Ultra MLC Technology Introduction

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1. Introduction

Flash memory is a non-volatile storage element that can be electrically programmed/re-programmed and erased. As technology continuously advances, the demands for greater density and better performance with flash memory become large as well. Most importantly, flash memory is no longer a component that resides only in your computer – It could act as a photo album or a file cabinet that stores all your personal treasures or business portfolios.

The purpose of this paper is to provide an overview on flash technology, specifically on NAND flash, a memory technology that has been deeply connected to our day-to-day life. In addition, we would like to introduce another MLC flash member, Ultra MLC, which delivers better performance and endurance – just like the legendary SLC flash.

The paper is organized as follows: Section 2 explains the differences between NAND and NOR flash, and provides information on NAND flash including SLC and MLC. Section 3 introduces Ultra MLC – the mechanism and its advantages. Section 4 and 5 provide performance and endurance information with Ultra MLC, respectively. Finally, a conclusion is provided.

2. Flash Memory

Physical Structure

NAND and NOR are the types of flash memory, commonly taken side-by-side for comparison due to their nature in data storing. To distinguish their differences, one could think that NOR flash is used for code storage whereas NAND flash is used for file storage.

The reason for such a differentiation comes from the fact that NOR flash is capable of achieving fast random access and performing fast read operations, but is restricted by slower write and erase operations. Therefore, NOR flash is more suitable for infrequent data modification, and it is common to see that boot code, firmware or operating system to be stored in NOR flash.

On the other hand, NAND flash is capable of performing fast write and erase operations. It also consumes less layout area, which could be translated to greater density and lower cost-per-bit. Almost as good as it sounds, NAND flash has one thing that is unable to outperform NOR flash: That is, slower random access, as the trade off to space saving. Nevertheless, NAND flash is still widely used in various types of file storage elements such as USB flash drives and memory cards, where data constantly needs to be loaded and updated.

Figure 1 represents the physical differences between NOR and NAND flash. The NOR structure (Left) is designed to connect each memory cell (highlighted in yellow) vertically, whereas the NAND structure (Right) is designed to connect each memory cell (highlighted in yellow) horizontally. 10F2 and 4F2 represent the layout area per cell for NOR and NAND, respectively. As we mentioned before, NAND flash requires less layout-area consumption and therefore delivers a wider range of capacities and lower bit-cost.

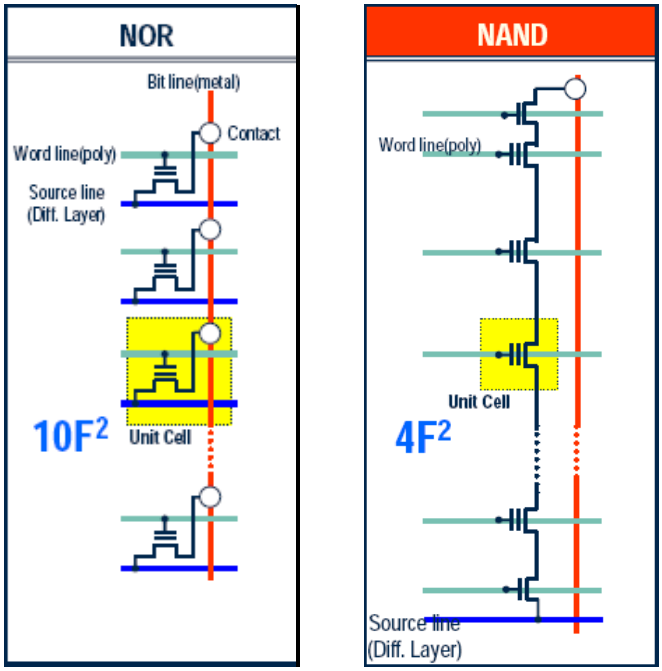

Figure 1: (Left) Cell Array for NOR and (Right) Cell Array for NAND

In the rest of the paper, we will focus on NAND flash and introduce Phison's unique design of Ultra MLC including its mechanism, performance and endurance.

Types of NAND Flash

Generally, NAND flash is categorized in two types – SLC (single-level cell) and MLC (multi-level cell). NAND-makers have recently announced the latest flash technology - TLC (ternary-level cell), also known as three-bit per cell, which is the new addition to the NAND family. However, it is beyond the scope of our topic, and will not be covered in the paper.

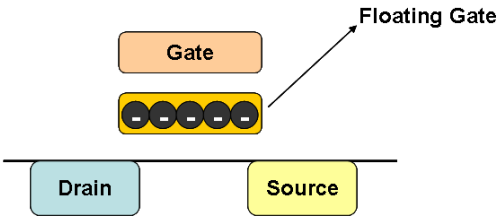

Figure 2: Basic Structure of a Memory Cell

Each cell is consisted of a single transistor and a floating gate, which is located between Gate and Source/Drain and allows electrons to be stored inside, as shown in Figure 2. For SLC flash, only one bit could be stored to each cell at a time, and there will be two possible states for each cell – 0 or 1. As for MLC flash, two bits could be stored to each cell at a time and there will be four possible states for each cell – 00, 01, 10 or 11. Cell state is determined by the threshold voltage (Vt) of each cell, and the voltage is an interpretation of the amount of charges stored inside the floating gate, as shown in Figure 3.

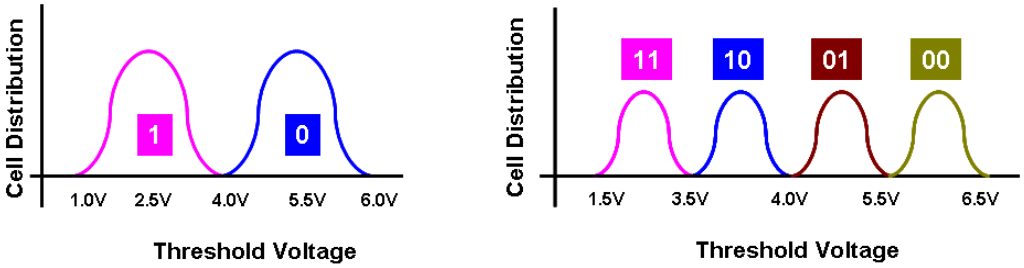

Figure 3: Cell Distribution vs. Threshold Voltage for SLC Flash (Left) and MLC Flash (Right), Respectively

Because MLC flash stores 1 more bit at each cell than SLC flash does, MLC provides higher density and lower bit-cost. Unfortunately, nothing comes for free – the trade off for cost-saving is greater power consumption and poorer endurance, due to more voltage levels required and technology limitation. It is common to see that SLC flash is used in industrial applications, whereas MLC flash is used in commercial applications.

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