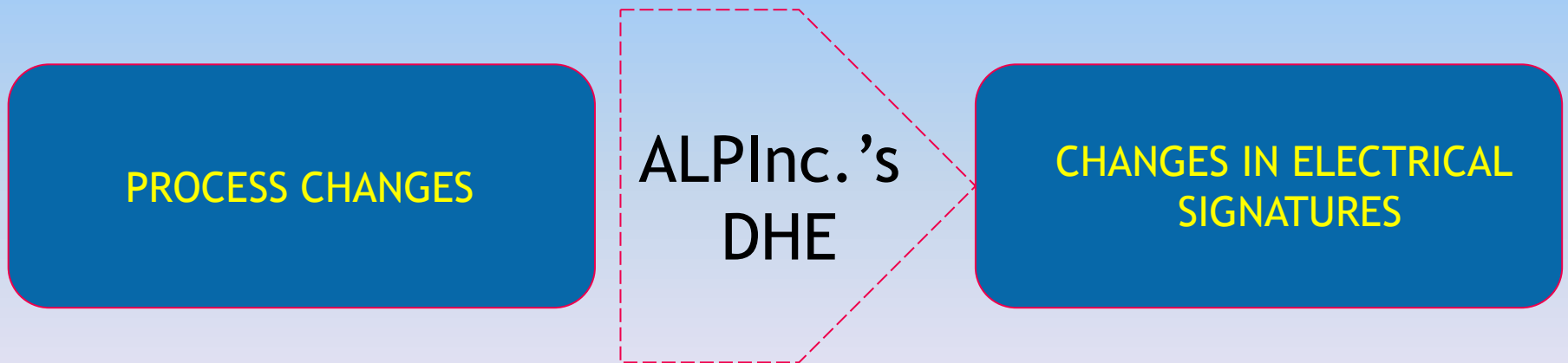
Charge/ Activation Profiles (n) : E-CV

COMPLETE Electrical Profiles

Majority Carrier Mobility (μ)

Sheet Resistance (R_s) and Resistivity (ρ)

Active Carrier Concentration (n)



DHE System: Analytical Process

- Blends the Best of E-CV and Hall Measurements:
 - Low Sample Prep. Burden
 - Measurement of Resistivity *AND* Mobility
- Customizable Step-size
 - User determined step-resolution [from 3-5 Angstroms and up]

$$n(x) = \frac{1}{\mu(x) \rho(x) q_{electron}}$$



Direct measurements

ALP Differential Hall Effect (DHE) System

- Measurement Resolution ~3-5 Angstroms
- Room Temperature Process - No Thermal Steps required
- Clean Procedure
- Fully Automated Measurement Operation - Repeatability
- Provides Junction profiles for n , μ and ρ

Germanium Data

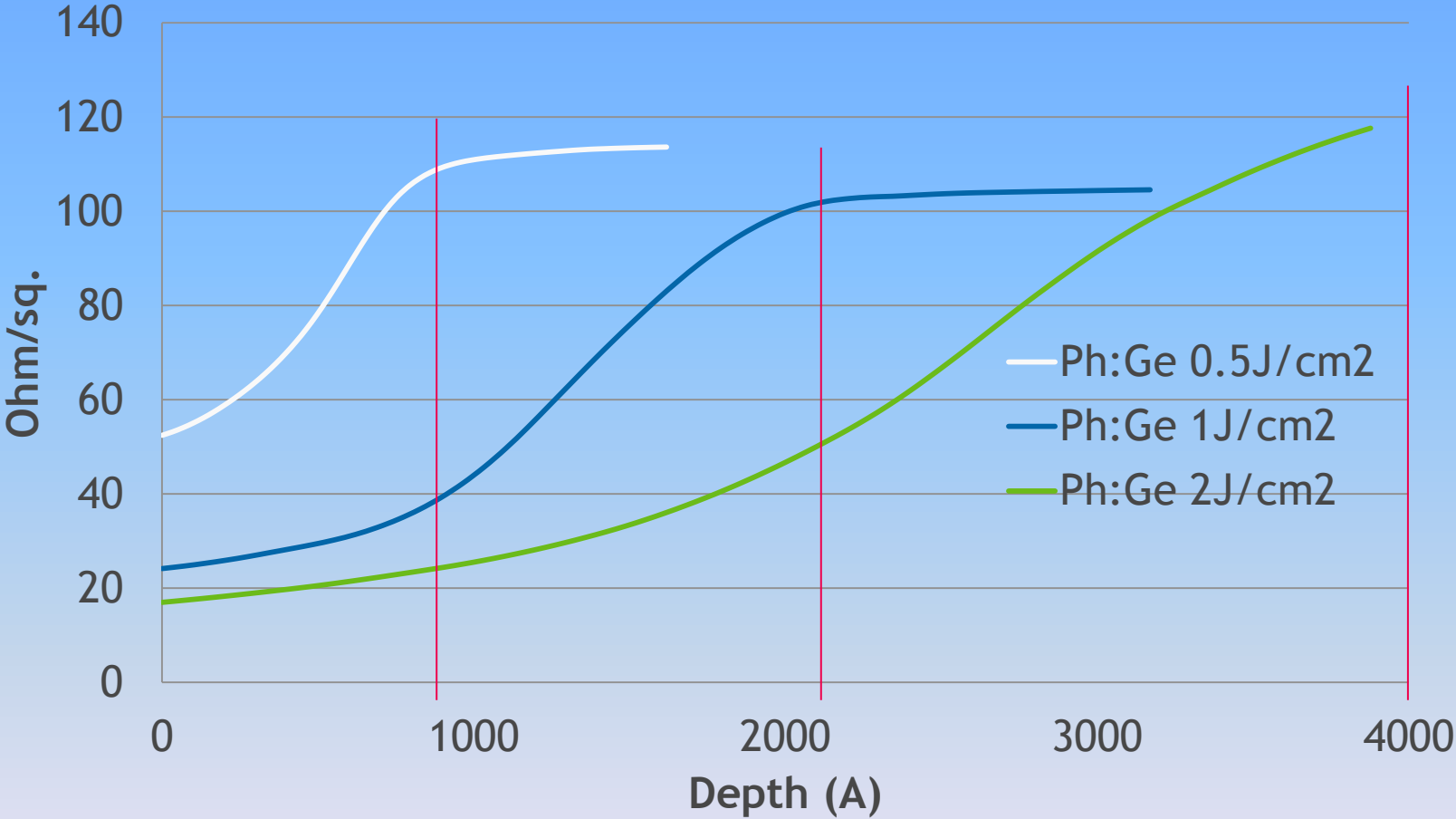
- Courtesy: John Borland
- Epi-Germanium - Laser Anneal Split
- Ph doped in Ge in-situ
- *ACTUAL* Electrical Junction Location

Bulk Properties

Property	Ph:Ge 0.5J/cm ²	Ph:Ge 1J/cm ²	Ph:Ge 2J/cm ²
Average Bulk Drift Mobility (cm ² /V-s)	196.94	148.06	42.16
Average Dose (#/cm ²)	6.05E+14	1.75E+15	8.72E+15
Bulk Sheet Resistance (Ohm/Sq.)	52.44	24.16	16.99

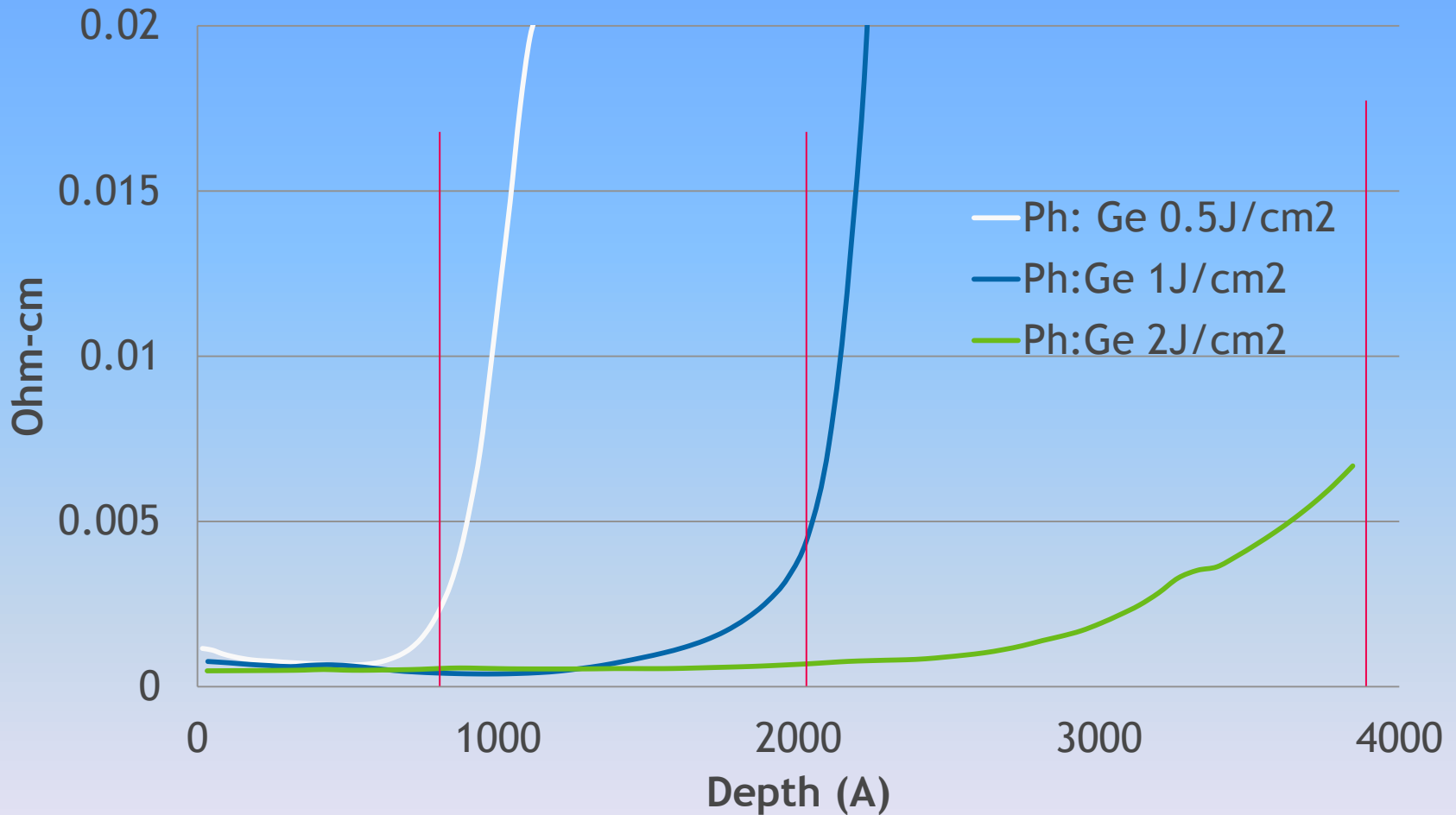
Bulk Sheet Resistance

Bulk Sheet Resistance



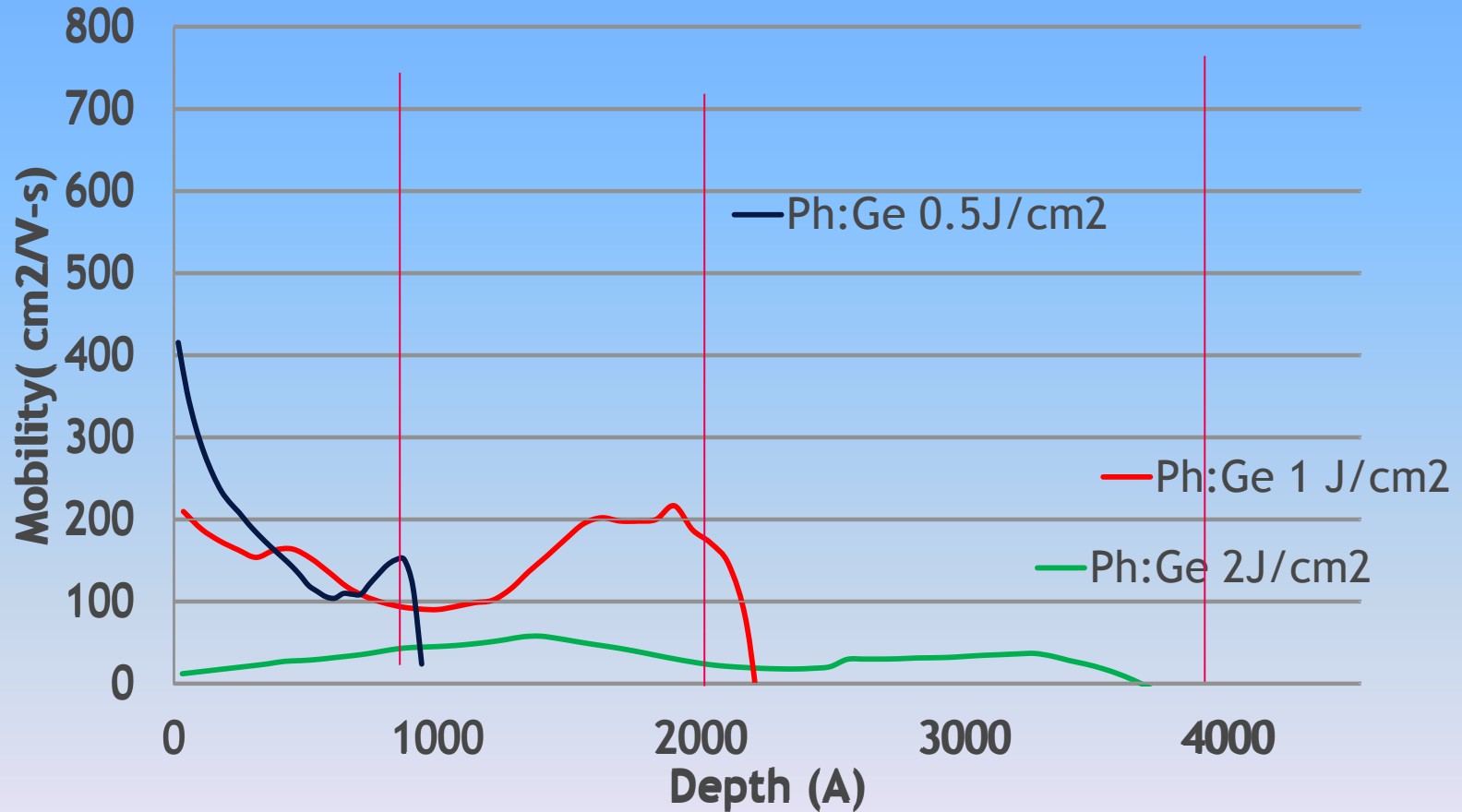
Layer Resistivity

Layer Resistivity



Layer Mobility Data

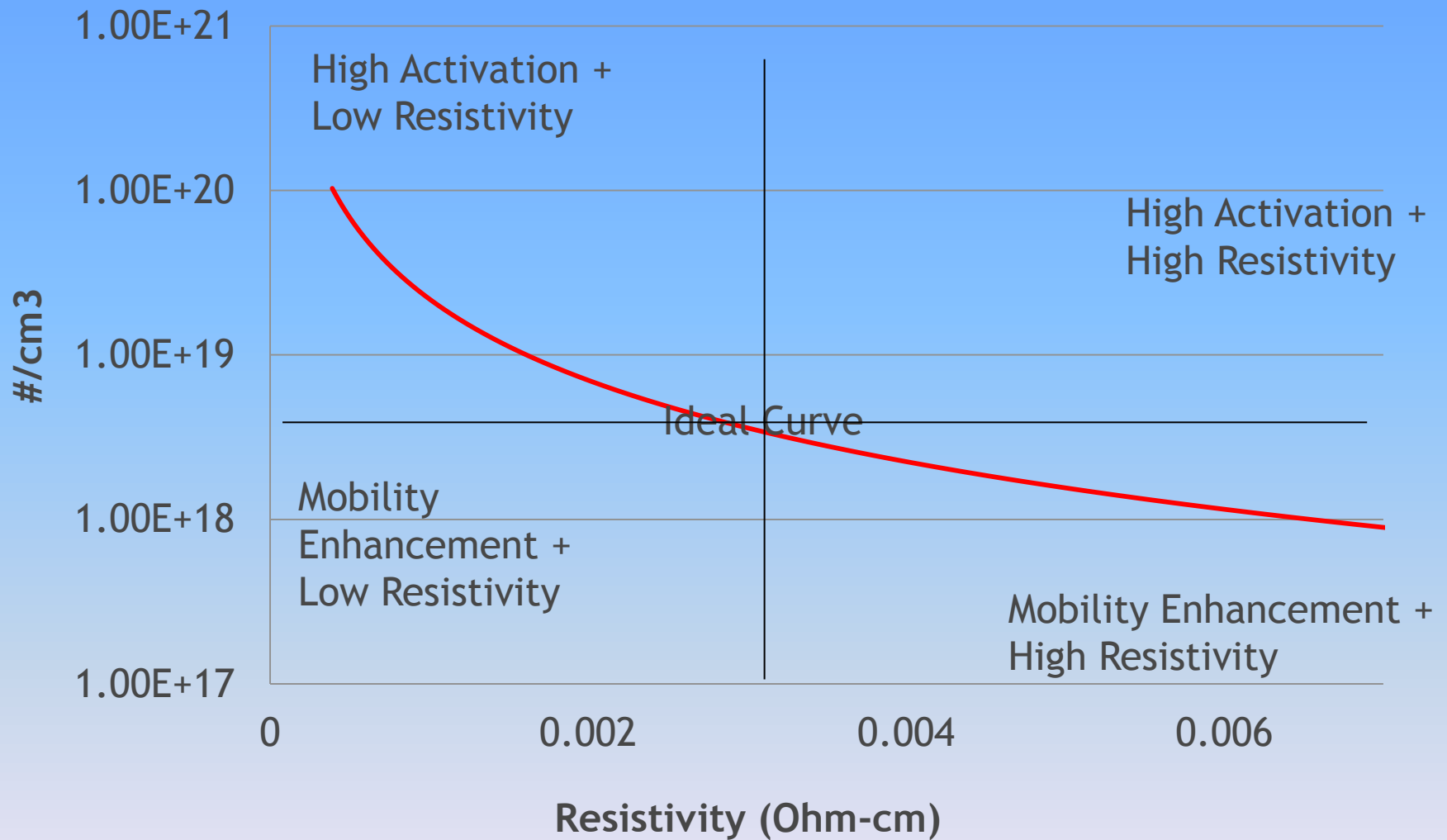
Layer Mobility



Conclusions: Germanium Data

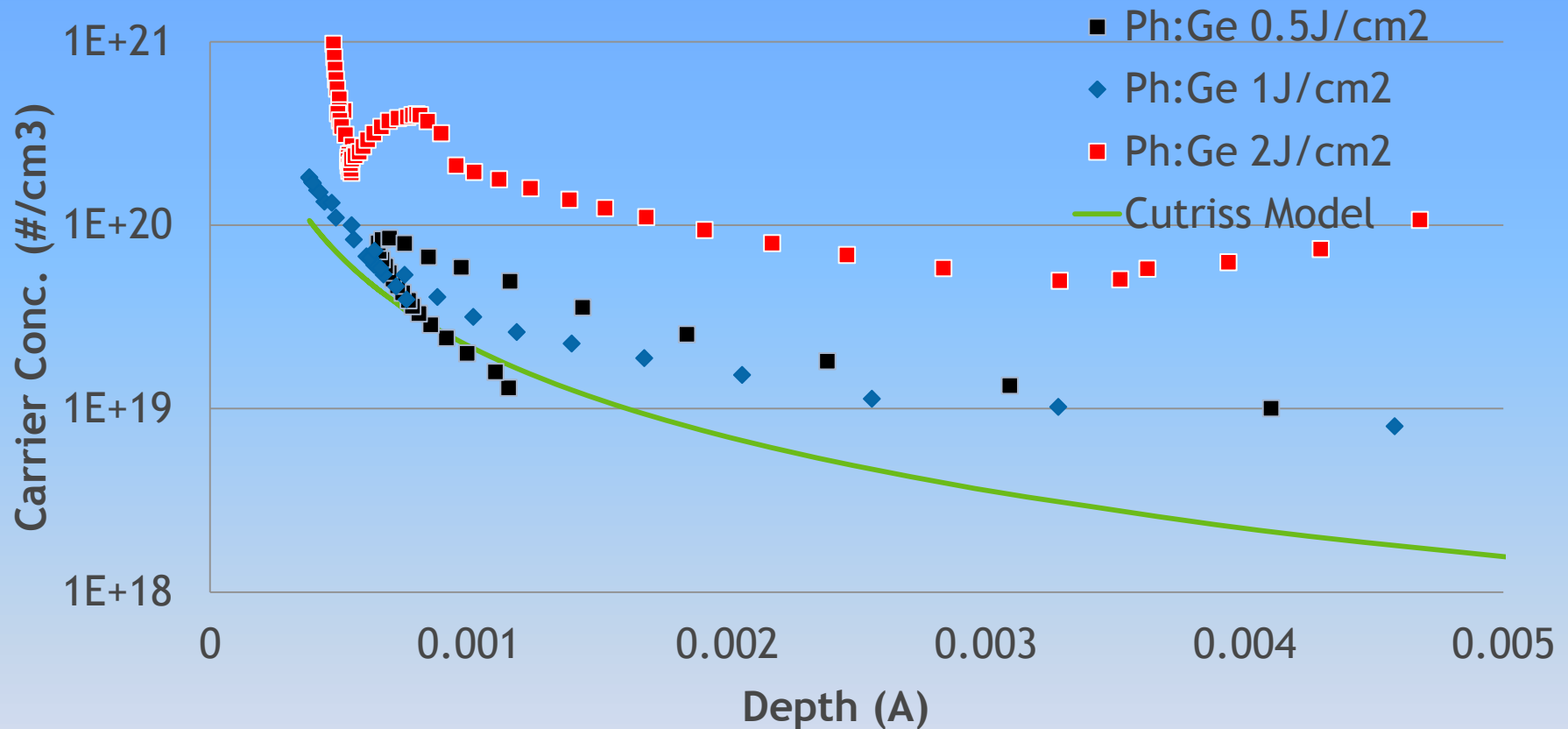
- Material Study
- *Measured* Electrical Activation variation with Fluence

Carriers Vs Resistivity



Carriers Vs Resistivity

Carrier Concentration

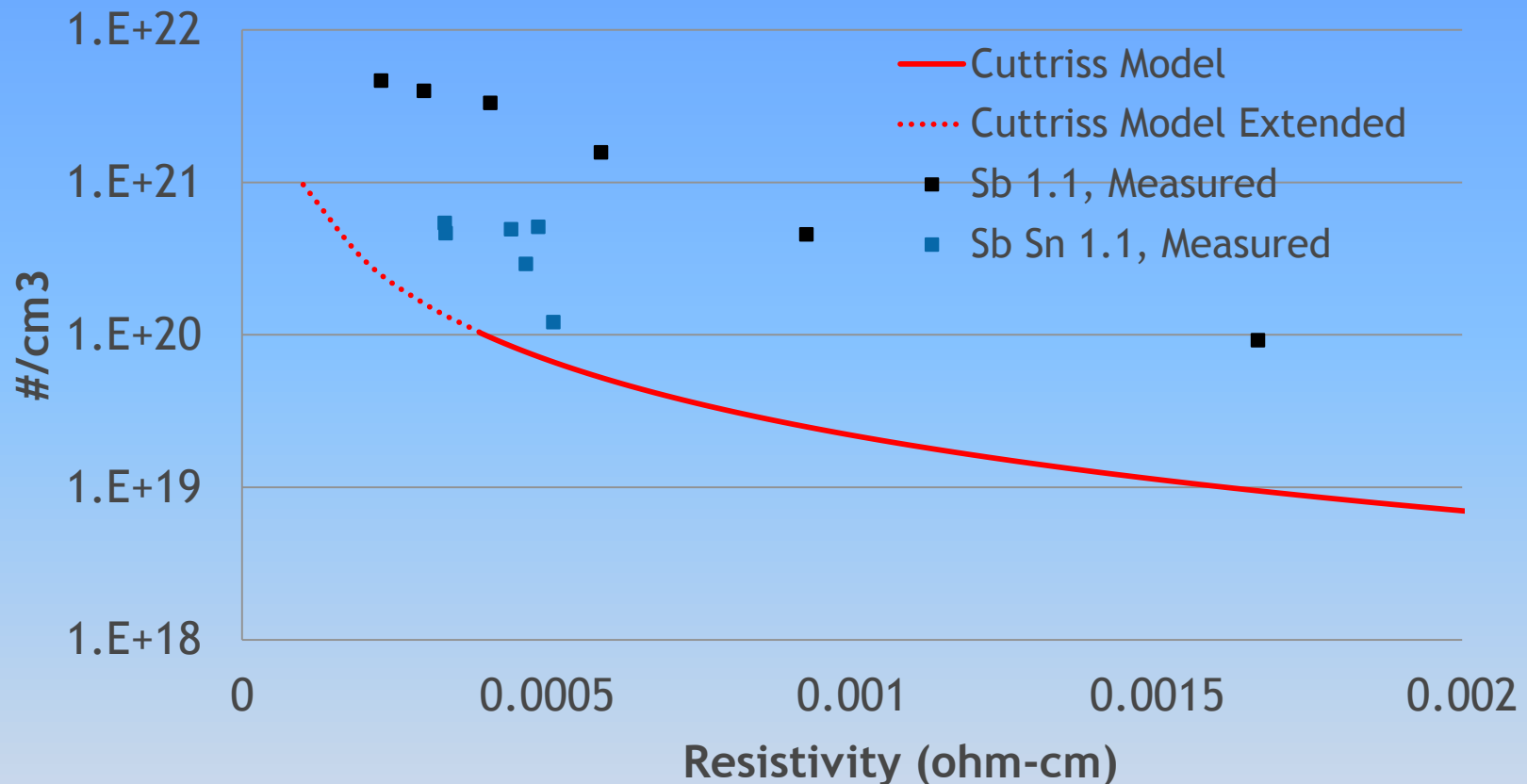


- 1J/cm² ~ 200nm Junction

More Germanium

- Sb Vs Sb + Sn
- Laser Anneal
- Concentration Vs Resistivity Parametric Curves

Carriers Vs Resistivity - 1.1J/cm²



- Adding Sn to Sb gets us CLOSER to the IDEAL curve



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Abhijeet “AJ” Joshi (PhD), Founder
info@alpinc.net