Envoy Data Memory

SSD CONTROLLER
Technical Brief
GuaranteedFlush

Introduction

NAND Flash is a non-volatile memory which composed of millions of floating-gate transistors to capture electrons within the gate. These floating-gate transistors can be identified as many memory cells. Millions of memory cells are connected in array. Each array is consisted of blocks and each block contains numbers of pages. Fig. 1 gives a brief illustration of NAND array from the viewpoint of schematic level.

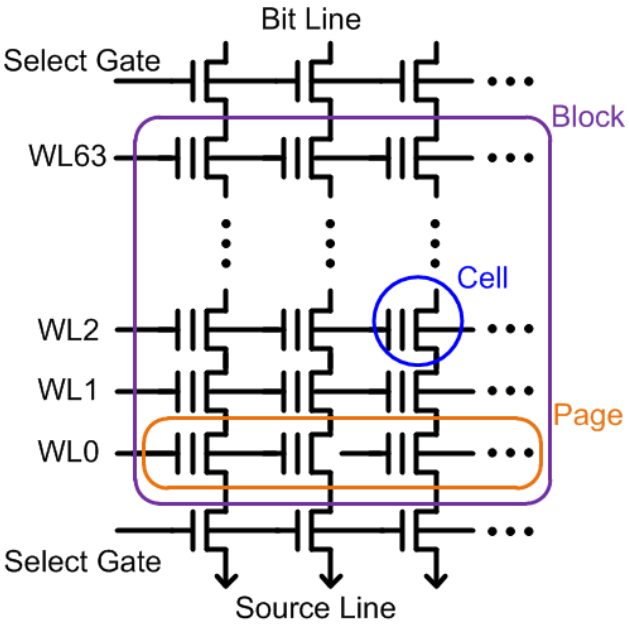

Fig.1 NAND Composition in Transistor Level

Each Word-Line (WL) can be regarded as a page which is the basic unit of Read / Program operations in NAND. However, the number of pages for each WL is different in Single-level Cell (SLC) / Multi-level Cell (MLC) / Triple-level Cell (TLC) type NAND.

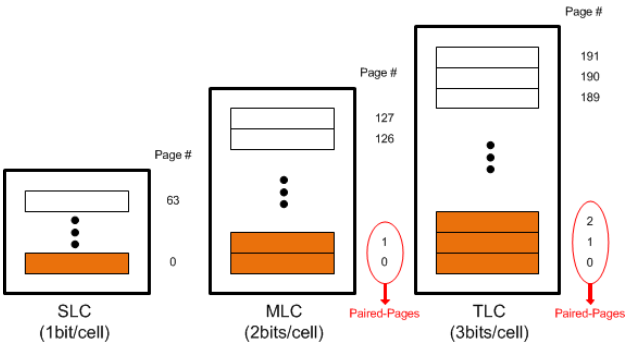

Fig.2 Paired-Pages

Fig.2 shows that there would be two pages (Lower / Upper Page) sharing the same WL in MLC NAND and three pages (Lower / Middle / Upper Page) sharing the same WL in TLC NAND. These pages sharing the same WL are considered as paired-pages. Regarding NAND programming operation, there are two golden rules needing to be followed because of the physical characteristics of NAND flash:

- ***Programming operation needs to follow the order specified based on NAND flash characteristics***
- ***If the programming operation on Word-Line (WL) is not completed, the data integrity of this WL cannot be guaranteed***

For MLC or TLC NAND flash, data programming in single page will not be 1-step operation. That is, MLC/TLC pages need to be programmed 2 or 3 times to accomplish data programming purpose. This phenomenon is actually caused by the physical characteristics of flash memory.

Integrity Concerns with User Data in Paired-Pages

For current consumer Solid State Drive (SSD) market, MLC and TLC flash are actually the most popular memory types by considering some economical concerns. MLC and TLC flash can offer much larger storage capacity with lower cost, especially TLC. However, the programming operation on MLC and TLC flash is more complicated than SLC. If we take TLC flash as an example, we need to program the paired-pages on the same WL three times to complete the whole operation. Fig. 3 simply illustrates the complete program operation of TLC flash. Only when the 3rd programming operation on WL_x is done, the data stored at WL_x is able to be identified as reliable data.

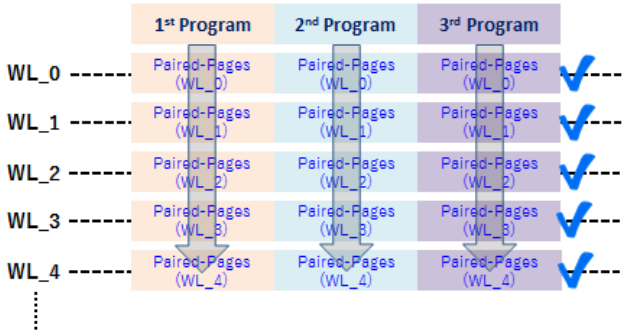

Fig.3 Programming Operation of TLC Flash

Unfortunately, this complexity of programming operations injects the risk of data corruption. Since the integrity of data can be guaranteed only after the entire programming sequence has been done (i.e. 1st program + 2nd program + 3rd program), any unexpected events happening prior to the completion of programming operation will cause the distortion or loss of data. Fig. 4 is an illustration of what will happen if any unexpected event interrupts data programming operations. In this case, power loss happens before the completion of programming operation for WL_2, only the data stored in WL_0/WL_1 can be guaranteed. In other words, other data will be distorted or lost because of the unexpected power loss.

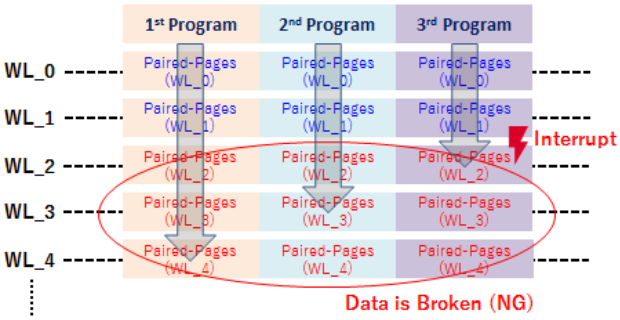

Fig.4 Power Loss during Data Programming

EDM Technology: GuaranteedFlush

EDM proprietary technology introduced as GuaranteedFlush is designed for preventing our storage devices from data corruption which caused by any unexpected interruption during programming operations. GuaranteedFlush would not be performed for every single data programming command from operating system. Instead, GuaranteedFlush feature will be automatically triggered in background once the storage device receives FLUSH_CACHE command sent from host side. Consequently, the integrity of all the data programmed into the device prior to FLUSH_CACH command can be guaranteed by this technology. Fig.5 is an

illustration of the user data range GuaranteedFlush is able to cover.

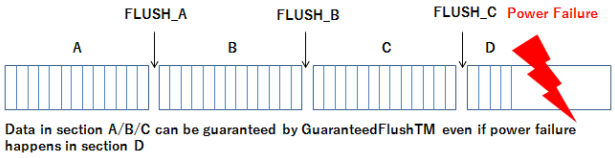

Fig.5 Timing of Triggering GuaranteedFlush™

GuaranteedFlush is actually implemented by a multi-layer algorithm. We are going to share two basic ideas about how EDM's product protects user's data from sudden power loss.

Concept 1: Dummy Data Compensation

The first idea is speeding up the programming operations. We know that the programming sequences of different NAND flash types may be different. No matter how the programming sequence varies, the duration of data programing on single WL will decide the risk of data loss due to any unexpected interruption. If this duration becomes longer, the possibility of interruption happening will be higher as well. In order to improve this phenomenon, we will insert necessary dummy data into specific WLs to make sure the WL storing user data is allowed to complete the entire programming operation (i.e. 1st program + 2nd program + 3rd program) like Fig. 6 shows. By inserting dummy data into the following WLs, user data programming operations must be completed. In this way, the integrity of user data can be guaranteed even if any unexpected event interrupts upcoming programming sequence afterwards.

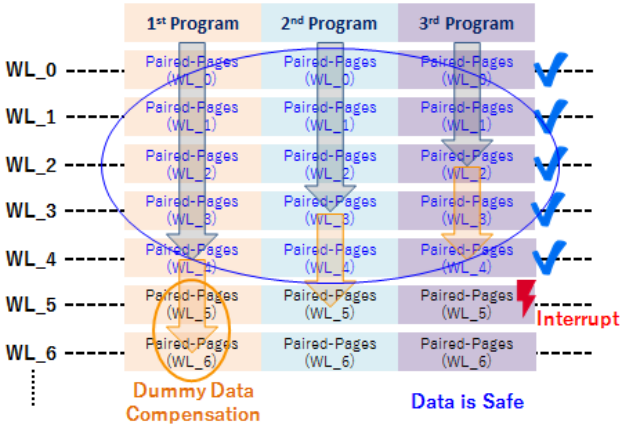

Fig. 6 Dummy Data Compensation

Concept 2: Real-time Data Backup

The second idea to protect SSD from data corruption caused by paired-pages effect is directly backing data up to the pages without paired-paged issues in the first place. Those pages which have been configured as SLC mode are able to meet this requirement. Apparently, it is a radical way to keep user data far from the issue we discussed since no paired-pages need to be considered. However, the capacity of SLC mode will be one-third unavoidably. The implementation of Real-time Data Backup becomes another issue.

Summary

To sum up, GuaranteedFlush is a EDM proprietary technology implemented with multi-level algorithm to make sure data correctness while any power loss happens unexpectedly. GuaranteedFlush is able to strengthen the reliability of EDM SSD products.