Soft errors considerations for low power, high reliability applications

IEEE Santa Clara Components, Packaging and Manufacturing Technology Chapter

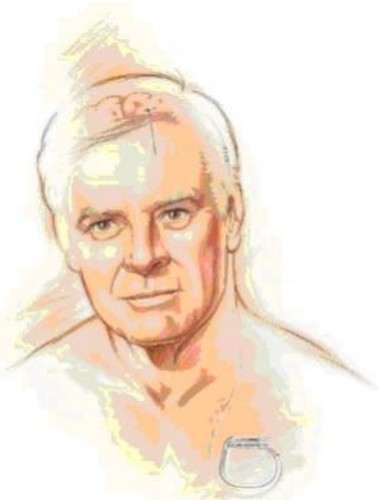
10/30/2009

Medtronic

Implanted electronic medical devices

Implantable defibrillator

Pacemaker & leads



Deep brain stimulator

Implantable cardiac monitor

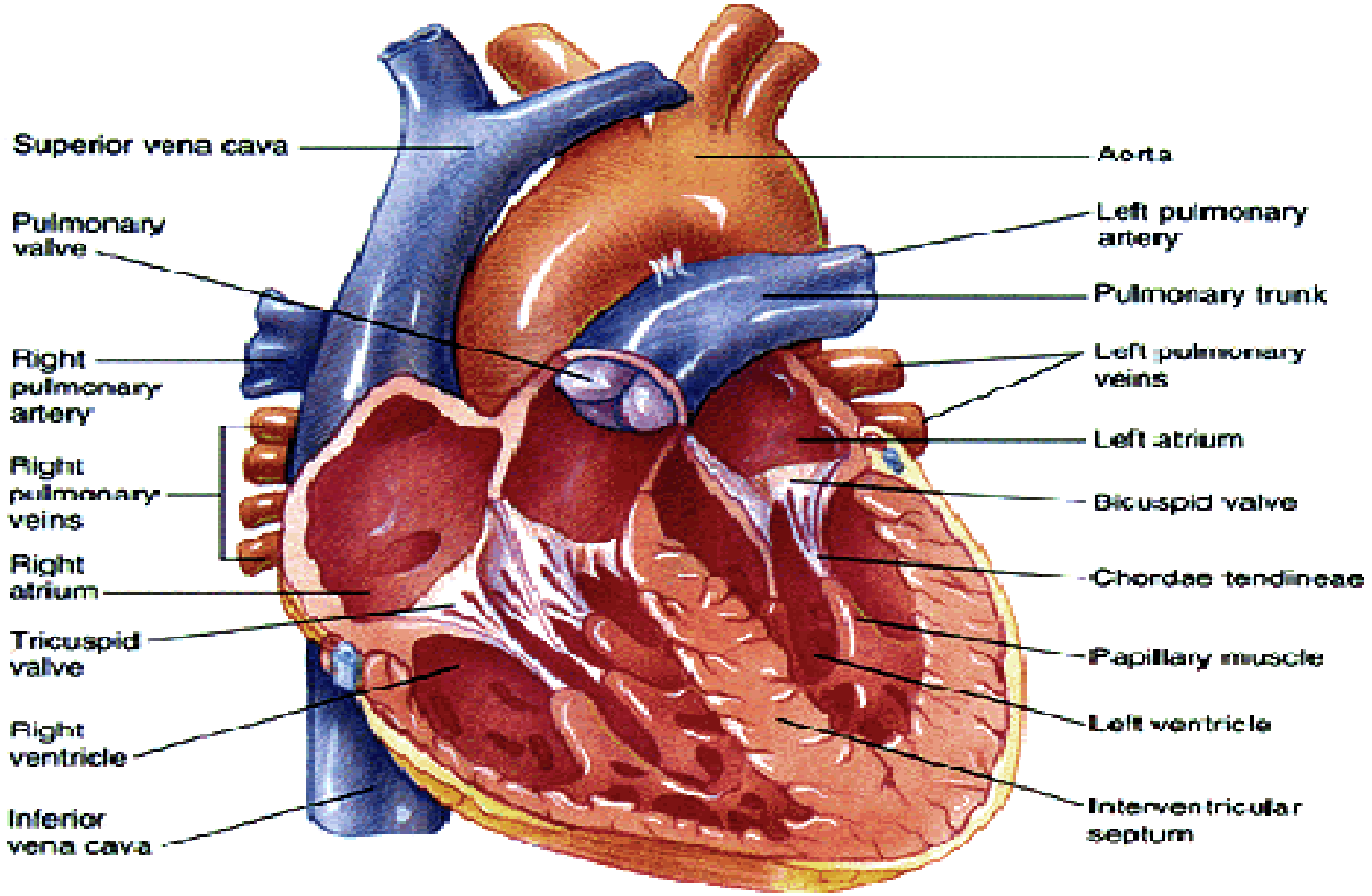
Cochlear implant

Drug pump & programmer

Neurostimulator

Medtronic

Cardiac anatomy



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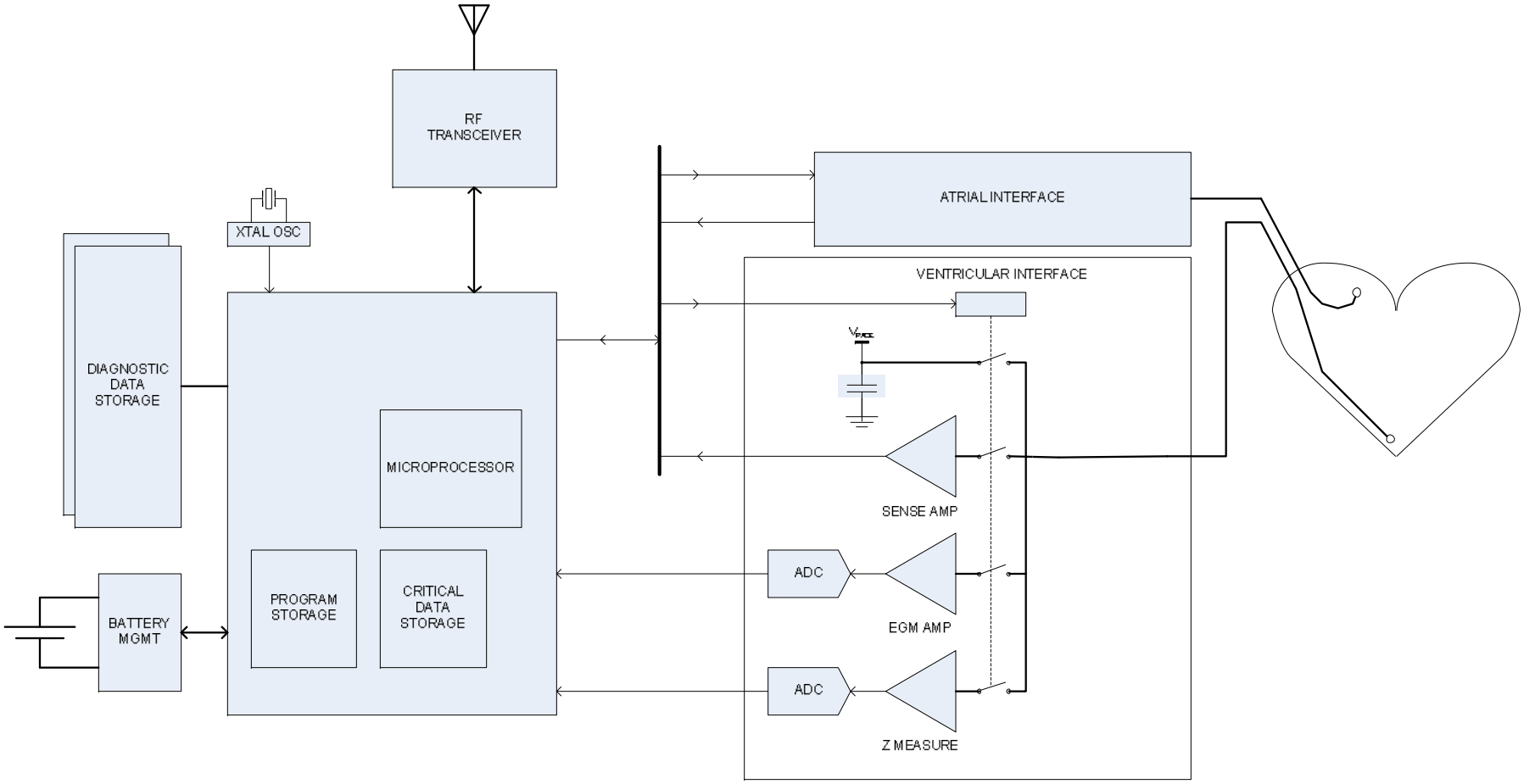
Simplified pacemaker



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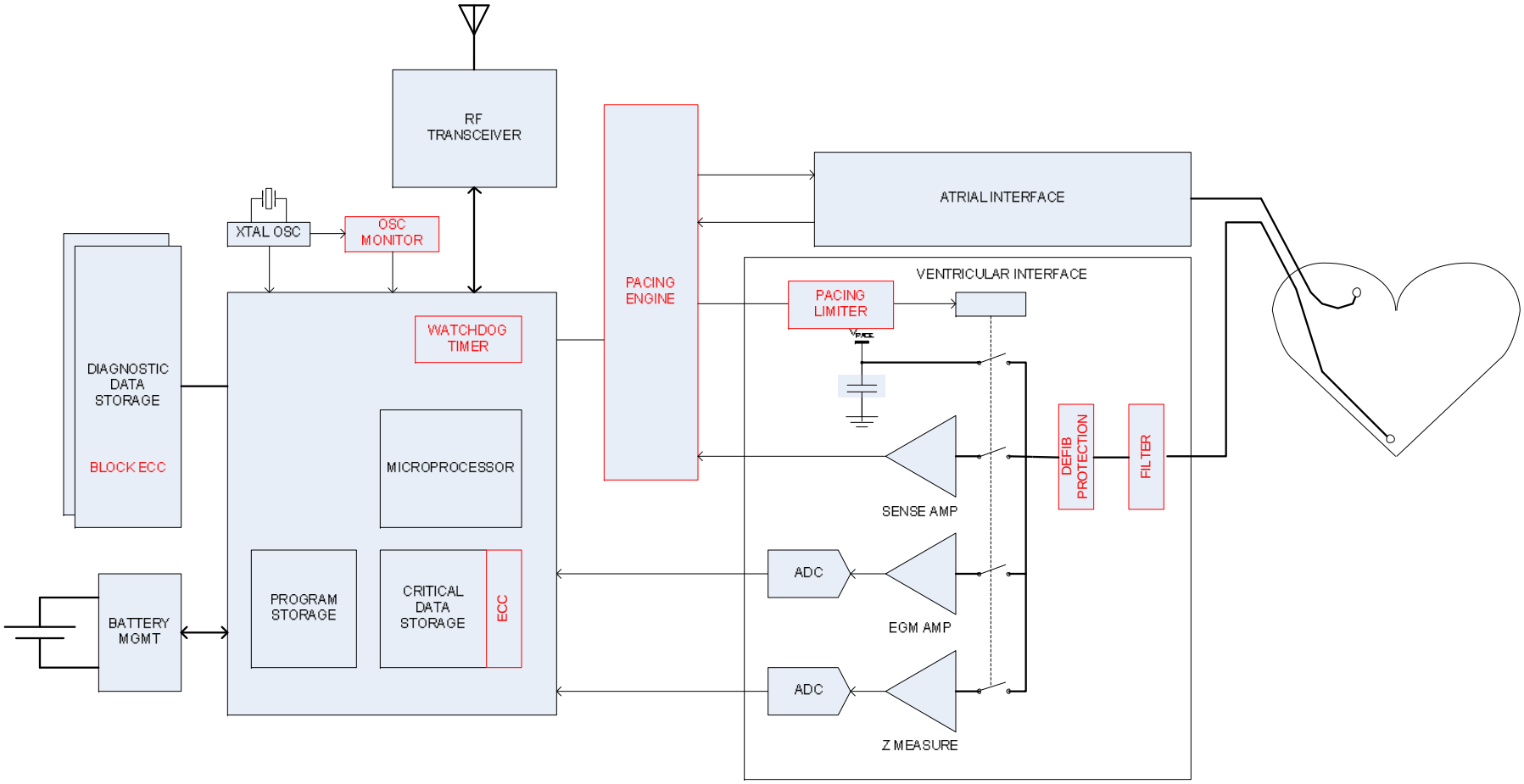
Pacemaker with redundancy



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Pacemakers Through the Years

5800

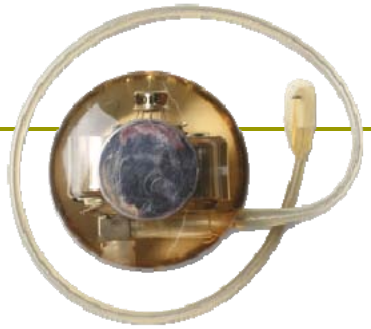
First External Pacemaker

1958

1960

First Implantable Pacemaker

Chardack-Greatbatch



5858

Pediatric Asynchronous Pulse Generator

1970

1979

Byrel®

Activitrax®

Rate response

1986

1989

Dual chamber rate response

Synergist™

MicroMinix®

Radically smaller size

1990

1991

Elite™

Thera ®

First Microprocessor-based, Mode switching

1995

1998

Rate response via activity & minute ventilation

Kappa®

EnPulse®

Full Automaticity

2004

2006

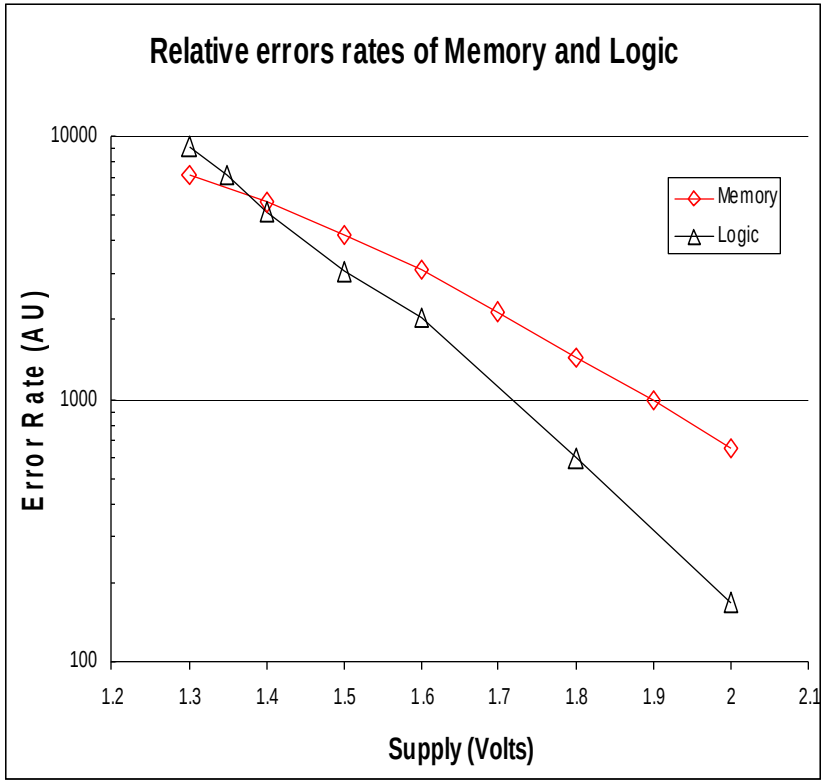
MVP, Full Automaticity

Adapta™

Trends & Requirements

- High reliability – extended service life
- No service calls or rebooting!
- Low power

Motivations for commercial devices



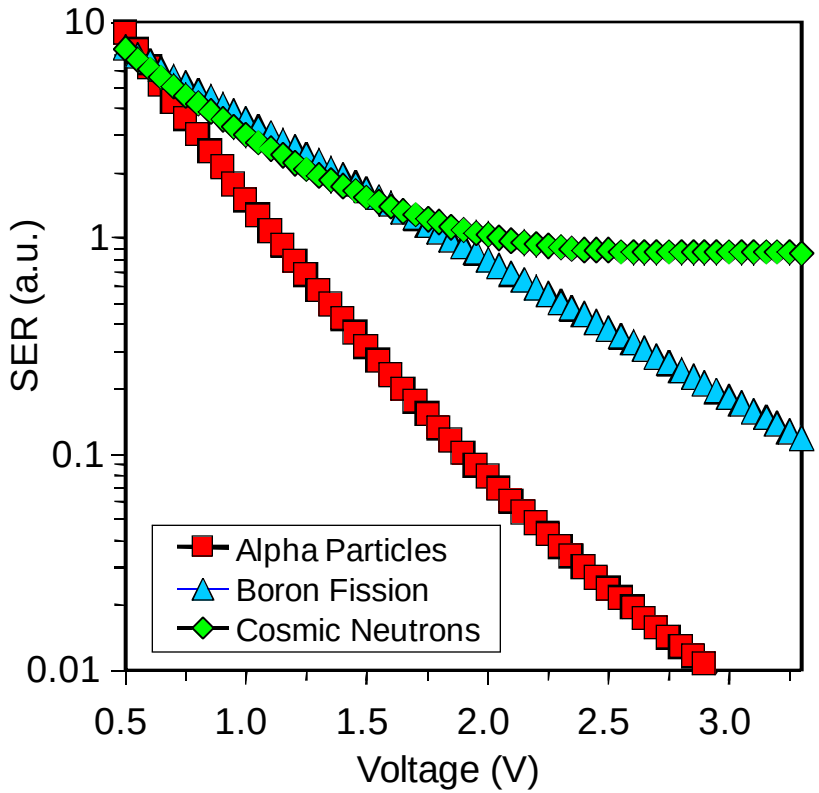
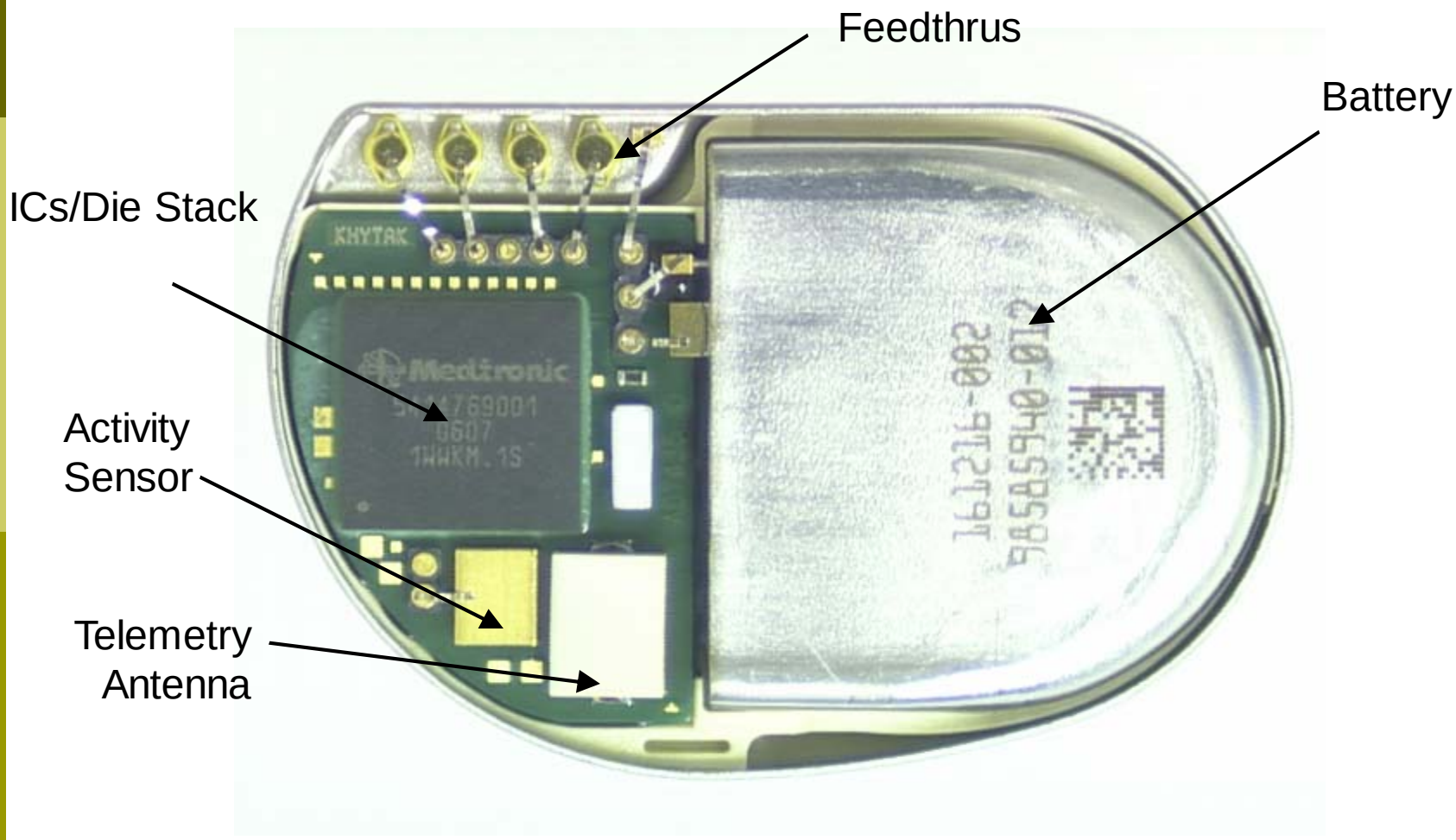


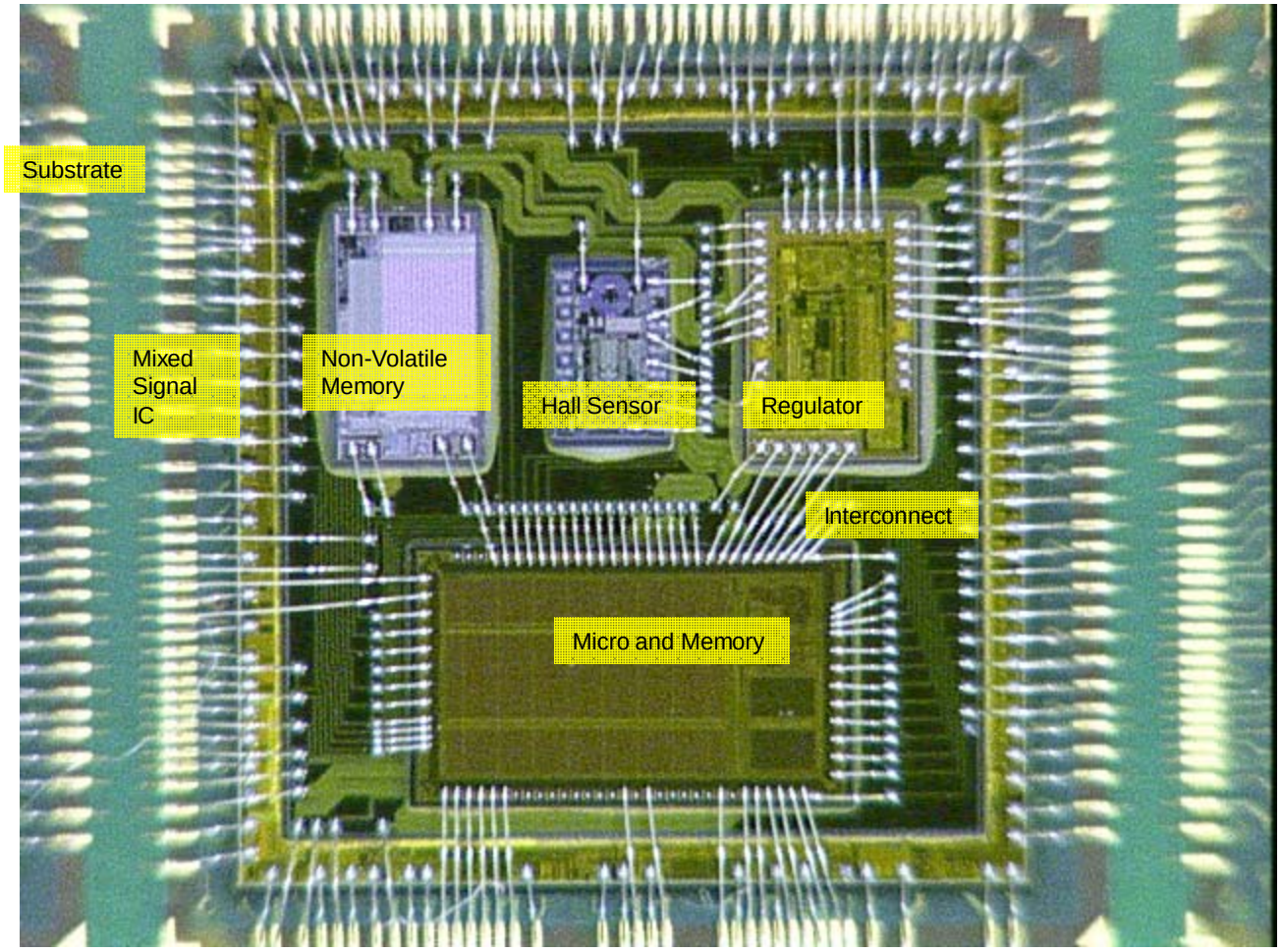
figure courtesy R. Baumann, 2008

What's Inside



Medtronic

Stacked IC Technology



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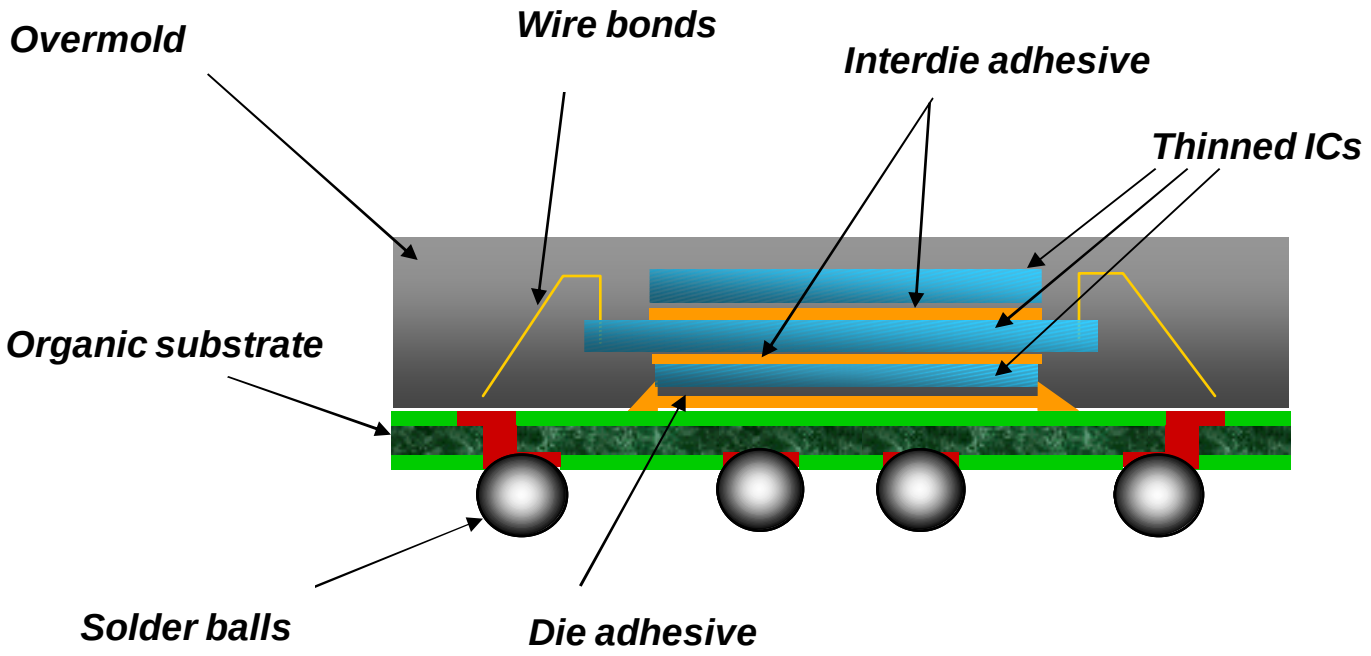
Simplified Stacked IC package



Appropriate materials selection

LOCTITE®

Technical Data Sheet

Hysol® QMI 536

March 2004

DMA Modulus @ 25°C, GPa DMA Modulus @ 25°C, psi	0.3 43,000	TM 458	
Volume Resistivity, ohm-cm	$>10^{13}$	TM 572	
Dielectric Constant @ 1 MHz, 25°C	2.6	TM 588	
Thermal Conductivity, W/m°K	0.3	ASTM 1461	
α emissions count particles/cm²/hr	0.0007	DITM 0031A	

The above figures are typical material properties only and are not to be used for material specification purposes. To generate a specification

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QMI 536 is a

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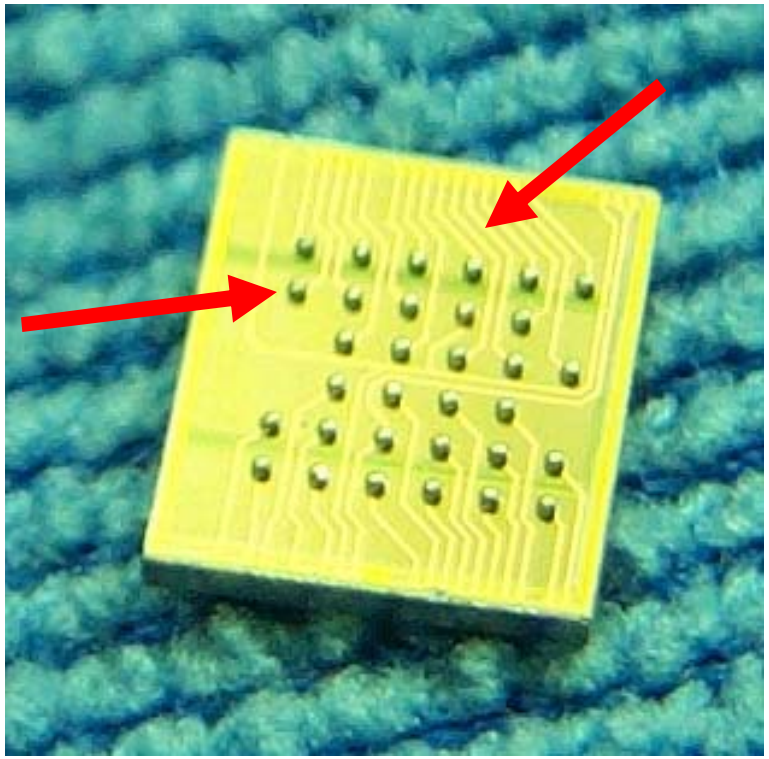
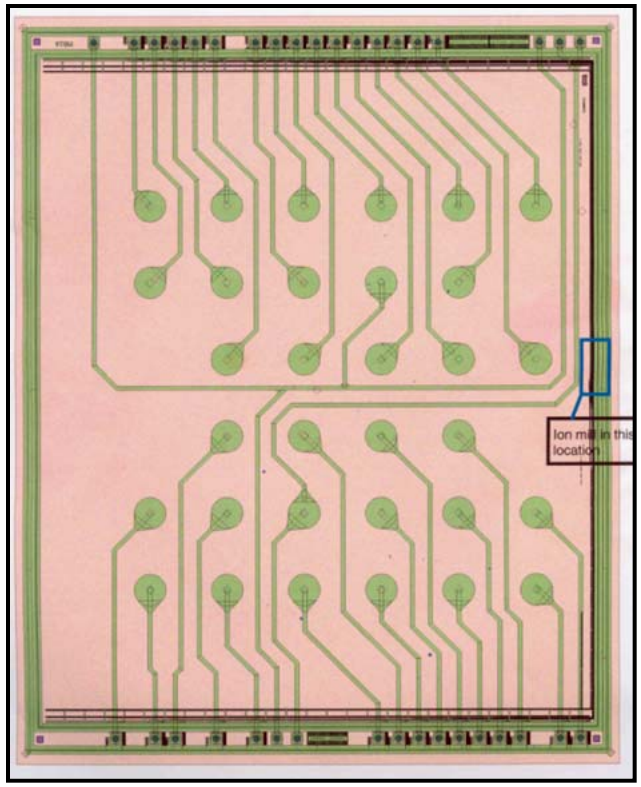
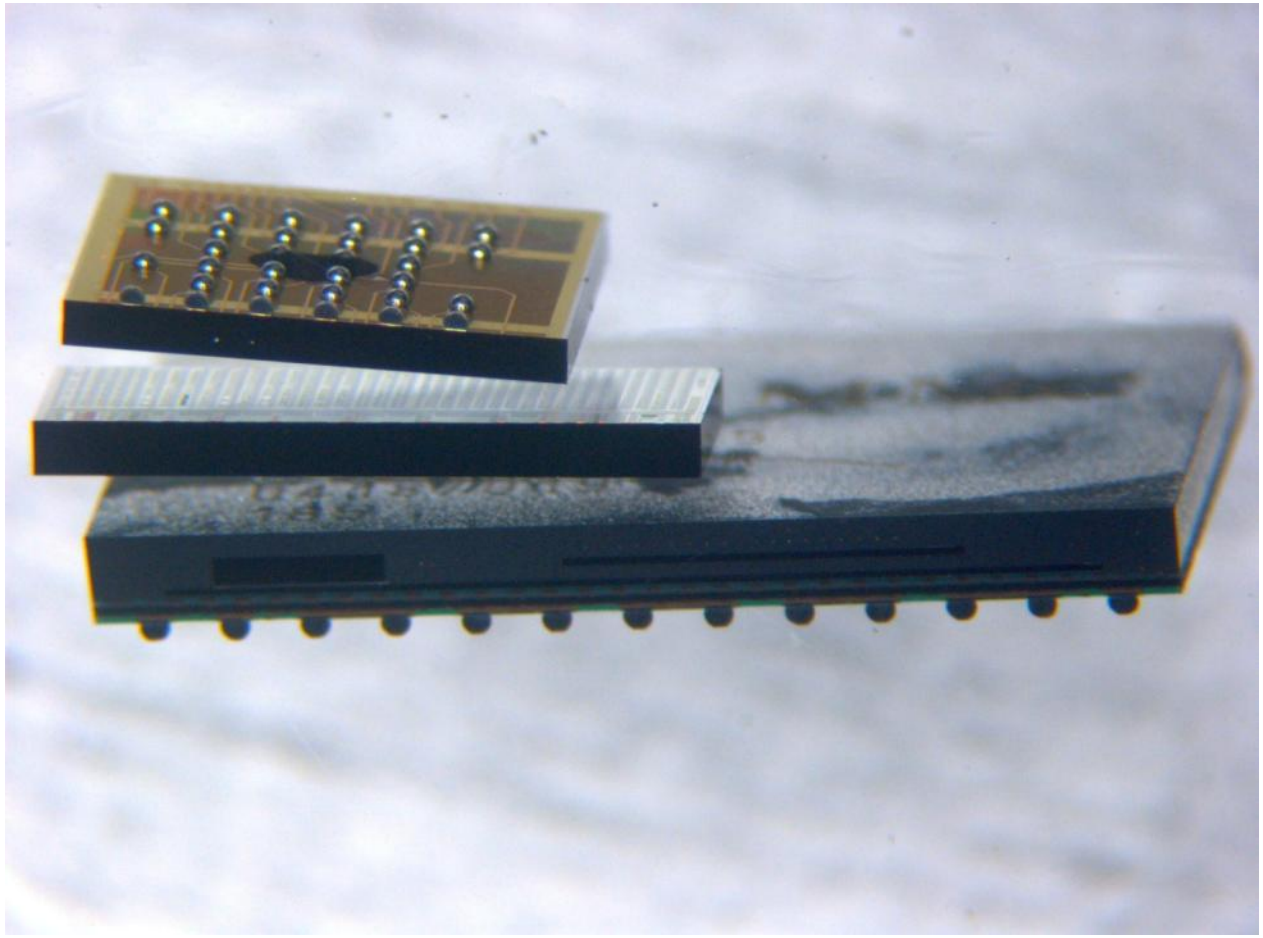
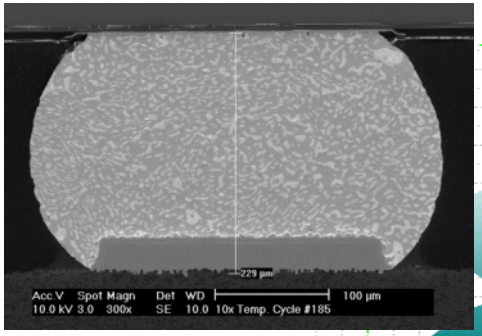
Case Study: Chip Scale Packaging

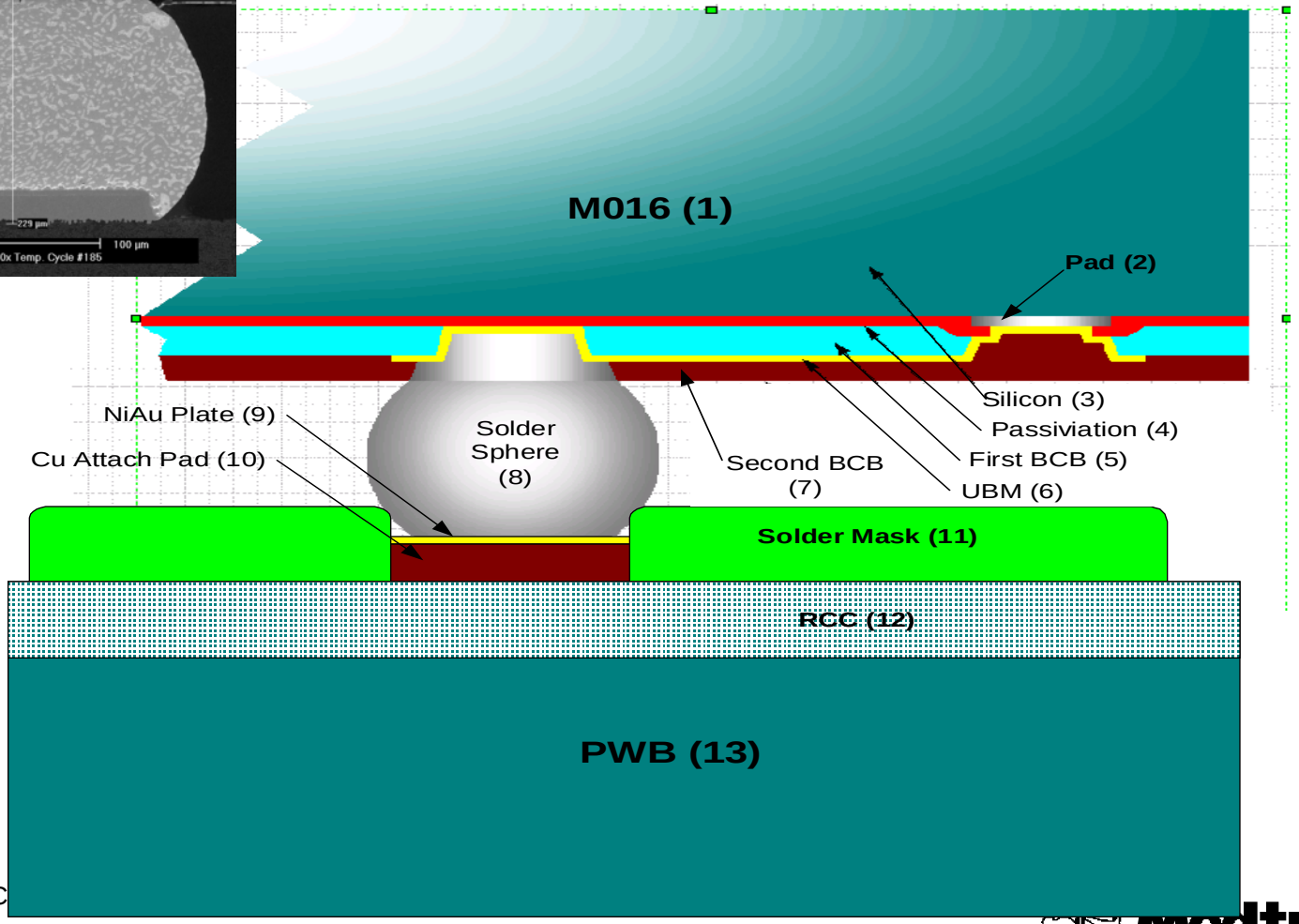
Chip scale SRAM package detail








Acc.V Spot Magn Det WD 100 µm
10.0 kV 3.0 300x SE 10.0 10x Temp. Cycle #185


M016 (1)
Pad (2)
Silicon (3)
Passiviation (4)
First BCB (5)
UBM (6)
Second BCB (7)
Solder Sphere (8)
NiAu Plate (9)
Cu Attach Pad (10)
Solder Mask (11)
RCC (12)
PWB (13)

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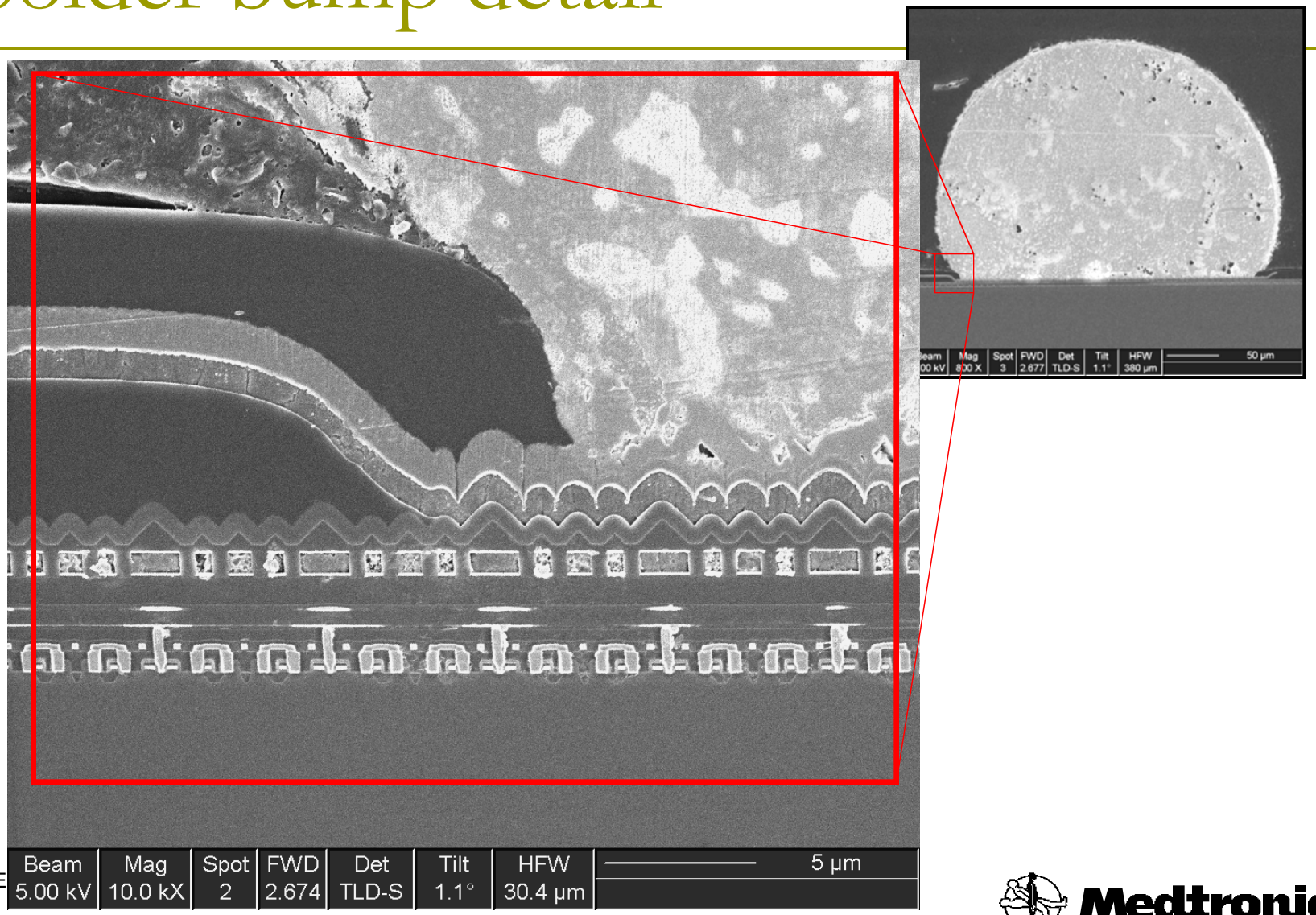
Solder bump detail



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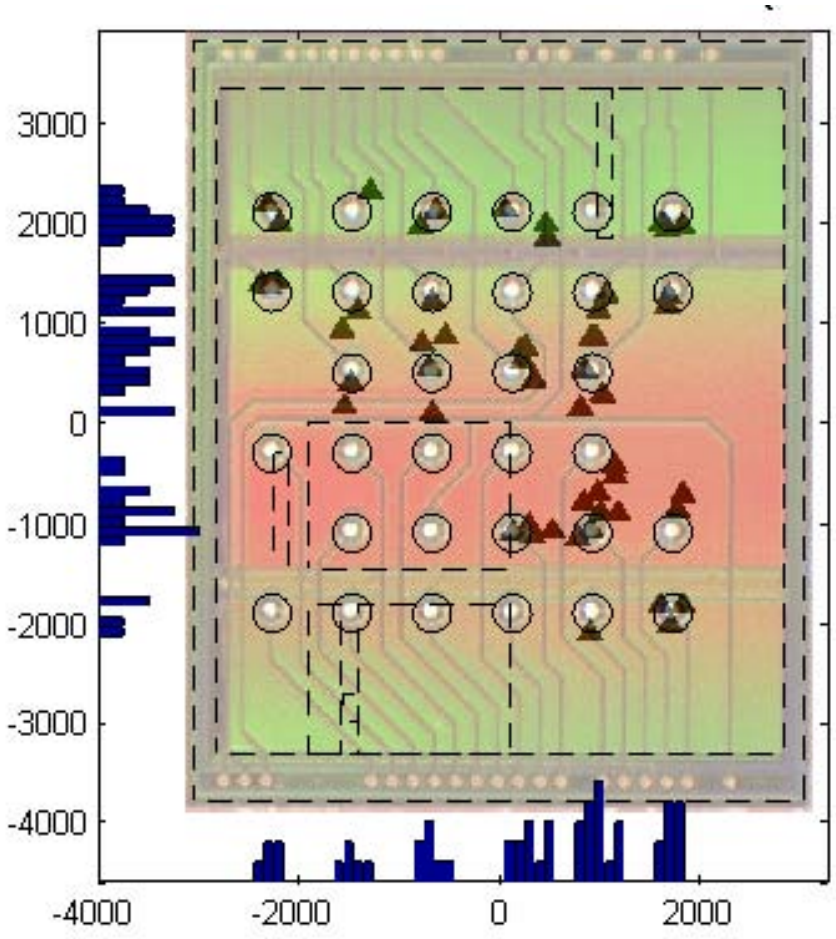
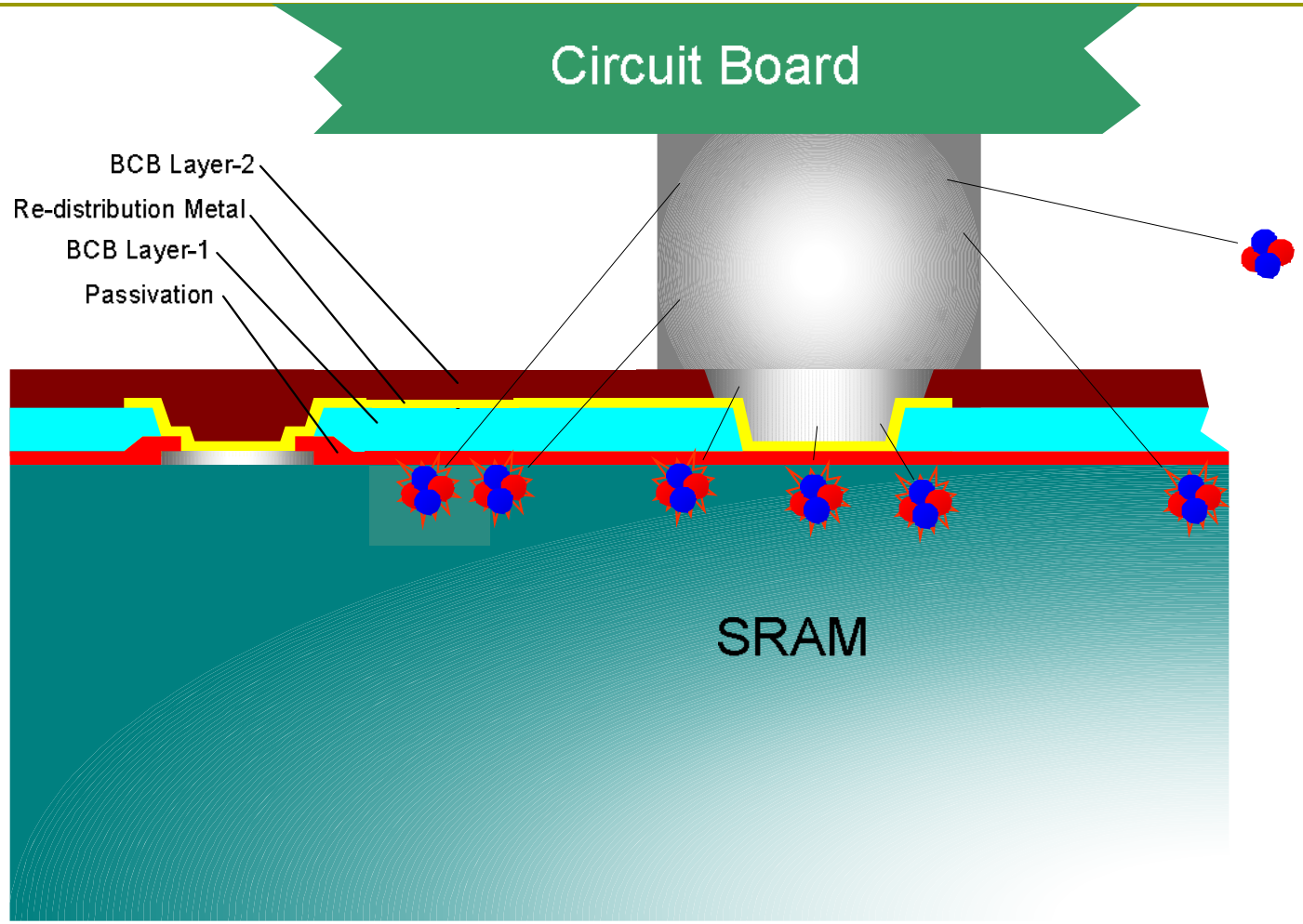
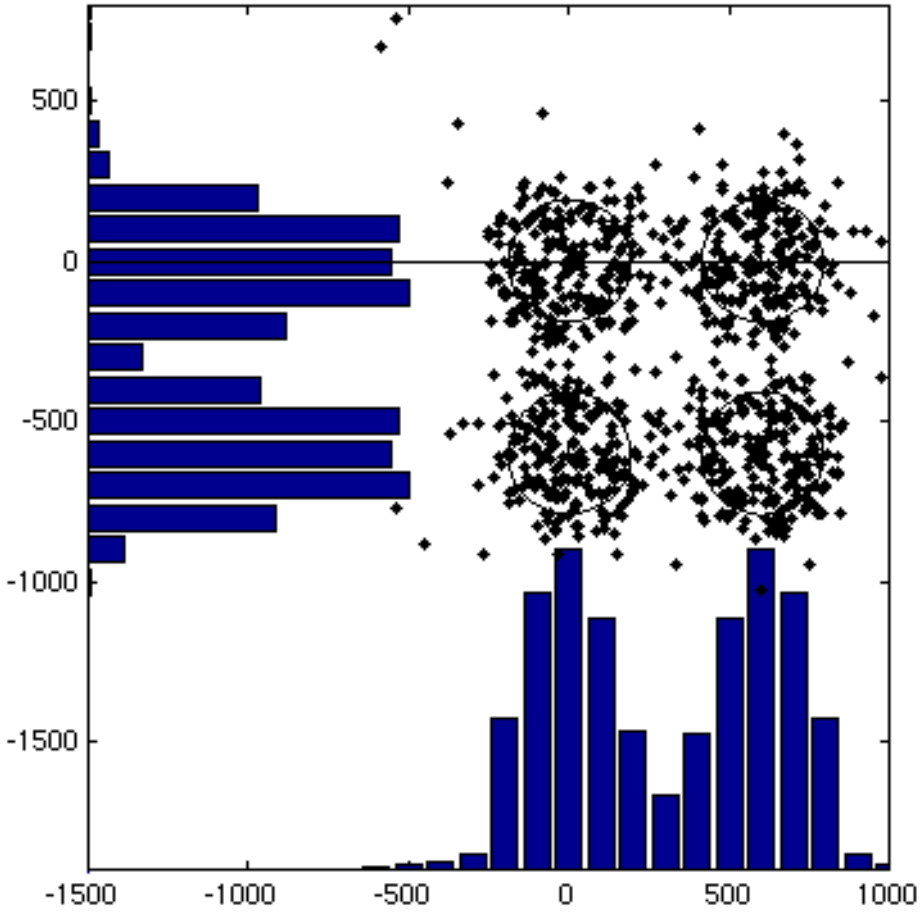
Physical error mapping



α-particles from solder balls



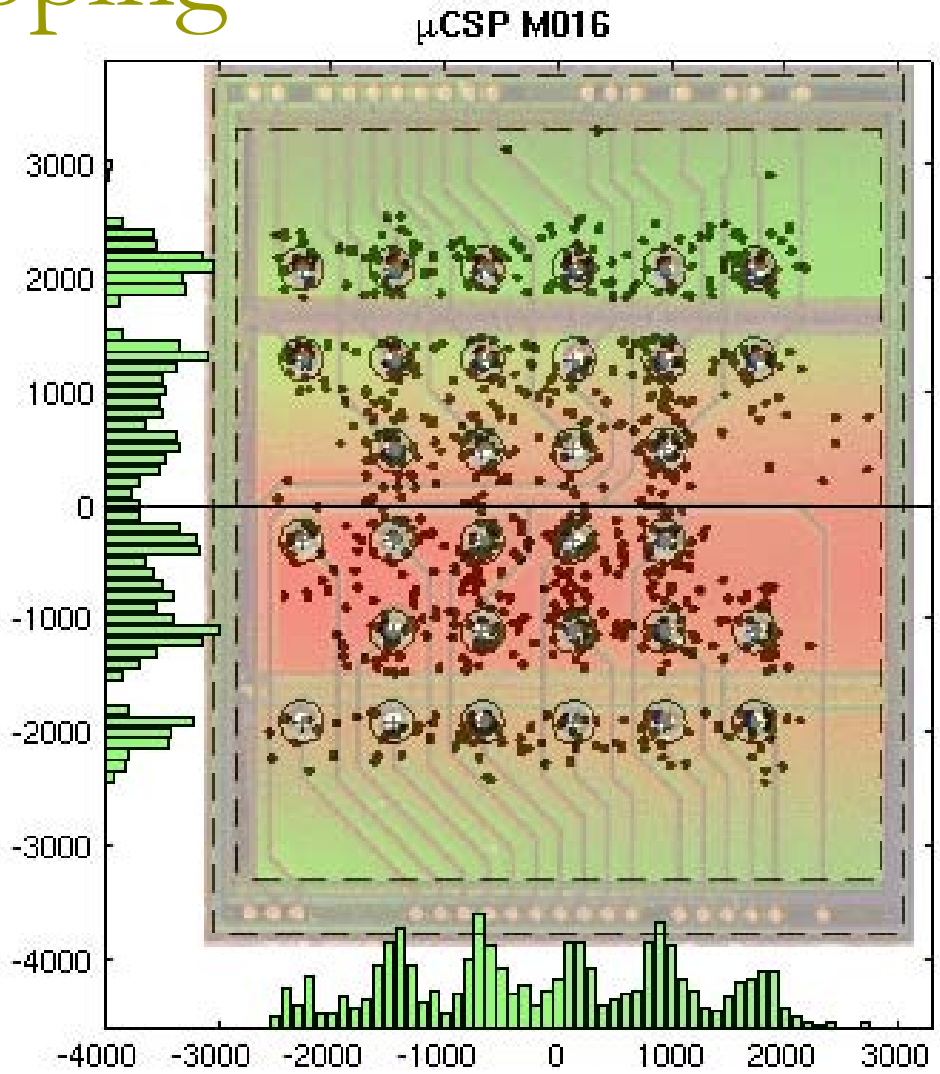
Soft-error range modeling



Wilkinson, Hareland, IEEE T-DMR, Sep. 2003

Medtronic

Error mapping



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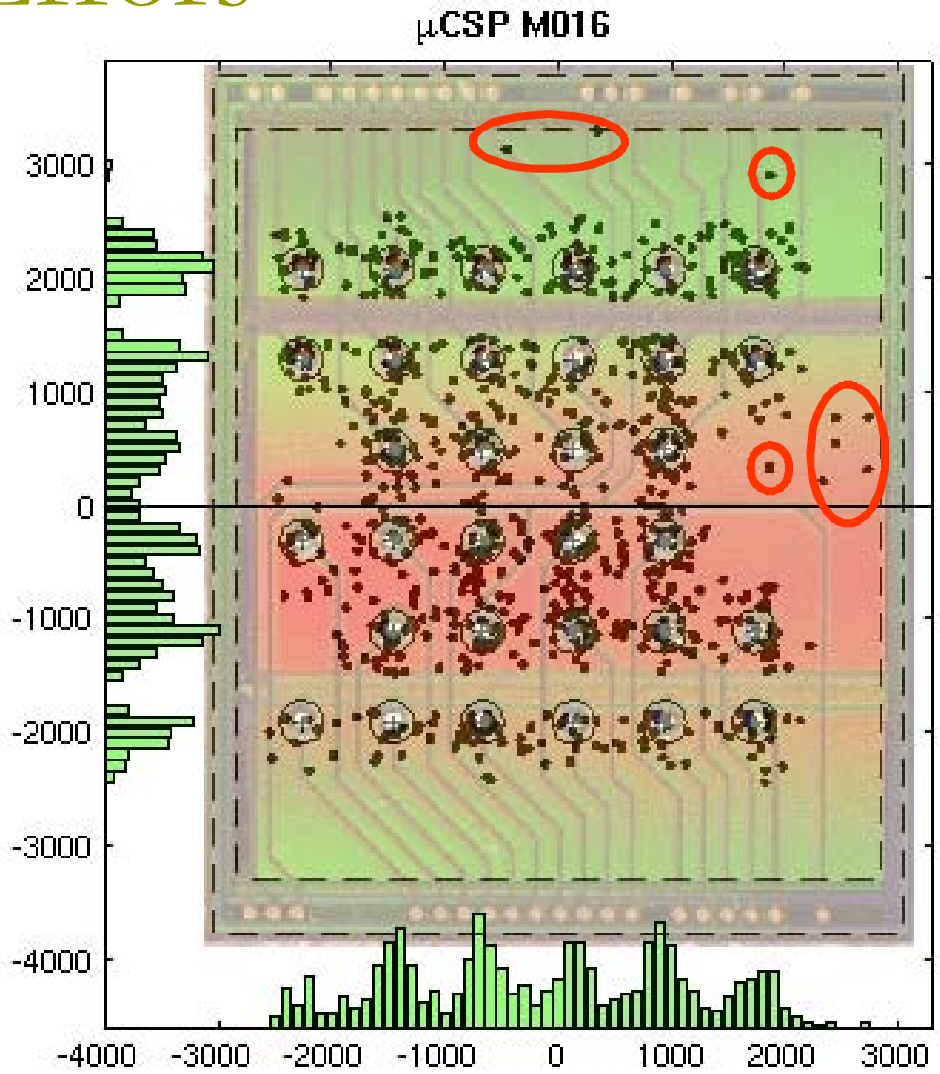
Residual Errors



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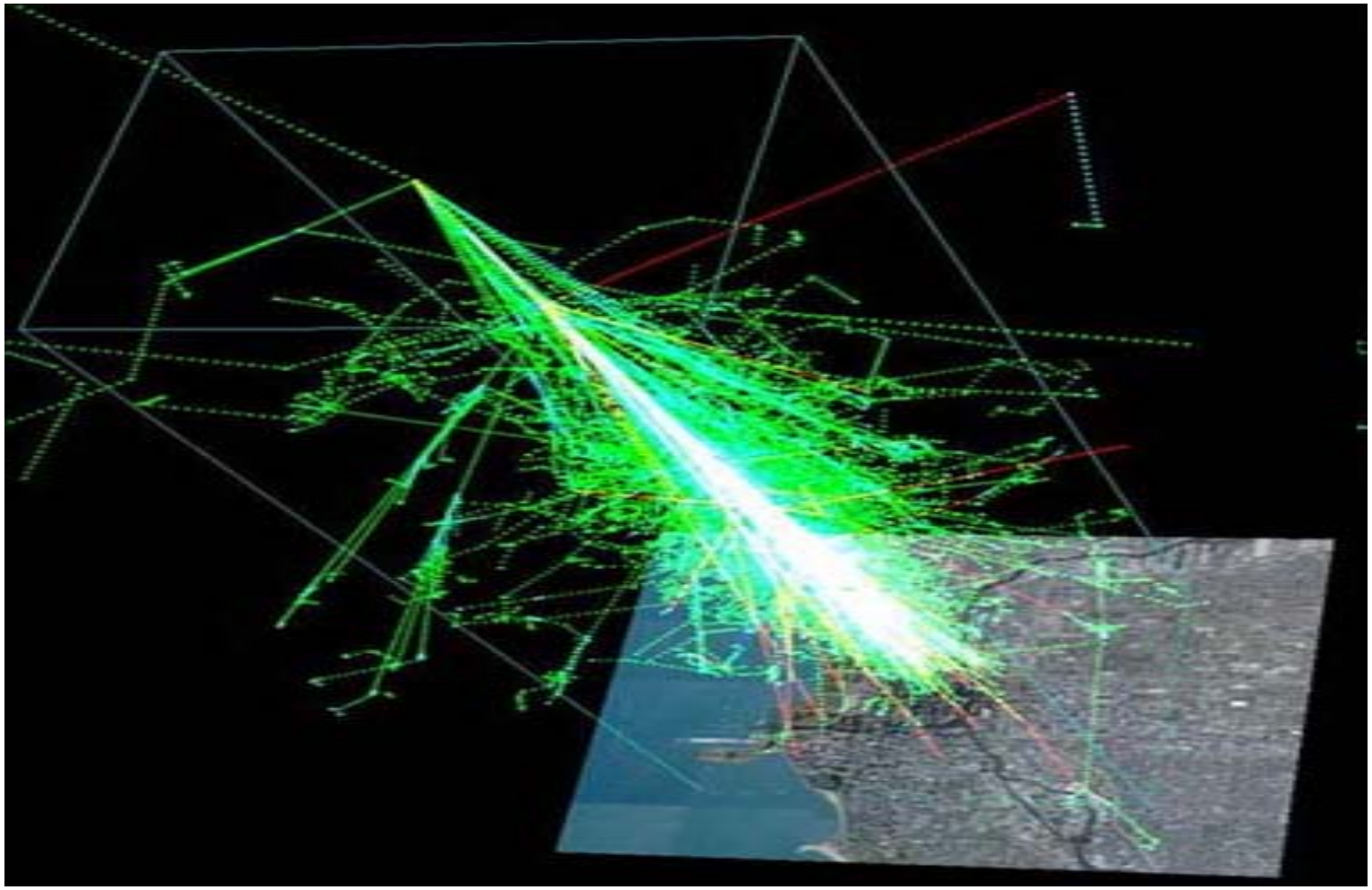
Cosmic rays?



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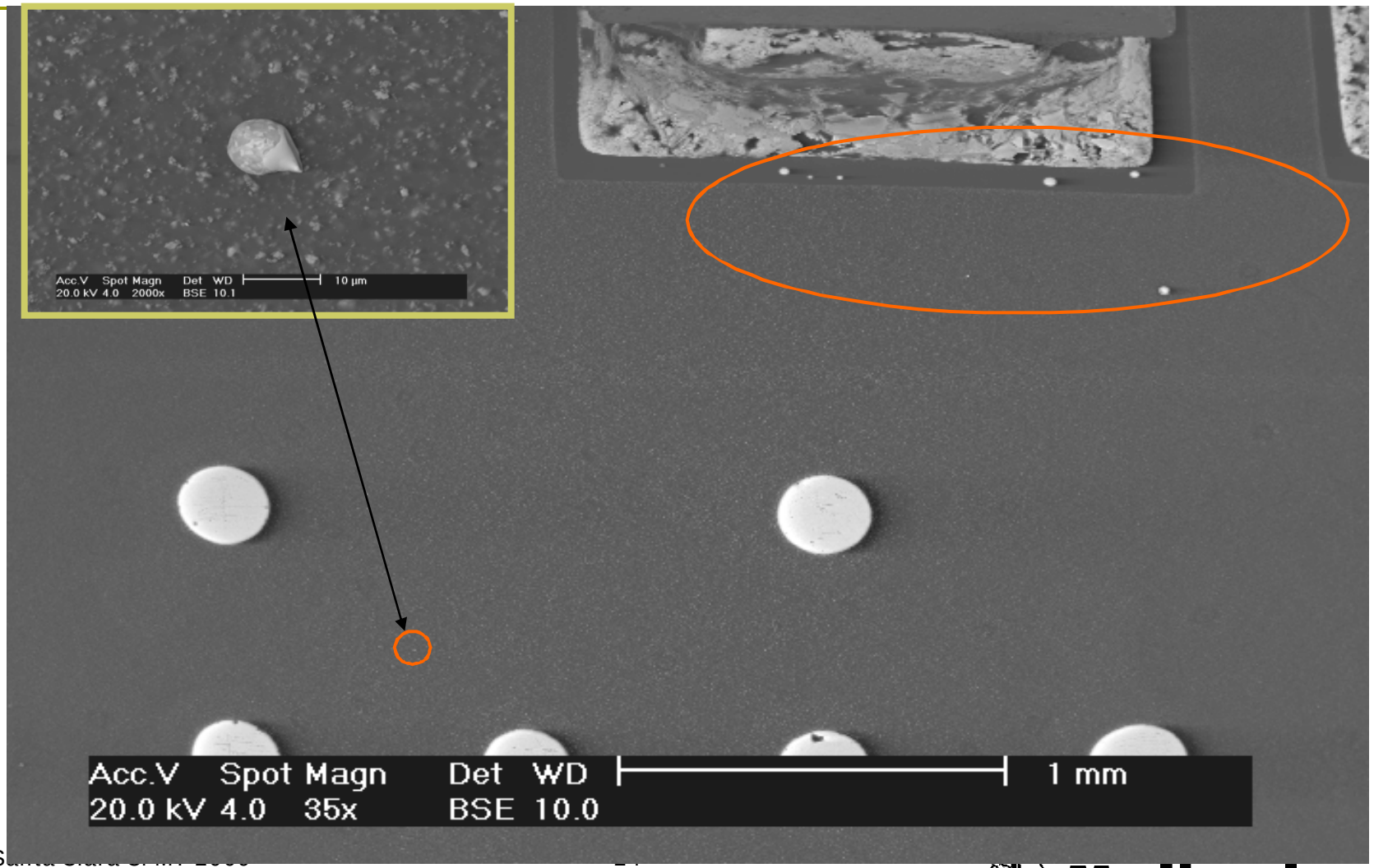
Solder spits?



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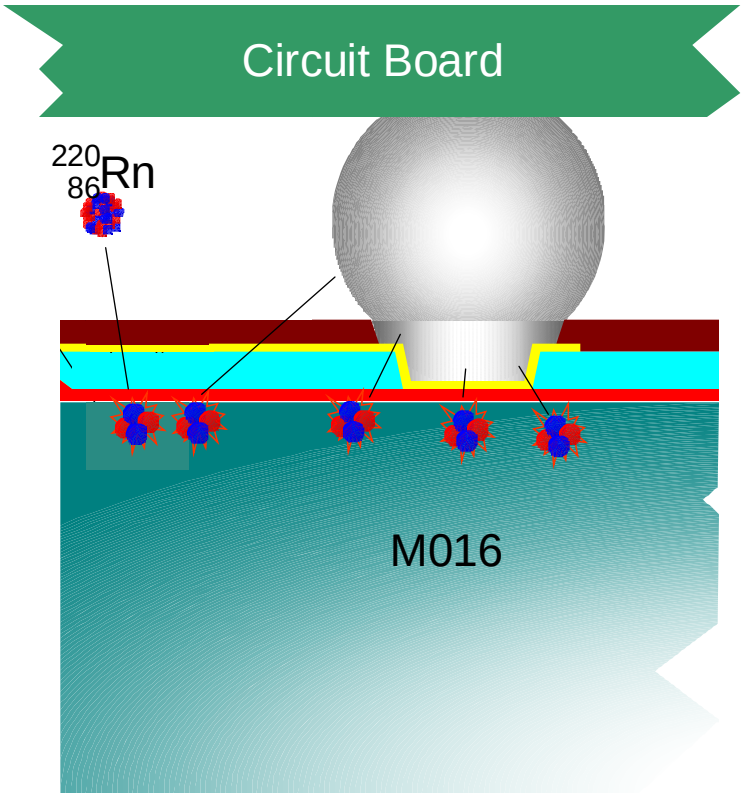
Data and photographs courtesy of Mark Henschel

Radon in the air?



- Radon is an α emitter
- 10 pCi/liter would explain excess errors
- EPA limit for homes is 4 pCi/liter

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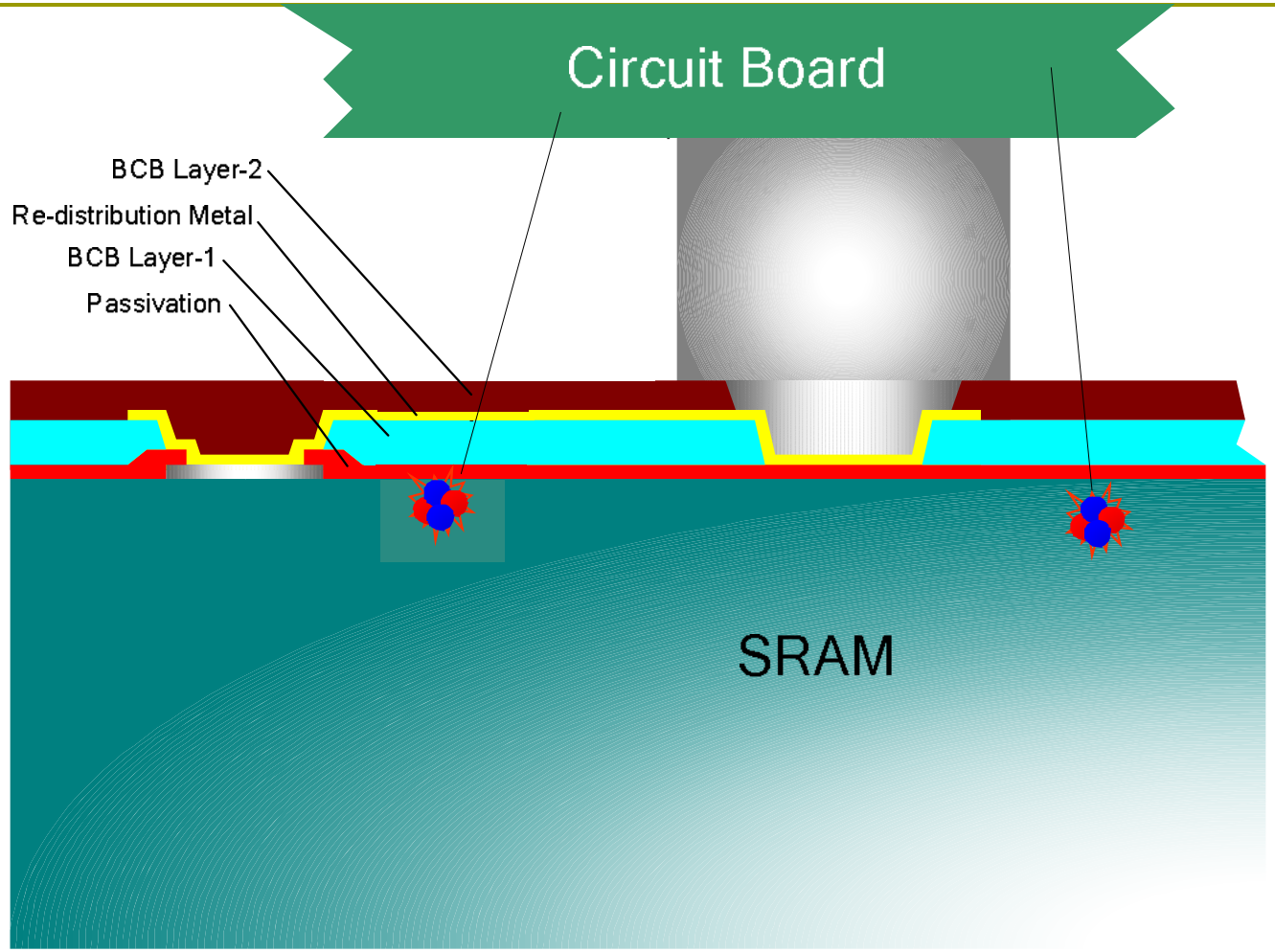
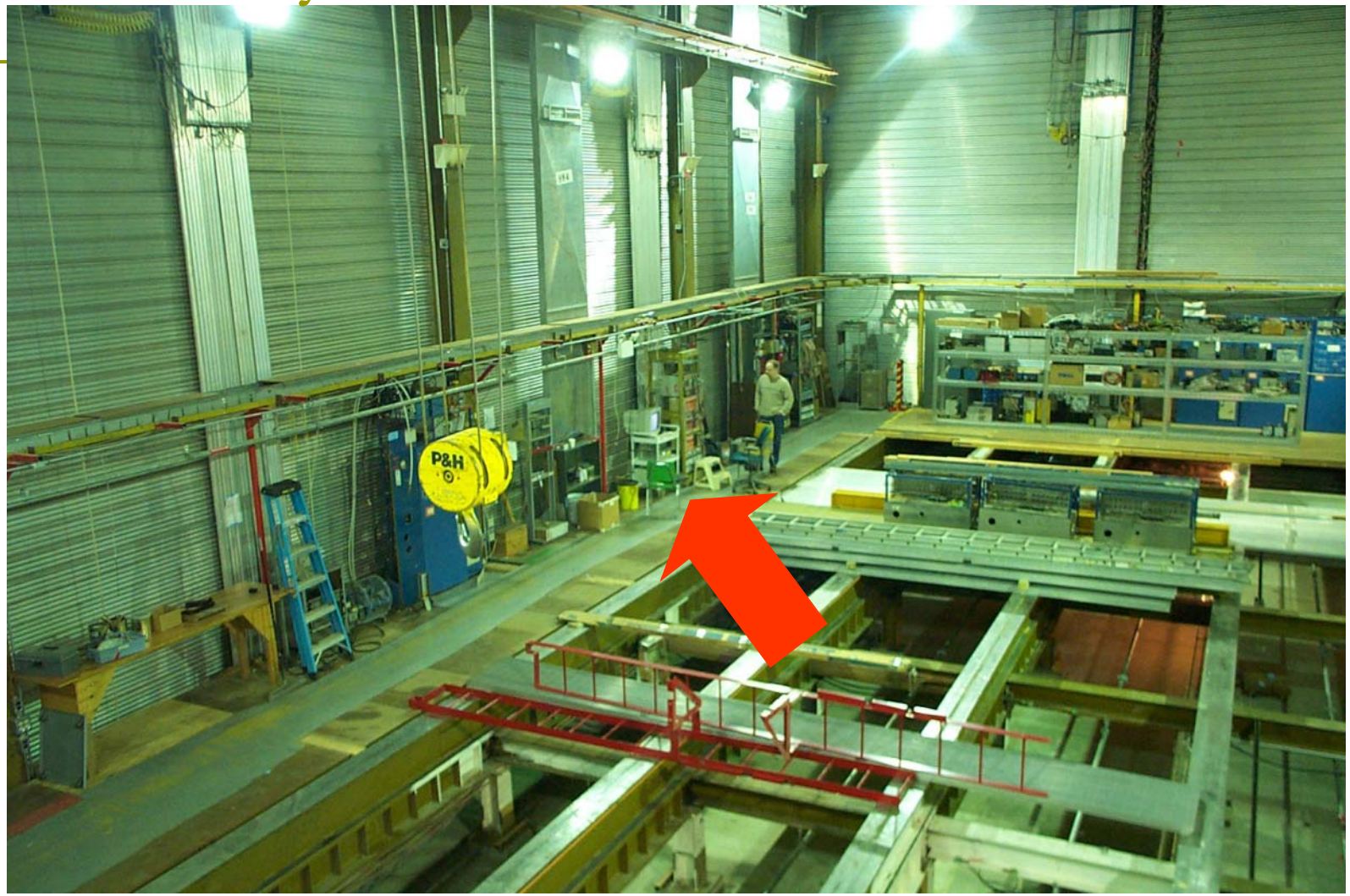
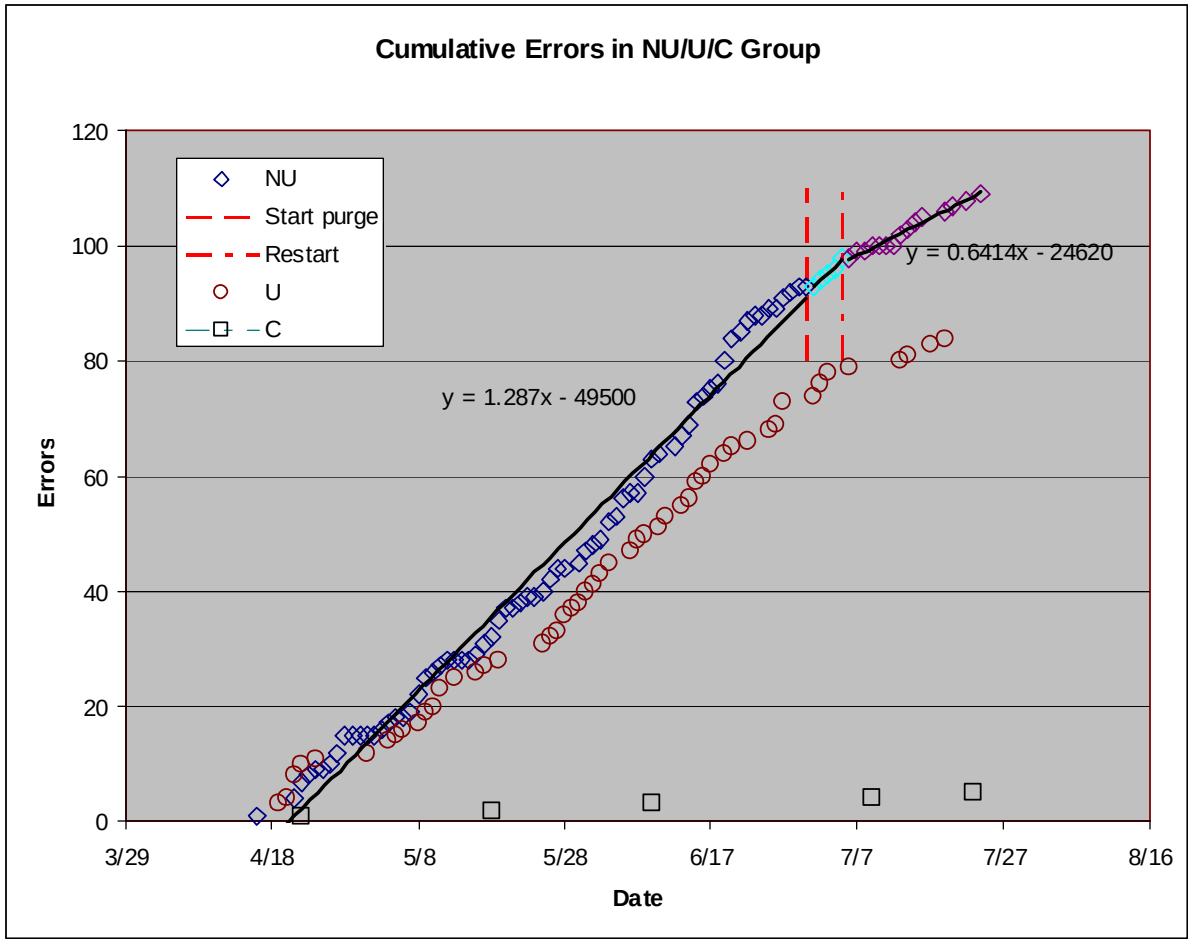
α-particles from circuit board



Bulk Memory Test at Soudan Iron Mine



Soudan Iron Mine Data



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Error rate summary

Experiment	Error Rate (a.u./Mbit)
Original spheres, no underfill	100
Low-alpha spheres, no underfill	2
Low-alpha spheres, clean underfill	0.5

Wilkinson et al, 2005

Excellent materials are available…

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Technical Data Sheet

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March 2004

PRODUCT D
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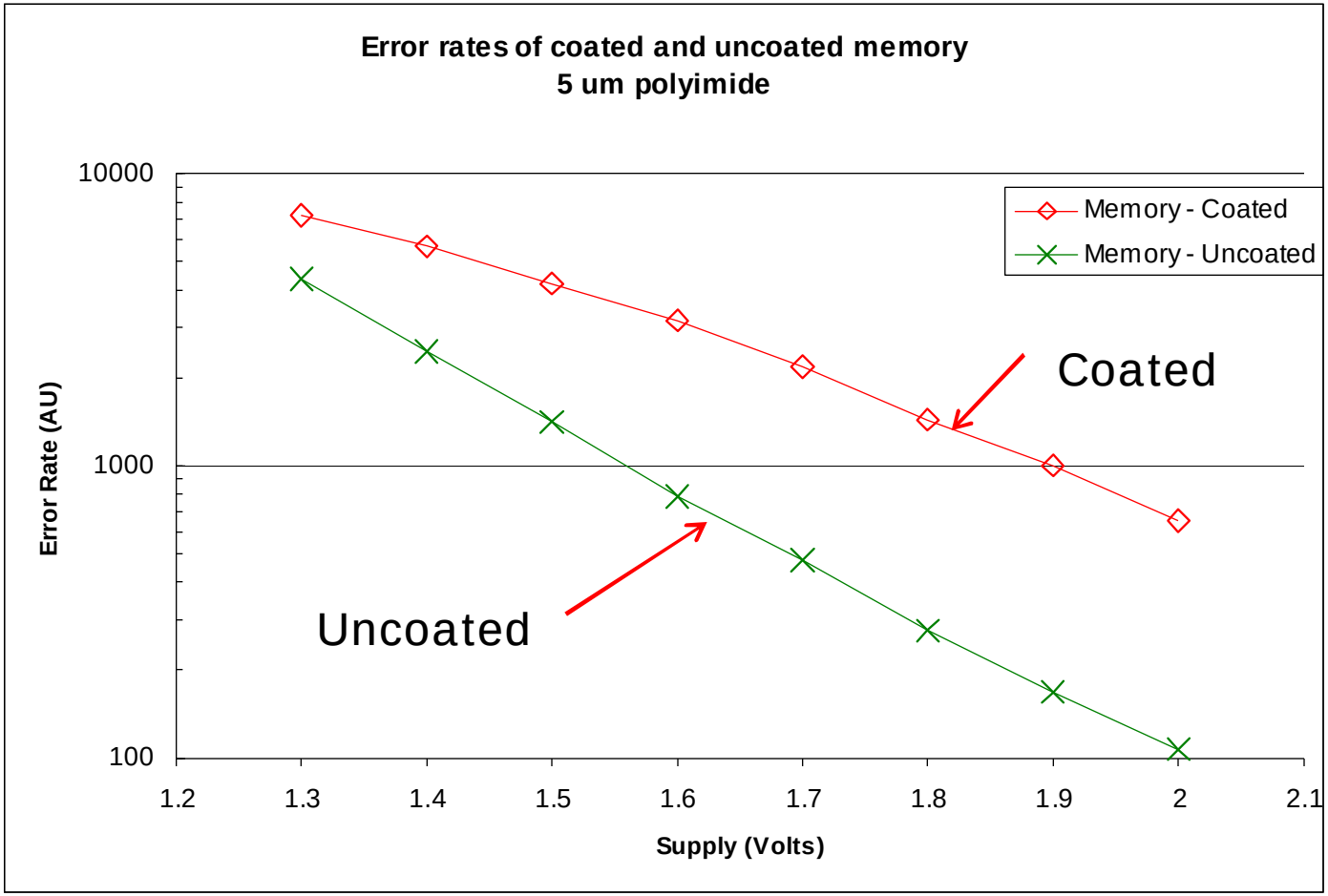
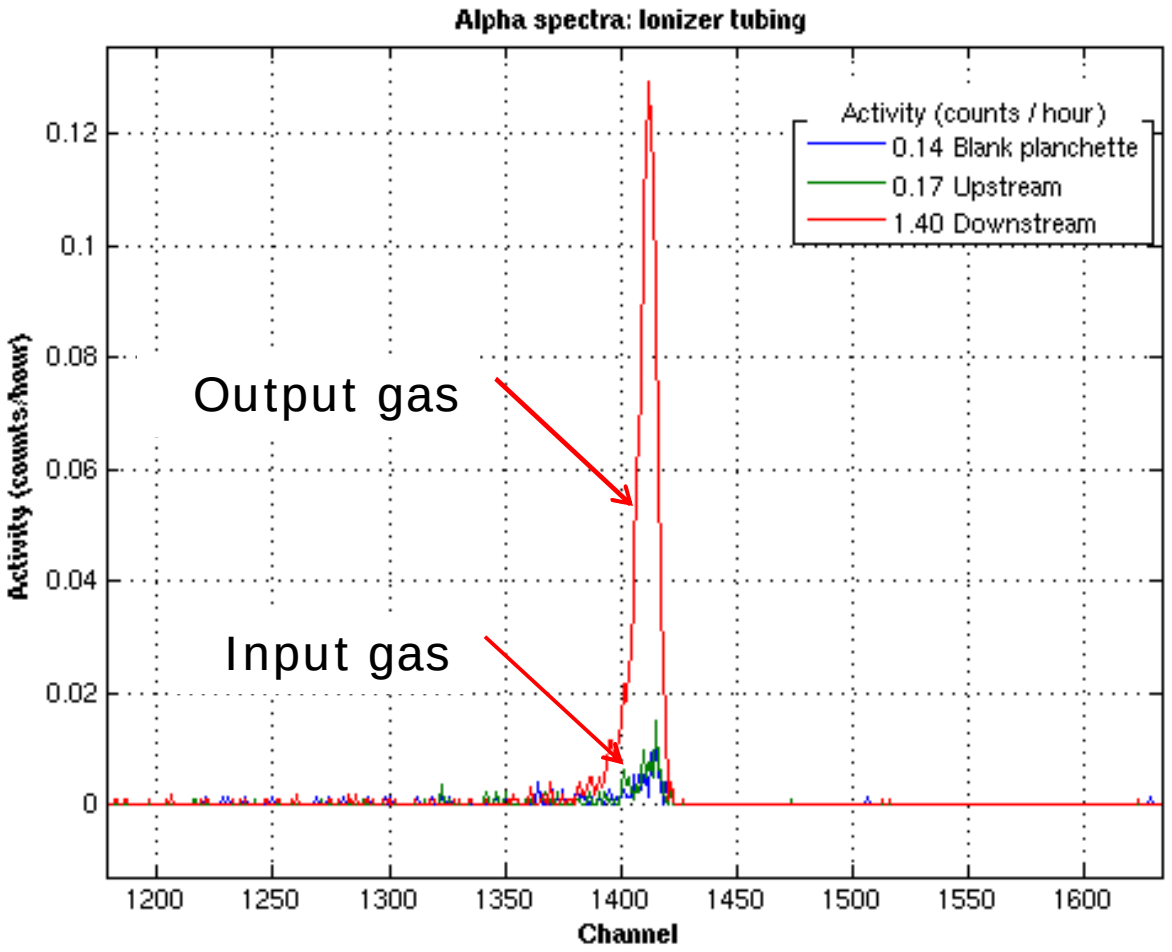
Low-α coatings

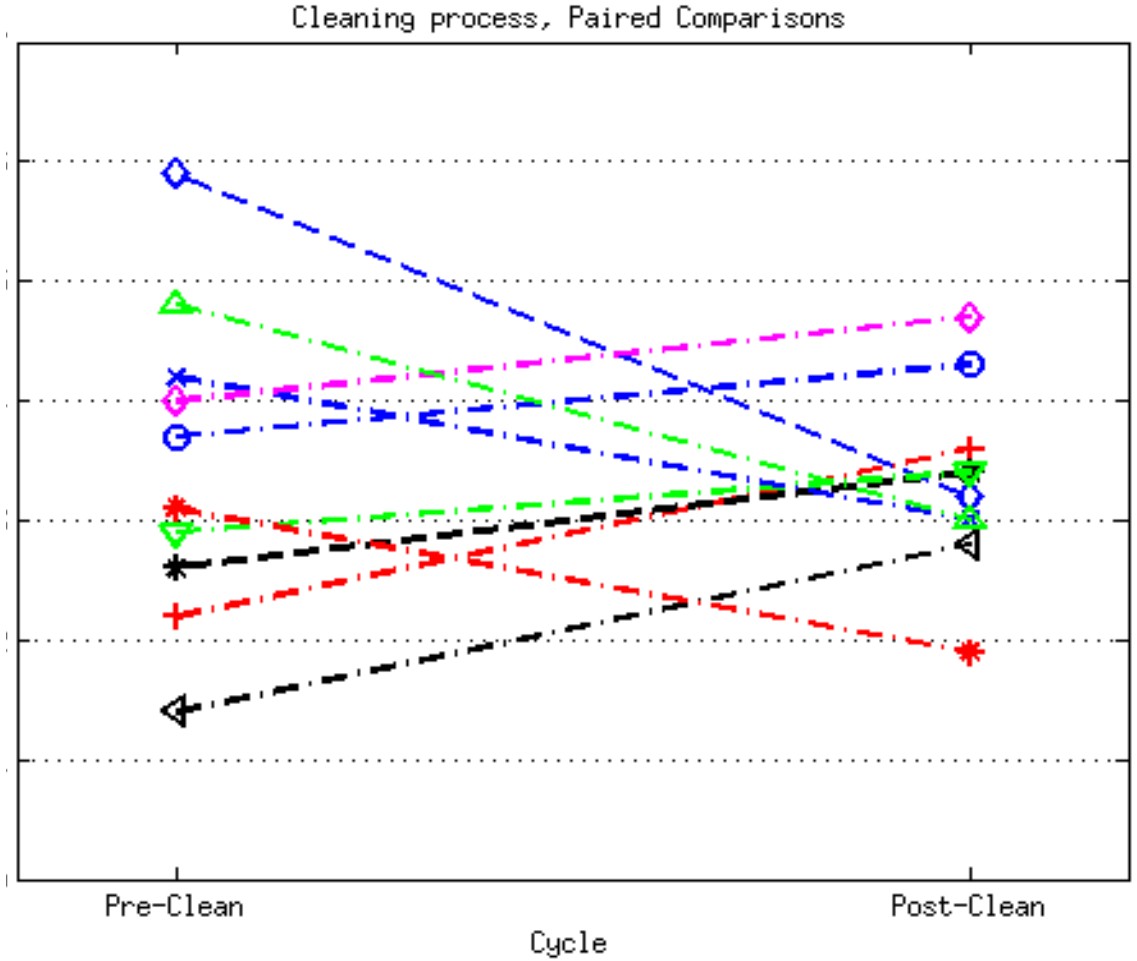


Manufacturing process will dominate

^{210}Po ionizer for static control



Low-α manufacturing



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Conclusions

- Commercial trends are making SEU an everyone's problem.
  - Packaging
  - Feature sizes
  - Supply voltages
  - System complexity
- Package engineering is critical to success.
- High quality packaging materials are available…

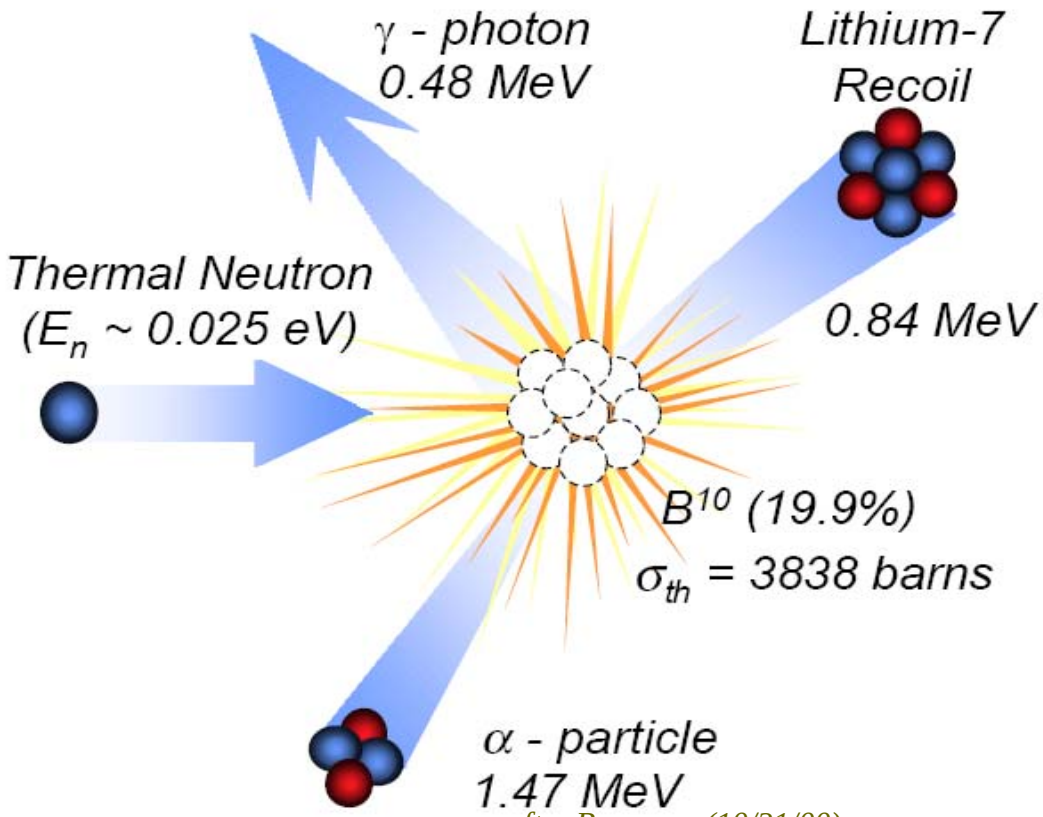
… but …

… the process determines alpha performance.

Questions?

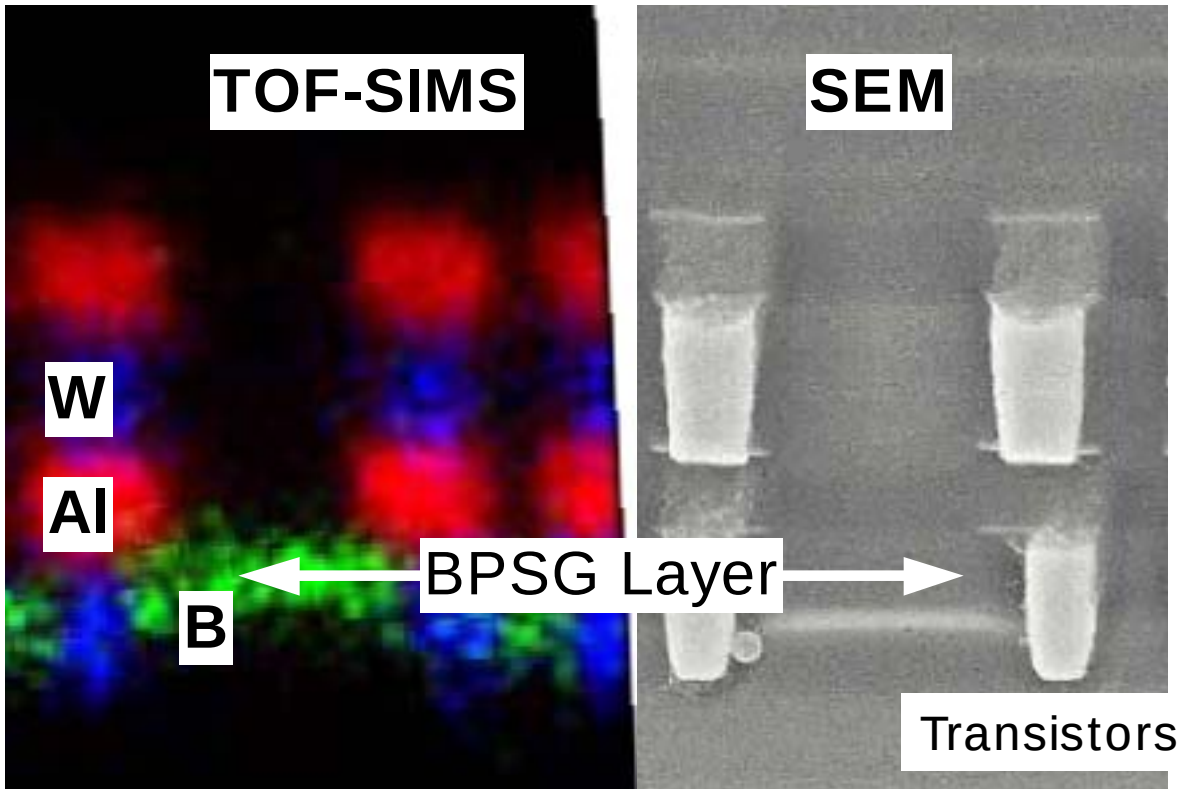
- JESD89A – JEDEC standard for soft-error testing.
- www.seutest.com – JESD89A soft-error testing resources

What's so special about boron?



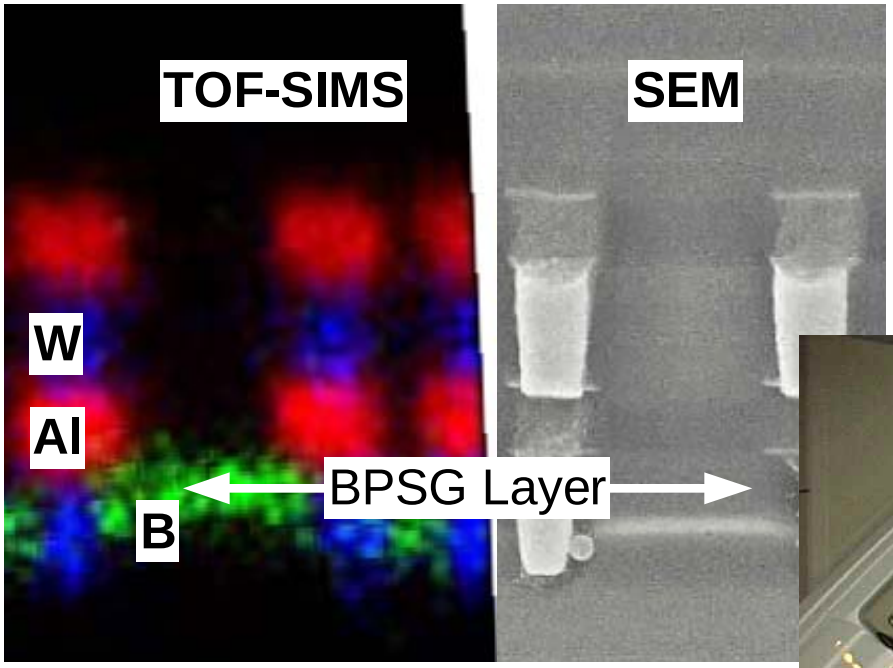
after Baumann (10/31/00)

Typical IC cross section



Wilkinson et al, 2005

BPSG and thermal neutrons are still problems for end users.



BPSG is still found in commonly available ICs.

Thermal neutron environment near cancer radiotherapy is $40x10^6$ X accelerated, leading to severe problems for medical devices

Wilkinson, et al, IEEE Transactions on Device and Materials Reliability, 2005

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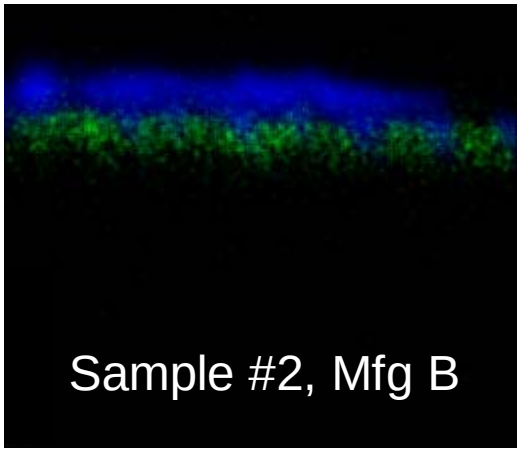
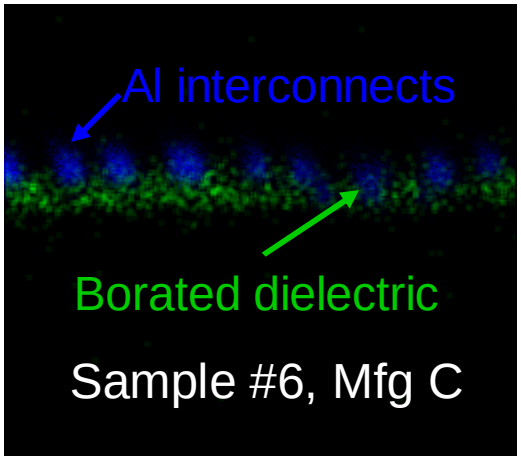
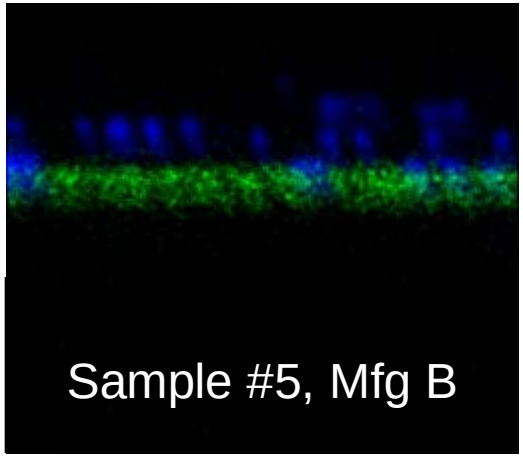
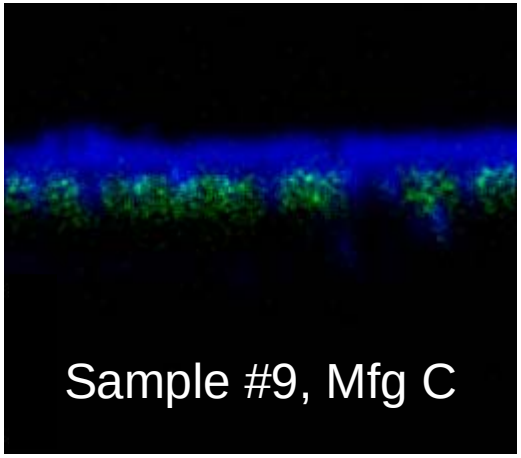
TOF-SIMS results for commercial ICs









Medtronic