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WHITE PAPER

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Enhanced Endurance Performance of 0.13 μm Nonvolatile F-RAM Products

Abstract

F-RAM (Ferroelectric Random Access Memory) is a nonvolatile memory that uses a ferroelectric capacitor for storing data. It offers higher write speeds over Flash/EEPROM.

This white paper provides a brief overview of the endurance performance of F-RAM products.

Introduction

Memory endurance is specified as the number of times that a memory cell can be written to or erased. For applications that require high data integrity despite rigorous and extensive use, memory endurance is one of the critical system performance characteristics and design considerations. Ferroelectric RAM, or F-RAM, is a fast, nonvolatile, and low-power memory that offers high endurance as one of its primary benefits compared with other forms of nonvolatile memory based on floating gate or phase change technology. F-RAM's "endurance" is defined as memory state retention after fatigue or as the ability to sustain the nonvolatile portion of the ferroelectric switch charge after many switching cycles.

The academic field has long and intensively studied to identify the origin of the switch charge (polarization) loss in materials after extensive switching cycles. Several mechanisms, such as oxygen vacancies, an opposite domain inhibition near ferro-electrode interface, and the spatial distribution of the internal bias field were proposed to be responsible for the fatigue phenomenon. These mechanisms cause ferroelectric domain pinning resulting in a reduced switching charge density at extended switching cycles.

F-RAM's manufacturing process has gone through several generations, such as the 0.5 μm, 0.35 μm and 0.13 μm technology nodes. The endurance performance is characterized in each generation. While F-RAM exhibits excellent endurance characteristics in each technology node, F-RAM memory in the 0.13 μm technology node is proving to be exceptionally high – measured as high as 10^{13} and characterized today as high as 10^{15} . This improved F-RAM endurance seen at 0.13 μm node creates a challenge to measure the actual maximum endurance behavior in a reasonable amount of time as given in Table 1. Extensive test time and innovative test methodologies are needed to determine the actual endurance limit of 0.13 μm F-RAM products.

Cycle		Number of endurance cycles			
		10^{10}	10^{12}	10^{14}	10^{15}
Time					
Days		0.025	2.55	255	2550

Table 1. Time to exercise a parallel F-RAM Byte.

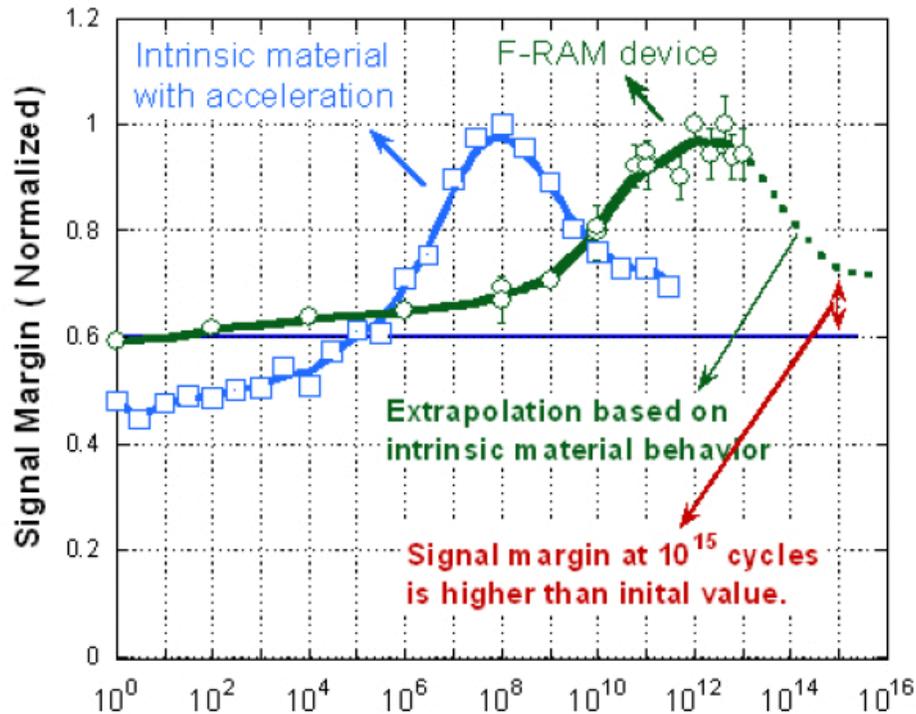


Figure 1. Signal margin vs. cycles for both F-RAM device and intrinsic material showing higher signal margin of the F-RAM device at 10^{15} cycles compared with the initial value.

The current endurance specification of 10^{15} cycles for 0.13 μm F-RAM is based on the preliminary evaluation of 1,280 bits of F-RAM memory from a sample of parallel F-RAM core memory products built using the 0.13 μm technology node. Figure 1 shows that the F-RAM device level signal margin reaches maximum between 10^{12} and 10^{13} cycles. Based on the endurance behavior of the intrinsic material for 0.13 μm F-RAM (shown in Figure 1), the F-RAM device level endurance behavior post 10^{13} cycles can be extrapolated using similar curve observed in intrinsic material as shown by dashed line in Figure 1. It can be seen that the remaining signal margin after 10^{15} cycles is still higher than the initial level (the signal margin at minimum number of cycles), indicating that there is enough signal margin to ensure the reliability of F-RAM device after 10^{15} cycles. This result is consistent with the endurance specification of the 0.13 μm F-RAM foundry.

Conclusion

When determining whether an F-RAM product is an appropriate solution for a given application, system designers should consider the following:

- Is the system designed to collect data?
- Does the configuration change often?
- Can power fail suddenly or frequently?
- Is the data highly valuable?
- □ Is power supply noisy?
- Is there a need to capture critical system data during power down, which will enable a graceful system recovery on power up?
- Is memory endurance vital for storing mission critical data?
- Is the system or MCU RAM-limited?
- Is there a strict power budget?

In such cases, F-RAM's technical features can reduce operational overhead and ensure optimal performance.

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