The Effect of Radon on Soft Error Rates for Wire Bonded Memories

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Introduction

Soft errors caused by different high energetic radiation particles, such as alpha, neutron, thermal neutron, proton, and heavy ions are well studied and understood. But few studies have been complete on effect of Radon on IC components soft error. Complicating matters, Radon – a naturally occurring radioactive gas – could diffuse into and through the different IC package materials and emit alpha particles as the gas atom and its progeny decay. While the diffusion constant and solubility of Radon in these materials are not well known, these decays could cause soft errors if they occur in regions near sensitive component nodes. Furthermore, different geographic location has different concentration of Radon. If Radon contributes to IC components soft error, its affect should be quantified. This paper reports the soft error test result in an accelerated Radon ambient and concludes Radon impact on soft errors.

Background on Radon

A radioactive noble gas, Radon (Rn) is produced during the decay of Uranium and Thorium, and is present to some extent in every environment. Radon-222, from the Uranium chain, is the isotope which is found in greatest abundance due to its relatively long half life (3.8 days) when compared to Radon-220 (1 min). Typical concentrations of Radon-222 in the environment range from 10 Bq/m^3 outdoors, to 100 Bq/m^3 indoors [1,2]. As a gas species, Radon-222 can diffuse into and through materials prior to decaying, posing a potential problem for semiconductor packages, as Radon and several of its progeny decay via alpha emission.

If Radon diffused into the package and decays near the silicon, it produces an alpha particle and leave polonium atom where Radon decayed. The decay chain will produce two more alpha particles relatively quickly until Pb210 which has a 22 year half life. Thus, three alpha particles are quickly released by the one Radon decay. See figure 1 below.

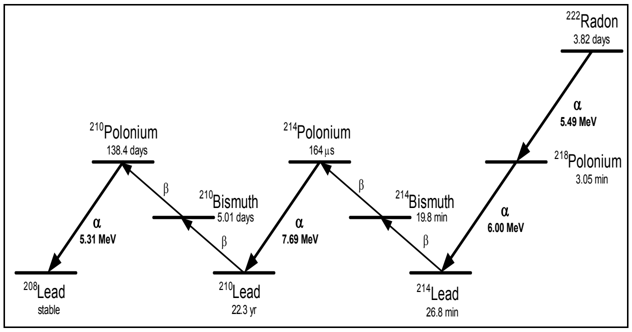

Figure 1: Radon-222 Decay Chain

Previous work had shown the Radon effected the soft error rate of flip chip devices when they were tested without underfill. The Radon would diffuse into the air gap under the die, decay and emit and alpha particle [3]. The purpose of this work is to determine if Radon can diffuse into the semiconductor molding compound, decay near the silicon surface and increase the soft error rate of the device

Experiment Setup

The device used in this work is a 18Mbit SRAM in a 100TQFP package (14 x 20 mm body size). The Si node is 0.15µm with dual gate oxide. The fab process for this device does not have BPSG layer, minimizing the soft error rate due thermal neutrons. Ultra low alpha (ULA) emission molding compound is used and the nominal emissivity is below 0.002 alpha/hour/cm^2.

Testing was done at sea level in the San Francisco bay area. Therefore, the measured FIT rates are a sum of the of the neutron, alpha and Radon soft error rate. If the Radon has a measurable effect on the soft error rate, the large increase in Radon concentration used for this experiment should produce a measurable increase in the soft error rate.

The devices were loaded into the hardware test setup which consisted of two chassis, each chassis containing 8 test cards. Each individual test card accommodated 64 devices, and the entire test setup totaled 1024 devices. For the purpose of this SER testing, a checkerboard pattern was written once to the entire memory, then read back and checked for errors every 255 seconds. Once the error occurs, the test program will write error bit(s) back and read again to validate if the error is soft error or hard permanent error. The test setup was monitored for 100 days to assess the failure rate of the devices in typical operating conditions. During the course of the testing, ambient Radon levels were monitored in the area surrounding the setup to establish baseline levels of concentration in the environment of the test setup. This first run is the control to measure SER due to the naturally occurring radiation

For the second phase of testing, a gas-tight metal weldament was constructed to enclose both the test setup and the Radon source. The enclosure was designed to minimize the inner volume – thus maximizing the achievable Radon concentration – while still allowing enough space for the two test chassis and various power and communication cables. Two ports were added to the enclosure to allow the Radon monitor to directly measure the Radon concentration in inner volume throughout the second phase of testing. Once the Radon source was affixed inside the enclosure, everything was sealed up and the test setup was again monitored for 100 days. The second run was completed is the identical location

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with the only difference being the Radon concentration in the ambient. The Radon was circulated by a small fan inside the enclosure.

The control was complete first because if Radon diffused into the package and decayed, it would leave behind Pb210 with a 22 yr half life. This species would change the long term alpha SER of the device.

Results

Figure 2 below shows the Radon concentrations observed during the first 100-day test. The Radon monitor was setup to sample the Radon concentration every 4 hours, shown in the plot as black points. The monitor was run for 1 to 3 days at a time, roughly every 2 weeks, throughout the 100 day test cycle. The blue squares represent the mean concentration observed during each monitor run.

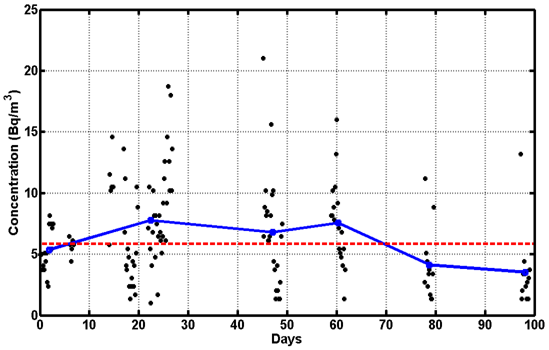

Figure 2: Background Rn Levels

Figure 3 shows the Radon concentrations observed during the second 100 day test cycle. The red curve shows the predicted concentration, and the black points show individual measurements recorded with the Radon monitor. By the end of the third day of testing, the concentration of Radon in the test setup was three orders of magnitude higher than the mean ambient levels observed during the first cycle of testing. As can be seen from the plot above, the typical Radon concentration after 15 days during run two was about 16,000 Bq/m^3, which is about 3000 times higher than the ambient Radon.

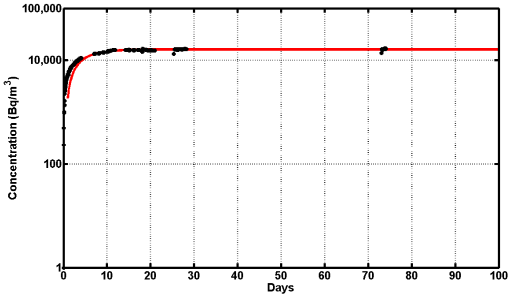

Figure 3: Predicted (red line) and Measured (black *) Rn concentration for run 2

Figure 4 shows the individual errors observed during the two runs, as well as the respective error rate (dashed lines). Figure 5 shows the normalized cumulative FIT rate observed in time for both test cycles. Two-thirds of the way through the second 100-day test cycle, the elevated Rn run FIT rate is 15% lower of the final ambient Rn run FIT rate. The SER rate for the elevated Radon is with the error bars of the ambient Radon.

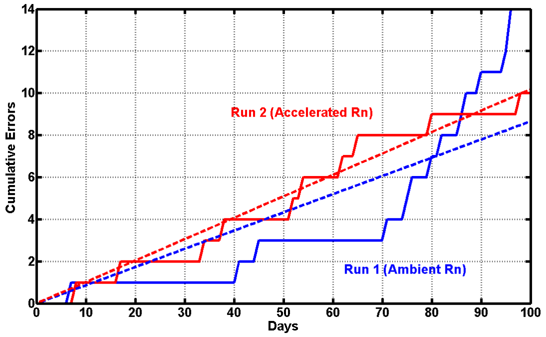

Figure 4: Observed errors in runs 1 and 2

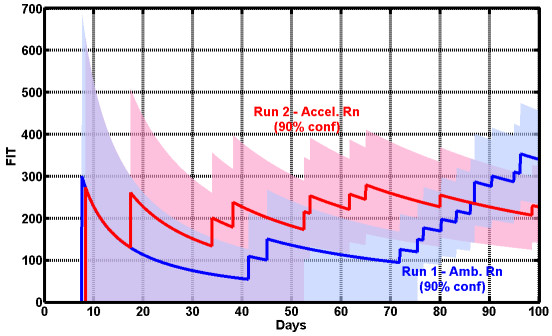

Figure 5: FIT rates observed in Runs 1 and 2, with 90% confidence levels.

Conclusion

The soft error rate of the wire bonded memory was not affected by the 3000X increase in the Radon concentration. The packaging material and thickness of the molding compound appear to provide a sufficient barrier to minimize Radon diffusion. Ambient Radon levels do not appear to contribute to current soft error rate observed in these devices.

Follow up experiments may be completed on flip chip device to determine Radon would diffuse into the flip chip package.

References

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