A Study of Temperature Induced Polonium Diffusion on SRAM SER Performance

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Outline

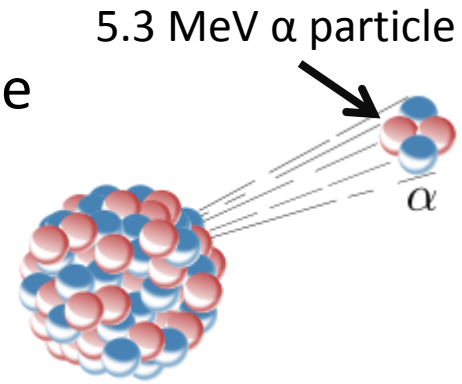
- Introduction to alpha induced SER
- Recent reported research review
- Experimental design and data collection
- Results &Conclusions

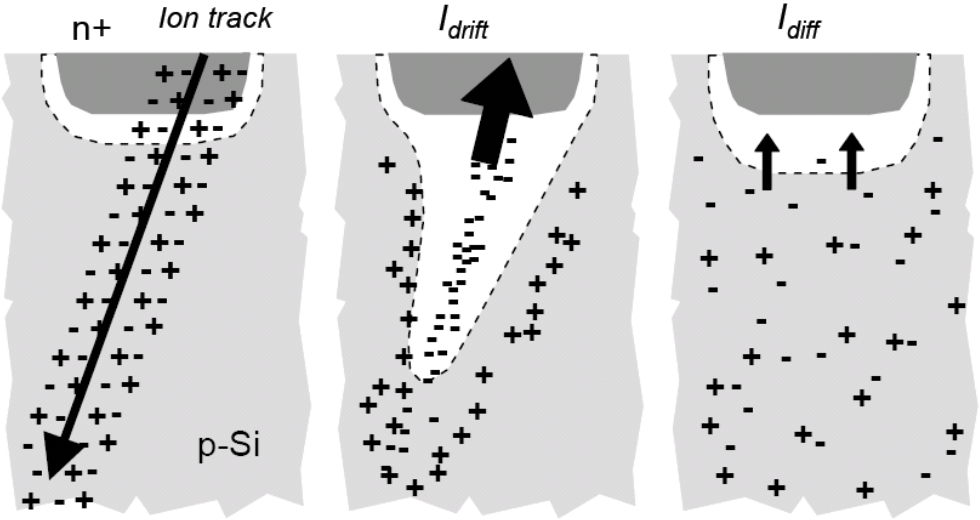
Introduction

- Recent data show Sn can have alpha emitting Po at higher concentrations below the Sn surface.
- Alpha particle induced SER experiment was conducted on 65nm 36Mb SRAM units to measure the soft error rate of the cells exposed to two Sn sources with varying emissivities to evaluate polonium diffusion effects on SER

Alpha Induced SER

- The Po decay produces the 5.3 MeV alpha particle.
- Alpha particle creates electron hole pairs in the silicon
- If the current is large enough, storage nodes such as SRAMs can switch states
  - Causing an error in the state





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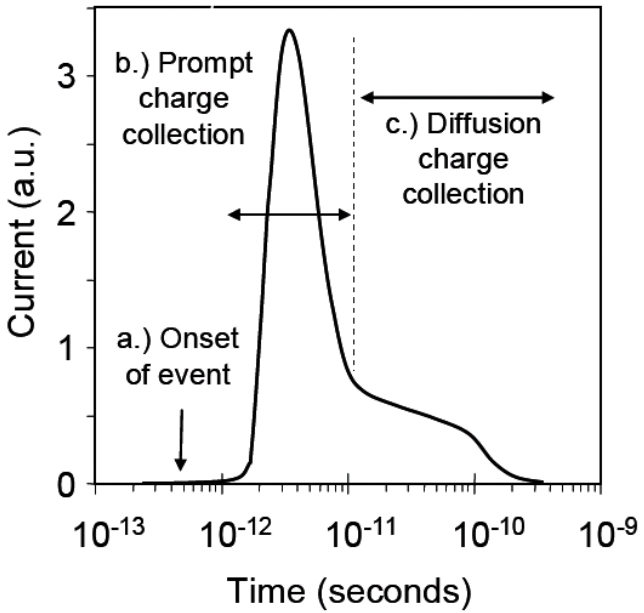
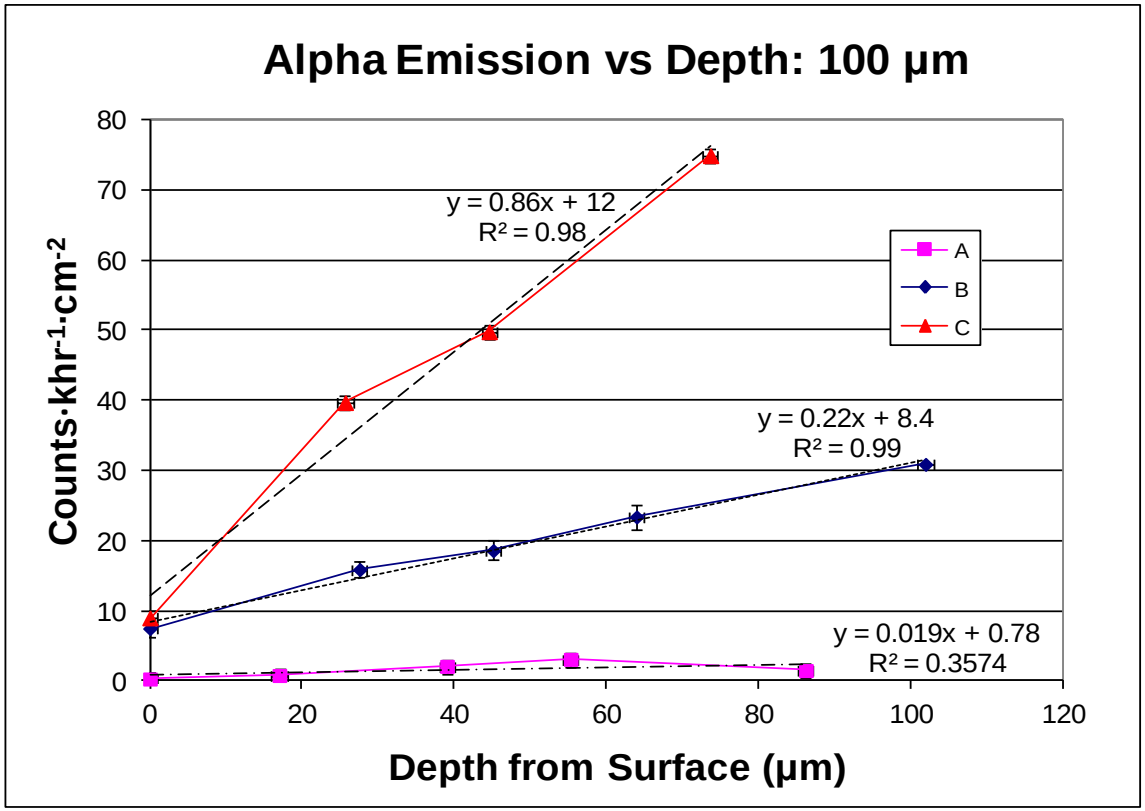


R. C. Baumann, ***IEEE Trans. Device Mater. Reliab.***, vol. 5(3), p. 305-316, Sept. 2005

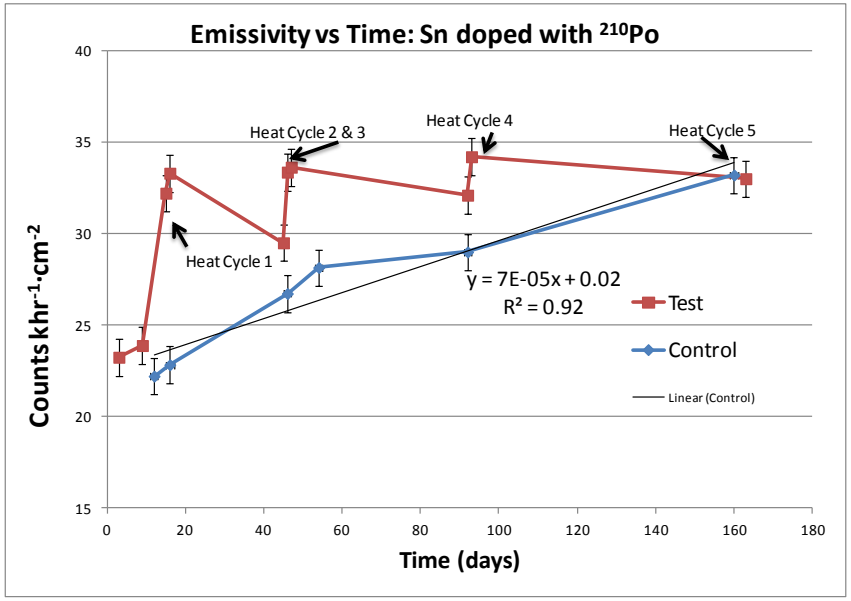
Introduction: Pb free solders

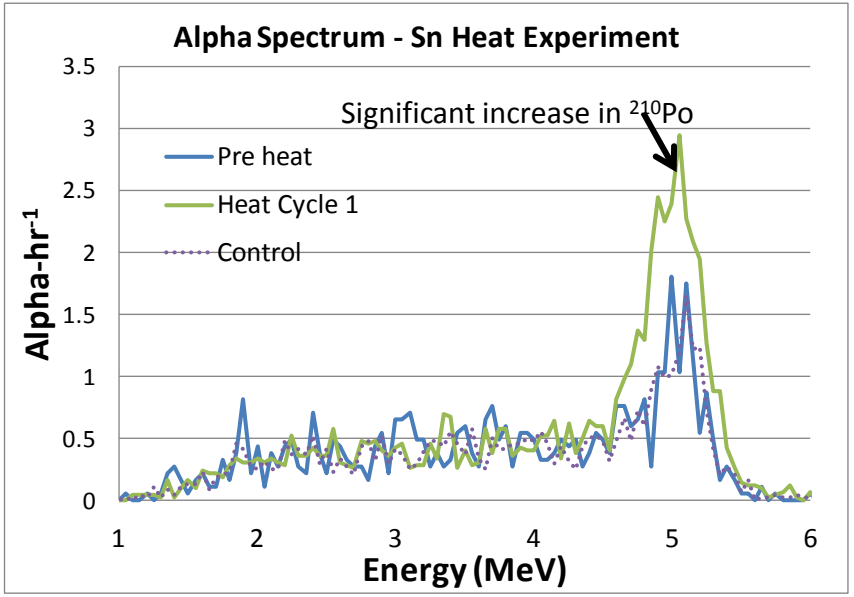
- Alpha emission increasing in some Sn solders over time
- Alpha emission increasing with depth in Sn



Polonium Diffusion Reported

- Alpha emission increasing over time from ^{210}Po diffusion
- Mechanism confirmed
  - Doped low alpha Sn with ^{210}Po
  - Sample heated & compared against room temp control
- Diffusion rate strong function of temperature





B. M. Clark, *Journal of Microelectronics and Electronics Packaging,* vol. 10, p. 10, 2013.

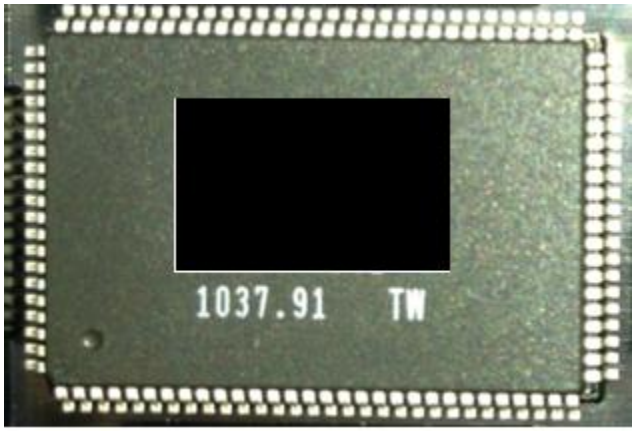
Polonium Transport Conclusions

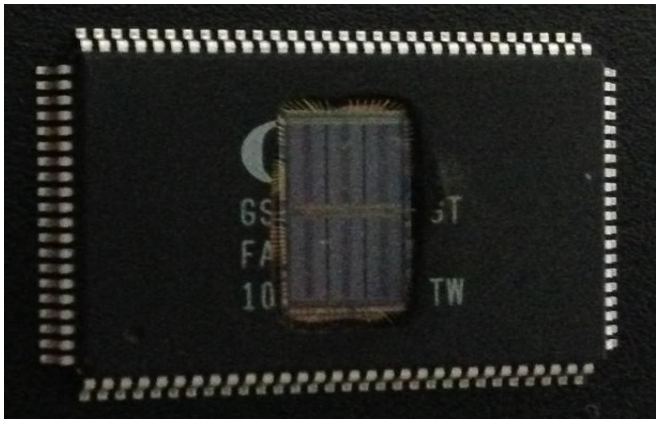
- Processes utilizing solid/liquid phase changes are susceptible to microsegregation effects.
- Polonium diffusion rate increases 230x from 298K to 498K
- Polonium present at levels below analytical detection limits presents significant SER risk
- Diffusion can increase the effective alpha energy E_α striking the device

Design experiment to evaluate relationship between temperature and alpha induced SER

SRAM Application Experiment

- Measure SRAM SER over time
  - Decapped 36Mb SRAMs
- Exposure conditions
  - Ambient conditions
  - Ultra low alpha Sn <2 $\alpha \cdot khr^{-1} \cdot cm^{-2}$
  - 99.99% grade non low alpha Sn 2000 $\alpha \cdot khr^{-1} \cdot cm^{-2}$
    - Initial run room temperature
    - Heated to 100°C for 1 hour
    - Final run

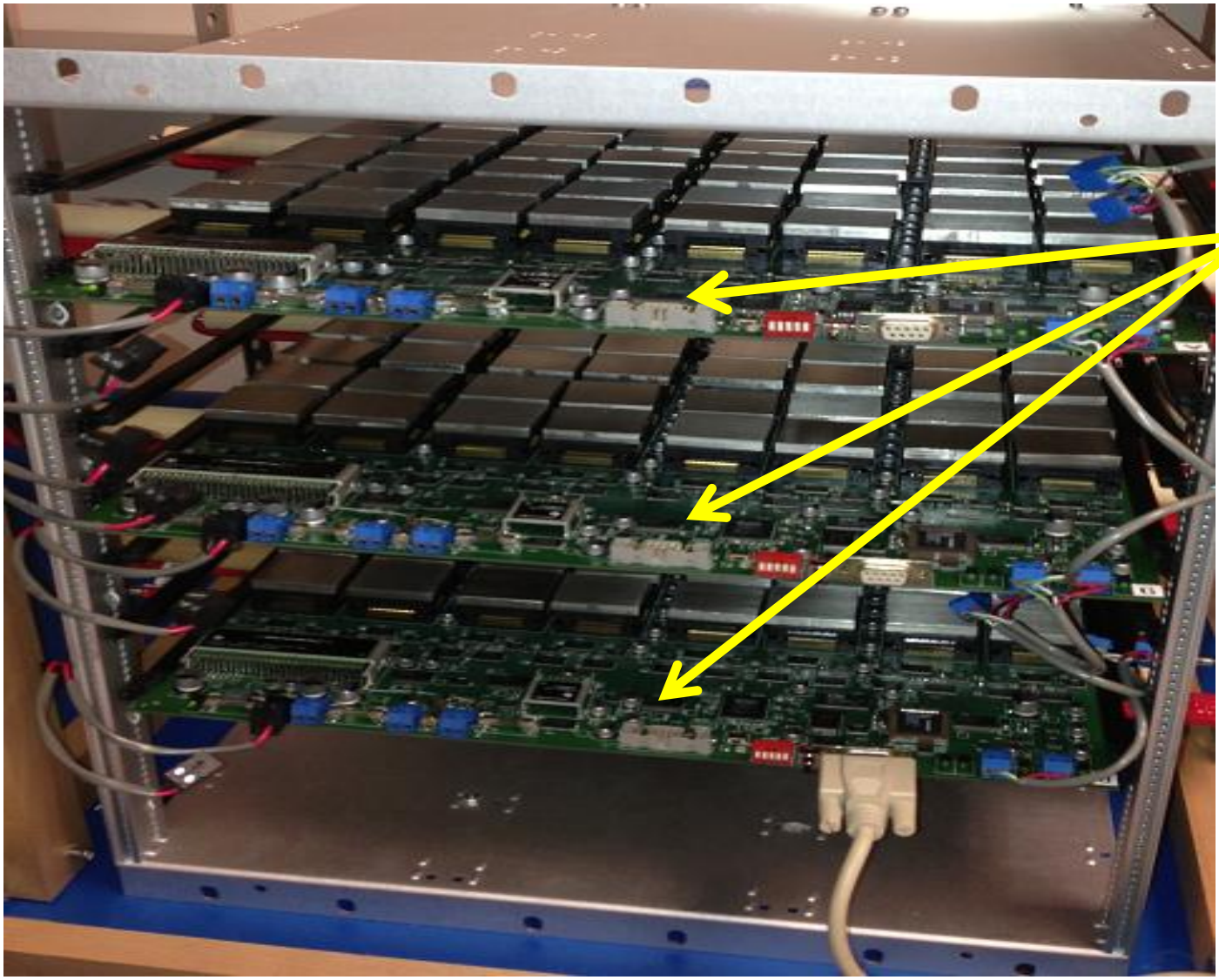




Experimental Procedure

Purpose	Runs	Alpha Source
Verify Rn and neutron SER	Dry Run	No Sn source
SER due to ULA Sn	ULA run	ULA Sn at 2 α/khr/cm2
SER due to 99.99% Sn	99.99% grade Sn Run	LA Sn at 2000 α/khr/cm2
SER due to 99.99% Sn post bake	Bake 99.99% grade Sn run	LA Sn post bake 2600 α/khr/cm2

Experimental Setup with Sn sources



3 boards in the chassis

Sockets with Sn sources on top

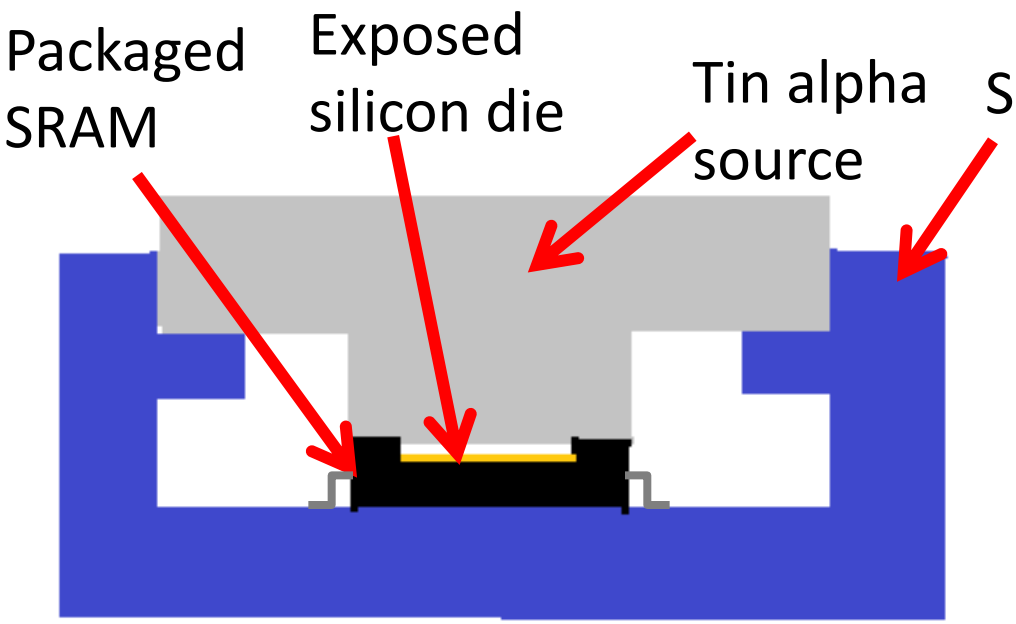
Baseline Run

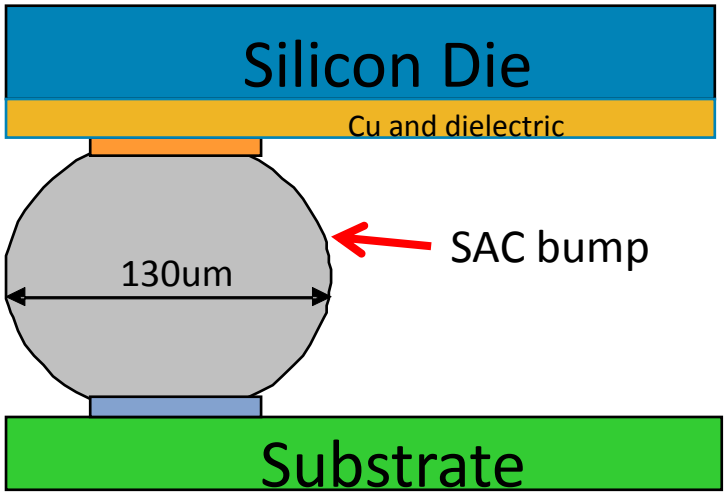
- Ambient Rn levels 1.2 Bq/m^3
  - 40 FIT/Mb
- Neutron SER measured at TSL
  - 240 FIT/Mb
- Run duration 744 hours
- No SER events observed
- Results match with the estimation within statistical error

Errors	Hrs	Devices	Alpha emission	Expected FIT/Mb(Rn+n)	Measured FIT/Mb
0	744	186	none	280	< 200

Sn Source Placement

- Sn alpha source used for SER measurements.
- Sources were made rest on the top surface of the package to minimize the air gap to 0.53 mm and to fit within the socket
- Devices at room temperature during experiment





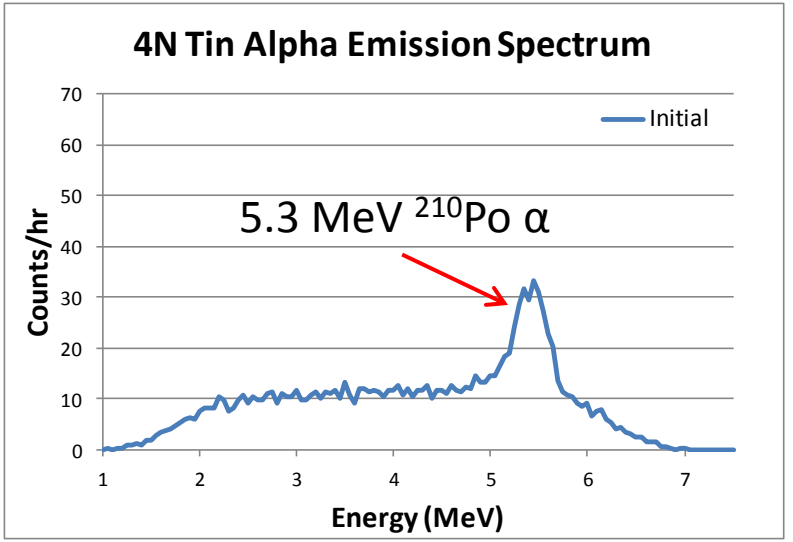
ULA Sn Run

- Sn sources rest on top of the package
- Sources were handled using latex gloves to avoid contamination
- Run duration 960 hours
- No SER events detected
- Results within statistical error

Errors	Hrs	Devices	Alpha emission a/cm2/khr	Expected FIT/Mb (Rn+n+a)	Measured FIT/Mb
0	960	186	< 2	< 480	< 200 FIT

99.99% Sn test run

- Source 0.12 mm thick 99.99% Sn sheet
- Measured with XIA UltraLo 1800 Alpha detector
  - 5.3 MeV Po alpha particle present in spectrum
- Sn source attached to the base of the ULA source with double sided tape.



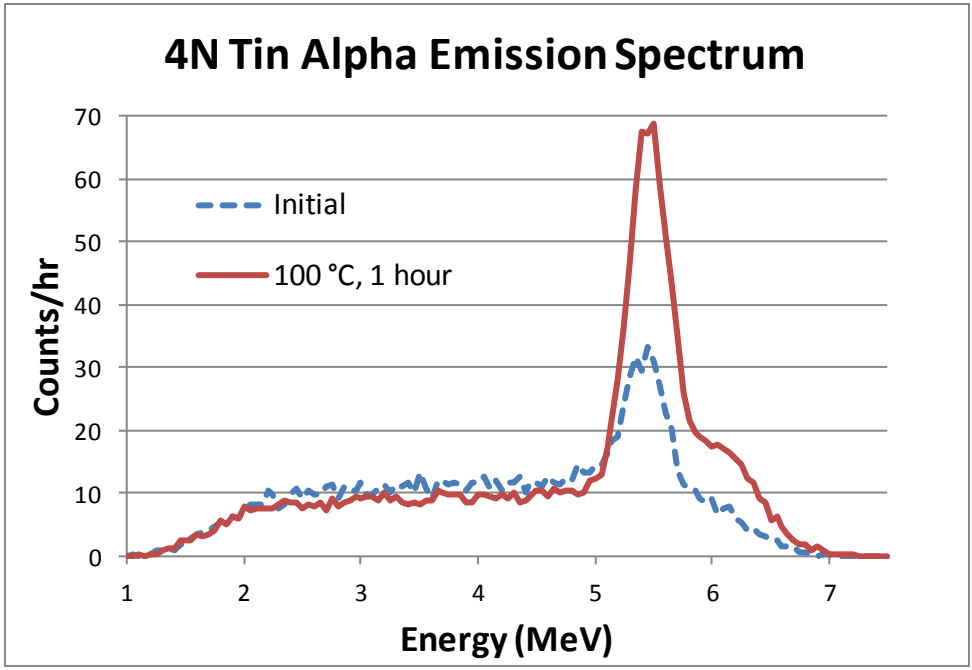
Low Alpha Results

- 53 events observed in 410 hrs on 62 devices
- Calculated Emission:
  - Low Alpha Sn FIT rate/ (200 FITs/Mb at 1 a/cm2/khr)

Errors	Hrs	Devices	Measured FIT/Mb	Calculated alpha emission a/cm2/khr
53	410	62	$6 * 10^4$	300

99.99% Sn Post Bake

- Low alpha Sn sources were baked
  - 100 C for 1 hour
- 256 SER events observed on 62 devices over 315 hrs



Errors	Hrs	Devices	Measured FIT/Mb	Calculated alpha emission a/cm2/khr
256	315	62	$3.6*10^5$	2000

SER Rate Temperature Dependence

- Alpha spectrum changed significant above 5 MeV after heating
  - 2x increase in 5-7 MeV range
- SER rate increased 7x .
- Potential increased SER sensitivity >5MeV

4N Sn source emissivity α/khr/cm2				
	1-5 MeV	5-5.5 MeV	5-7 MeV	1-7 MeV
Initial Alpha	994	348	465	1654
100 C, 1 Hr	839	602	901	2116
% Change	-16%	73%	94%	28%

Conclusions

- ULA Sn SER contribution negligible
- SRAM sensitivity to alpha induced SER confirmed
- Diffusion increased both alpha flux and effective alpha energy impinging on the device
- Device SER response alpha energy dependent
  - 2x increase in high energy alphas, 7x increase in SER rate
  - Need to investigate the non linear increase in FIT rate as a function of the alpha energy and flux

Further Study

- Resolve the 2x increase in flux to the 7x increase SER.
- Verify the error rate counts
- Cross section the SRAM to investigate the metal layers to the Si.
- Simulate various energy alpha particles going through the Si.

Acknowledgements

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