Improving the accuracy of alpha emissivity measurements for wafer and packaging materials

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Outline

- Background – What is it?
- Background – Why does it matter?
- Approach 1 – Gas proportional counter
- Approach 2 – XIA prototype ion chamber
- How the two approaches stack up
- Summary/Conclusion

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Introduction

- Pressing need to measure α-particle emissions in today's materials
- SEMATECH
  - alpha detection limit ≥ 0.0001 α/cm^2/hr,
  - measurement times ≤1 week
- Instrument *background* is currently limiting our ability to achieve these goals

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Background - Definition

In the context of alpha particle detectors:

back·ground \'bak-,(g)raůnd\ *n* :

The count rate observed while measuring a sample which produces zero counts.

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Background Subtraction

1. Measure Background Rate (*B*)
2. Place a sample into counter, measure rate (R)
3. Compute Sample Rate S

$$S \equiv R - B$$

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Sources of Background

- Intrinsic sources of alphas:
  - Alpha particle emissions from materials *comprising* the counter itself
- Extrinsic sources of alphas:
  - Counter/Sample Tray contamination
  - Radon in counting gas
- Fake/Spoofed sources of alphas:
  - Power line noise
  - Microphonics

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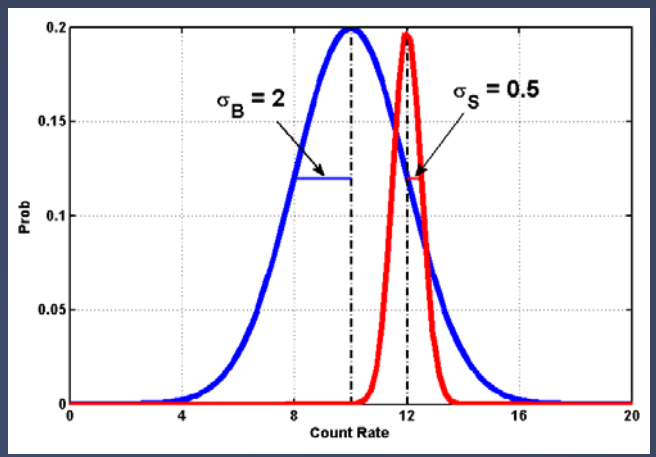
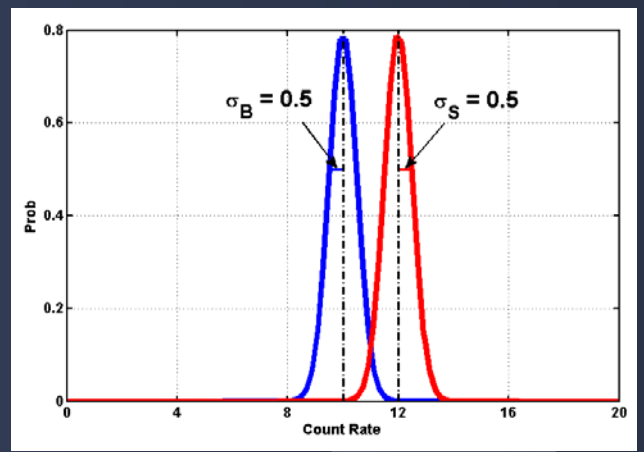
The Impact of Background

- **Error** in background term propagates to large errors in measurement data
- **Time** required to extract *S* to desired statistical significance in the presence of background, when background is well known





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Impact on Measurement Error

- Observed background count rate *B* ($\pm\sqrt{B}$) in background measurement lasting t_B
- Observed gross count rate (sample + background) *R* ($\pm\sqrt{R}$) in measurement lasting t_R
- Computed sample rate S = R - B
- Errors combine in quadrature:

$$\sigma_S = \sqrt{\frac{R}{t_R} + \frac{B}{t_B}}$$

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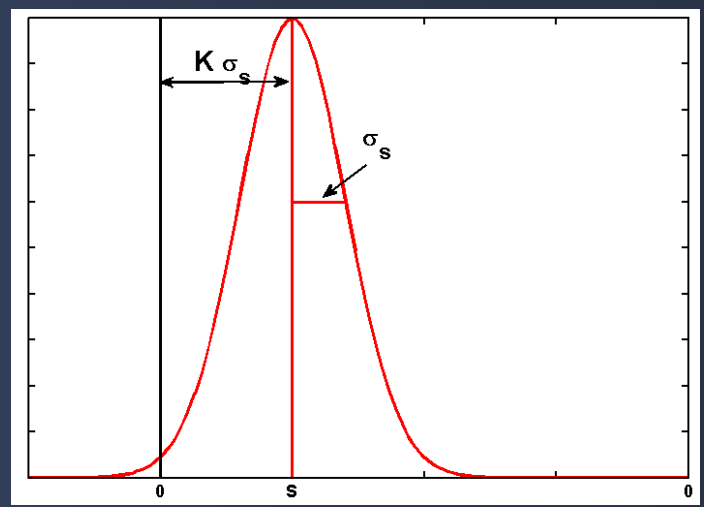
Impact on Measurement Time

- Sample with *S* counts/hour
- Instrument counted for t_B to obtain estimate *B* (background) counts/hour
- How long *t* to make a 90% (1.64σ) measurement?

$$t = \frac{K^2(S+B)}{S^2 - K^2(B/t_B)}$$



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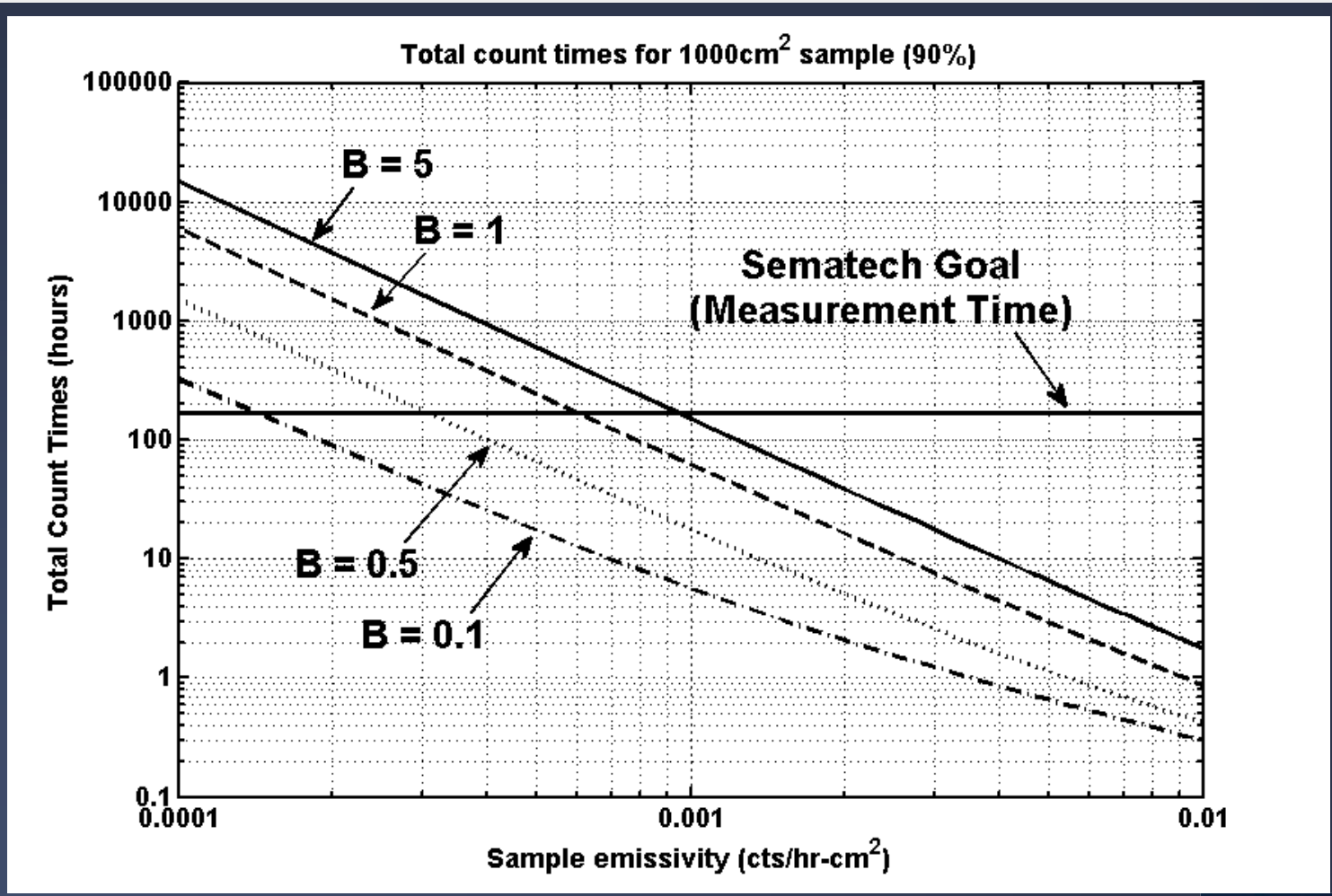
Impact on Measurement Time



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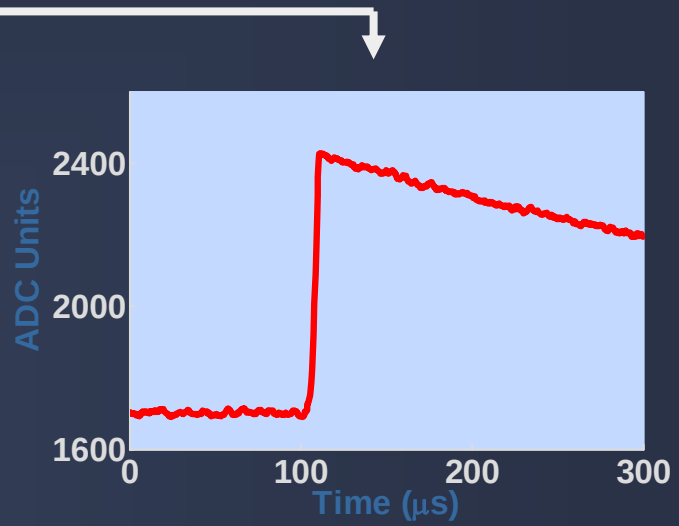
Backgrounds in practice

- Two approaches examined:
  - Gas proportional counter
  - XIA ionization chamber
- Theory of operation
- Practical measurement of background on each system

Gas flow proportional counter



Pulse Characteristics:

Good Signal/Noise

Risetime < 5 μs

- All pulses look the same!
- Intrinsic sources lead to a background of ~ 5 cts/hr

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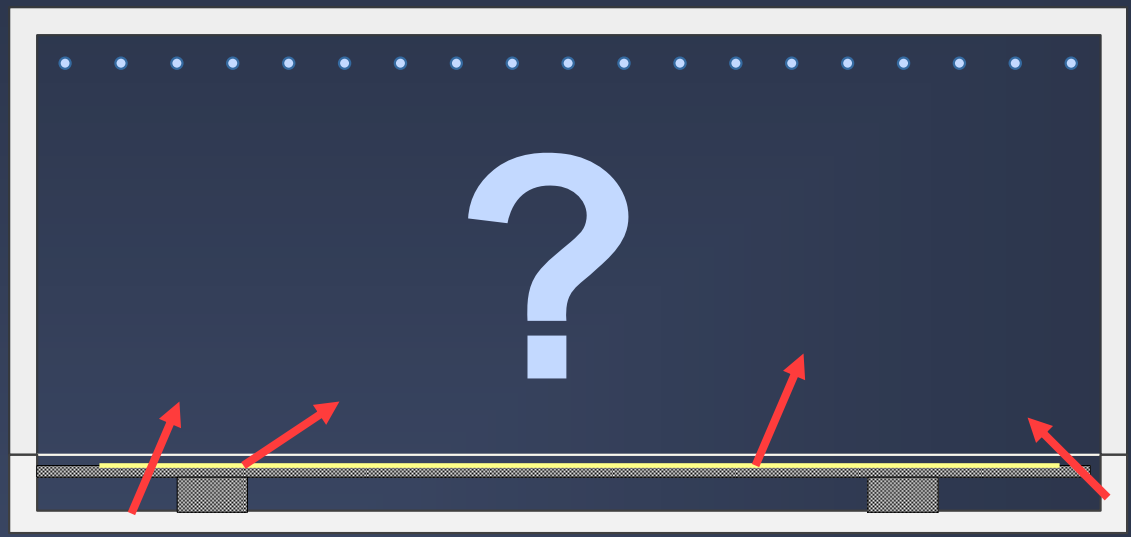
Practical difficulties



- Remove tray for background measurement?
- Empty tray for background measurement?
- Cover tray w/ zero-background material?

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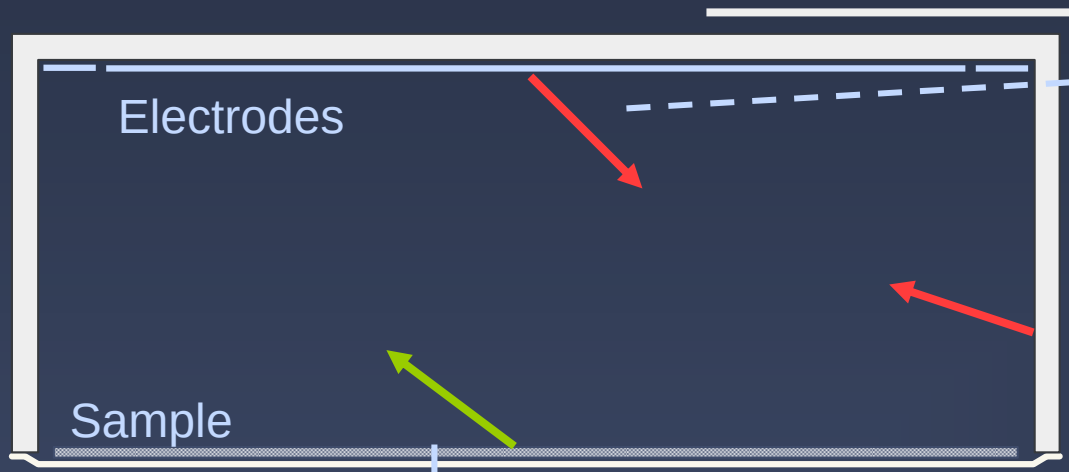
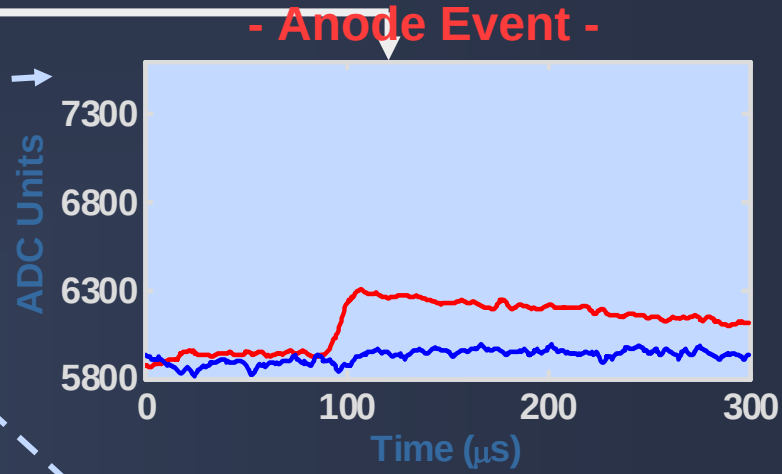
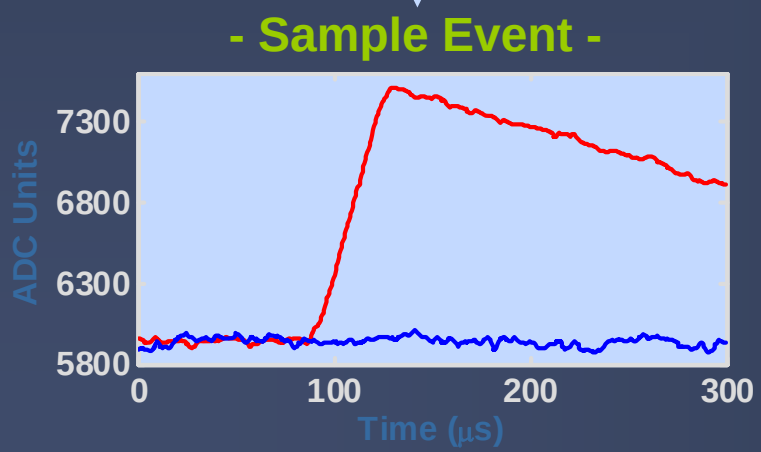
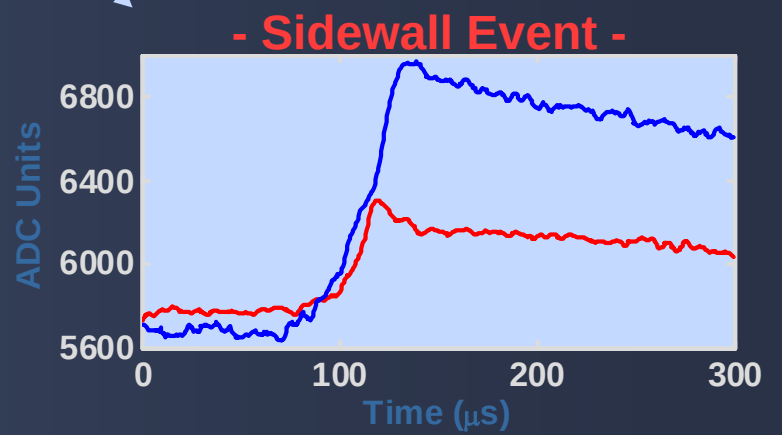
XIA's Dual Channel Ion Chamber









Pulse Shape Analysis reveals origin

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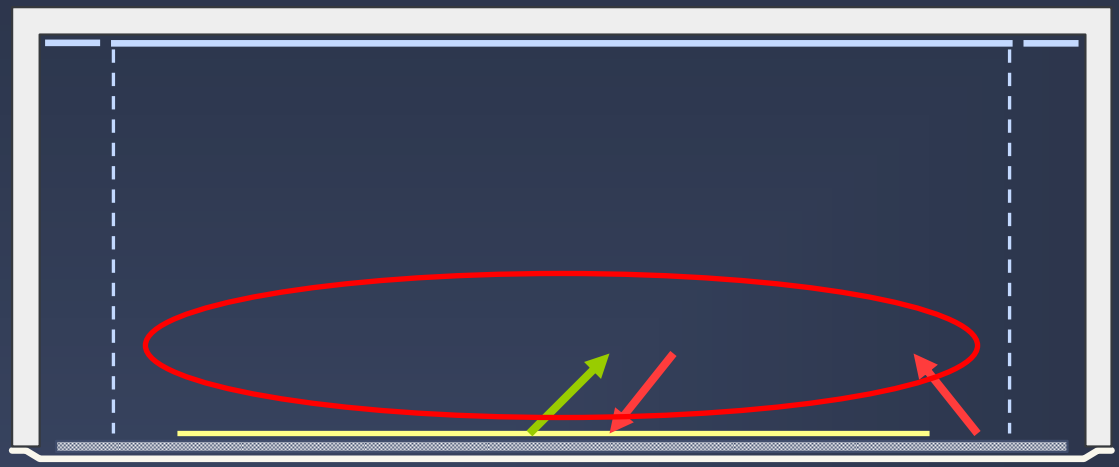
Background in practice



- Insensitive to emissions from surfaces other than sample tray
- Undersized samples? OK, but…
- No volume rejection
- Current estimate: 0.0006 $\alpha/cm^2/hr$

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Measurements in Practice

- IBM recently conducted a counter comparison study

- Sample 1: Bare wafers plated with low-alpha lead
- Sample 2: Flat sheet of Sn / 0.5% Ag
- Sample 3: IBM-proprietary ultra low emissivity material

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Measurement Results – Sample 1

Counter	*Count Time (hrs)*	*Activity (α/hr/cm^2)*
α-Sciences*	656 (4 x 164)	0.0040 (4)
XIA Prototype	10	0.0044 (6)

*Model 1950 – Count time doesn't include background measurement time

Sample Description: bare wafers plated with low-alpha lead

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Measurement Results – Sample 2

Counter	*Count Time (hrs)*	*Activity (α/hr/cm^2)*
α-Sciences*	273	0.0018 (2)
α-Sciences*	177	0.0014 (2)
XIA Prototype	70	0.0019 (2)
XIA Prototype	24	0.0019 (3)
XIA Prototype	24	0.0021 (4)

*Model 1950 – Count time doesn't include background measurement time

Sample Description: flat sheet of Sn / 0.5% Ag

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Measurement Results – Sample 3

Counter	*Count Time (hrs)*	*Activity (α/hr/cm^2)*
α-Sciences*	756 (4 x 189)	0.0001 (2)
XIA Prototype	116	0.0006 (1)

*Model 1950 – Count time doesn't include background measurement time

Sample Description: IBM-proprietary ultra low emissivity material deposited onto bare wafers

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Measurement Results - Summary

- Significantly reduced counting time
- Systematically larger emissivities
- Presence of background rate which is not currently accounted for

- Full paper *An Evaluation of An Ultra-Low Background Alpha-Particle Detector* presented at NSREC 2009, and will be published in IEEE Trans. Nucl. Sci. Dec 2009

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Summary

- Instrument background is critical when measuring low activity samples
- XIA's approach drives down background
  - Shortening required counting times
  - Reducing sources of measurement error
- Ongoing work to resolve remaining issues

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