Soft errors considerations for low power, high reliability applications

IEEE Santa Clara Components, Packaging and Manufacturing Technology Chapter

10/30/2009
Implanted electronic medical devices

- Implantable defibrillator
- Pacemaker & leads
- Implantable cardiac monitor
- Neurostimulator
- Deep brain stimulator
- Cochlear implant
- Drug pump & programmer
Cardiac anatomy
Simplified pacemaker
Pacemaker with redundancy
Pacemakers Through the Years


Trends & Requirements

- High reliability – extended service life
- No service calls or rebooting!
- Low power
Motivations for commercial devices

![Graph showing relative errors rates of Memory and Logic](figure)

![Graph showing SER in different voltages](figure)

Relative errors rates of Memory and Logic

Supply (Volts)

Voltage (V)

Error Rate (AU)

SER (a.u.)

**figure courtesy R. Baumann, 2008**
What’s Inside

- Battery
- ICs/Die Stack
- Activity Sensor
- Telemetry Antenna
- Feedthrus
- Battery
Stacked IC Technology
Simplified Stacked IC package

- Overmold
- Wire bonds
- Interdie adhesive
- Thinned ICs
- Organic substrate
- Solder balls
- Die adhesive

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Appropriate materials selection

Technical Data Sheet

Hysol® QMI 536
March 2004

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMA Modulus @ 25°C, GPa</td>
<td>0.3</td>
<td>TM 458</td>
</tr>
<tr>
<td>DMA Modulus @ 25°C, psi</td>
<td>43,000</td>
<td></td>
</tr>
<tr>
<td>Volume Resistivity, ohm-cm</td>
<td>&gt;10^13</td>
<td>TM 572</td>
</tr>
<tr>
<td>Dielectric Constant @ 1 MHz, 25°C</td>
<td>2.6</td>
<td>TM 588</td>
</tr>
<tr>
<td>Thermal Conductivity, W/m°K</td>
<td>0.3</td>
<td>ASTM 1461</td>
</tr>
<tr>
<td>α emissions count particles/cm²/hr</td>
<td>0.0007</td>
<td>DITM 0031A</td>
</tr>
</tbody>
</table>

The above figures are typical material properties only and are not to be used for material specification purposes. To generate a specification methods may be used.
Case Study:
Chip Scale Packaging
Chip scale SRAM package detail
Solder bump detail
Physical error mapping
α-particles from solder balls
Soft-error range modeling
Error mapping
Residual Errors
Cosmic rays?
Solder spits?

Data and photographs courtesy of Mark Henschel
Radon in the air?

- Radon is an $\alpha$ emitter
- 10 pCi/liter would explain excess errors
- EPA limit for homes is 4 pCi/liter
α-particles from circuit board
Bulk Memory Test at Soudan Iron Mine
Soudan Iron Mine Data

Cumulative Errors in NU/U/C Group

- NU
- Start purge
- Restart
- U
- C

\[ y = 1.287x - 49500 \]

\[ y = 0.6414x - 24620 \]

Date

Error

NU
Start purge
Restart
U
C


Errors

0 20 40 60 80 100 120

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## Error rate summary

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Error Rate (a.u./Mbit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original spheres, no underfill</td>
<td>100</td>
</tr>
<tr>
<td>Low-alpha spheres, no underfill</td>
<td>2</td>
</tr>
<tr>
<td>Low-alpha spheres, clean underfill</td>
<td>0.5</td>
</tr>
</tbody>
</table>

*Wilkinson et al, 2005*
Excellent materials are available…
Low-\(\alpha\) coatings

Error rates of coated and uncoated memory
5 um polyimide

Supply (Volts) | Error Rate (AU)
---|---
1.2 | 10000
1.3 | 1000
1.4 | 100
1.5 | 10
1.6 | 1
1.7 | 0.1
1.8 | 0.01
1.9 | 0.001
2.0 | 0.0001
2.1 | 0.00001

[Graph showing error rates for coated and uncoated memory with a decrease in error rate as supply voltage increases.]
Manufacturing process will dominate

$^{210}\text{Po}$ ionizer for static control
Low-\(\alpha\) manufacturing
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?

- **γ - photon**: 0.48 MeV
- **Lithium-7 Recoil**: 0.84 MeV
- **B^{10} (19.9%)**: \( \sigma_{th} = 3838 \text{ barns} \)
- **α - particle**: 1.47 MeV

*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 $40 \times 10^6 \times$ accelerated, leading to severe problems for medical devices.

TOF-SIMS results for commercial ICs

Sample #2, Mfg B

Sample #5, Mfg B

Sample #6, Mfg C

Sample #9, Mfg C

Al interconnects

Borated dielectric