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Weathers et al.

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(54) **APPARATUS AND METHOD FOR MULTI-MODE OPERATION OF A FLASH MEMORY DEVICE**

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(60) **Related U.S. Application Data**
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(51) **Int. Cl.**
G11C 29/00 (2006.01)
G06F 13/00 (2006.01)
G06F 13/28 (2006.01)
G11C 11/34 (2006.01)
G11C 16/06 (2006.01)
G11C 7/00 (2006.01)

(52) **U.S. Cl.**
USPC **714/773**; 714/763; 711/102; 365/185.09; 365/200

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,444,543 B2 * 10/2008 Babudri et al. 714/6.32
2006/0062046 A1 * 3/2006 Babudri et al. 365/185.09
2008/0072118 A1 * 3/2008 Brown et al. 714/763
2009/0327591 A1 * 12/2009 Moshayedi 711/103
2010/0122016 A1 * 5/2010 Marotta et al. 711/103
2010/0257430 A1 * 10/2010 Chen 714/773
2010/0332922 A1 * 12/2010 Chang et al. 714/704
2013/0003457 A1 * 1/2013 Wood et al. 365/185.03

OTHER PUBLICATIONS

Jagmohan, et al., "Write Amplification Reduction in NAND Flash through Multi-Write Coding", Storage Conference, 2010, MSST.
Birrell, et al., "A Design for High-Performance Flash Disks", ACM Operating Systems Review, Apr. 2007, pp. 88-93, 41(2).
Hu, et al., "Write amplification analysis in flash-based solid state drives", in SYSTOR, May 4-6, 2009, Haifa, Israel.
Rosenblum, et al., "The design and implementation of a log-structured file system", ACM TOCS, Feb. 1992, pp. 26-52, vol. 10, No. 1.

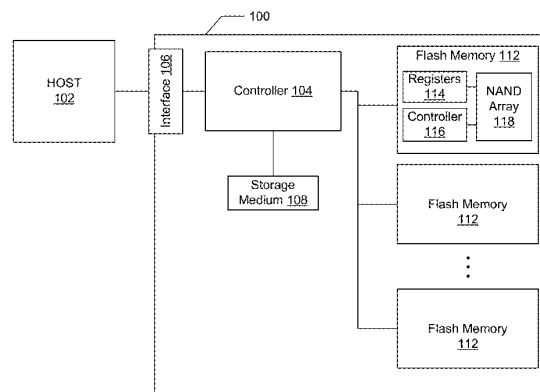
* cited by examiner

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(57) **ABSTRACT**

Disclosed is an apparatus and method for operating a multi-level cell (MLC) flash memory circuit. Data is read from a memory block of a plurality of memory blocks in the MLC flash memory circuit, wherein each of the plurality of memory blocks can operate in one of at least three modes of operation comprising an MLC mode, a single-level cell (SLC) mode and a defective mode, and wherein the memory block is initially operating in the MLC mode. Error correction is performed on the read data to correct read errors in the read data. A determination is made if a number of bits corrected by the error correction exceeds a predetermined threshold value. If the number of bits corrected by the error correction exceeds the predetermined threshold value, the operating mode of the memory block is switched from the MLC mode to the SLC mode.

20 Claims, 4 Drawing Sheets



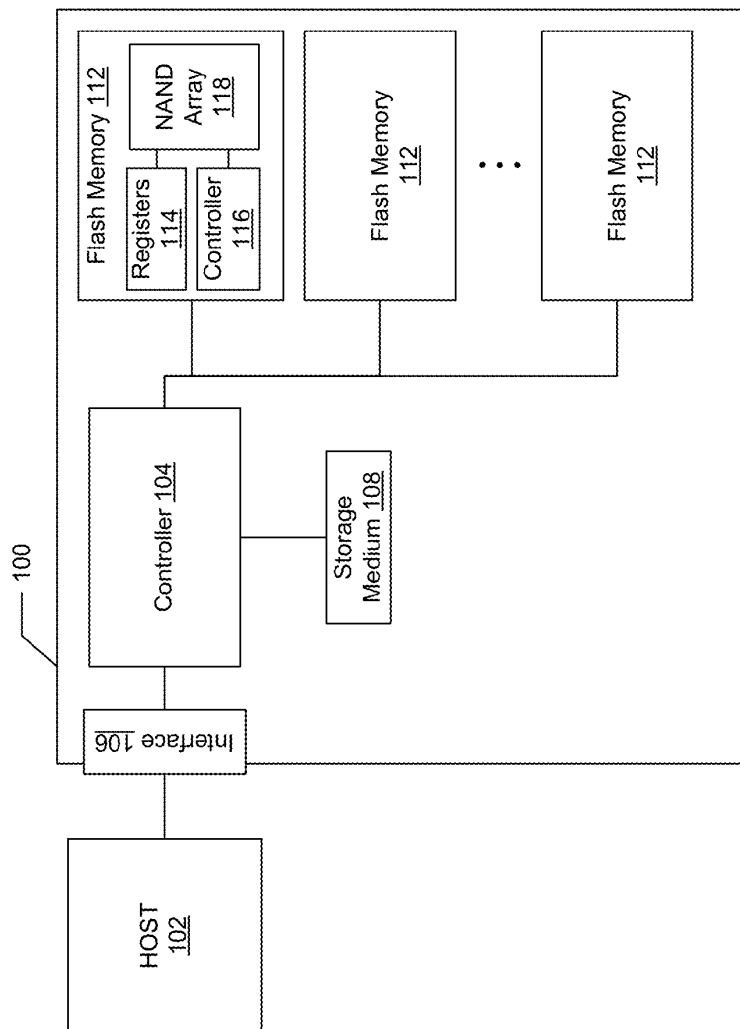


FIG. 1

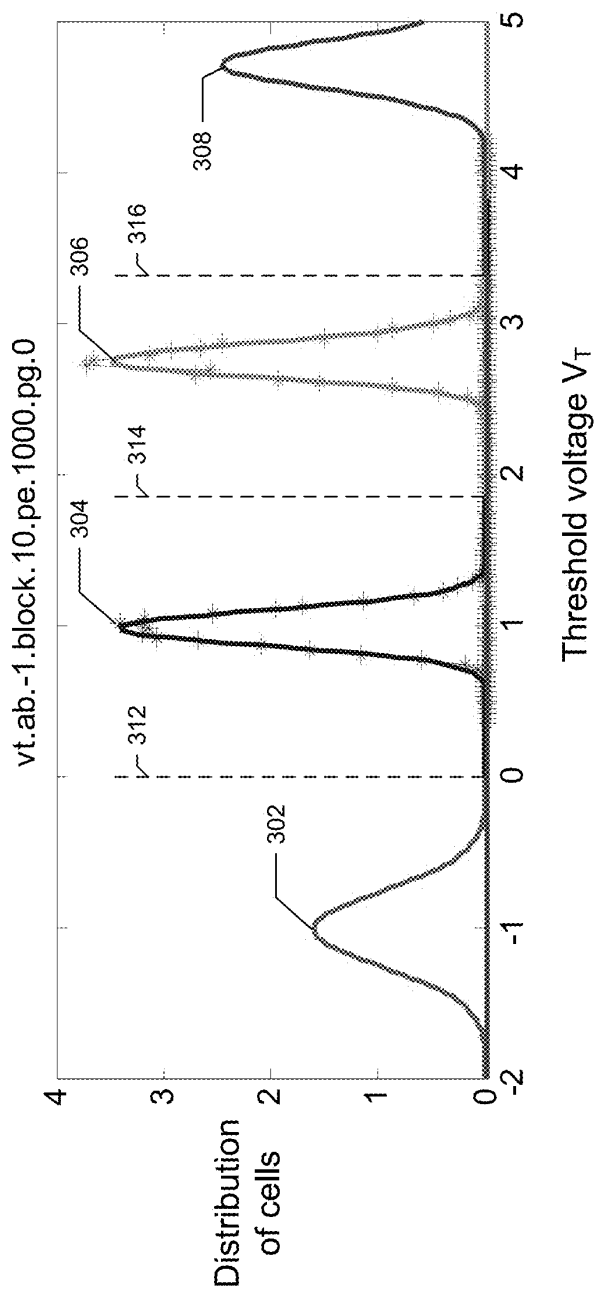


FIG. 2

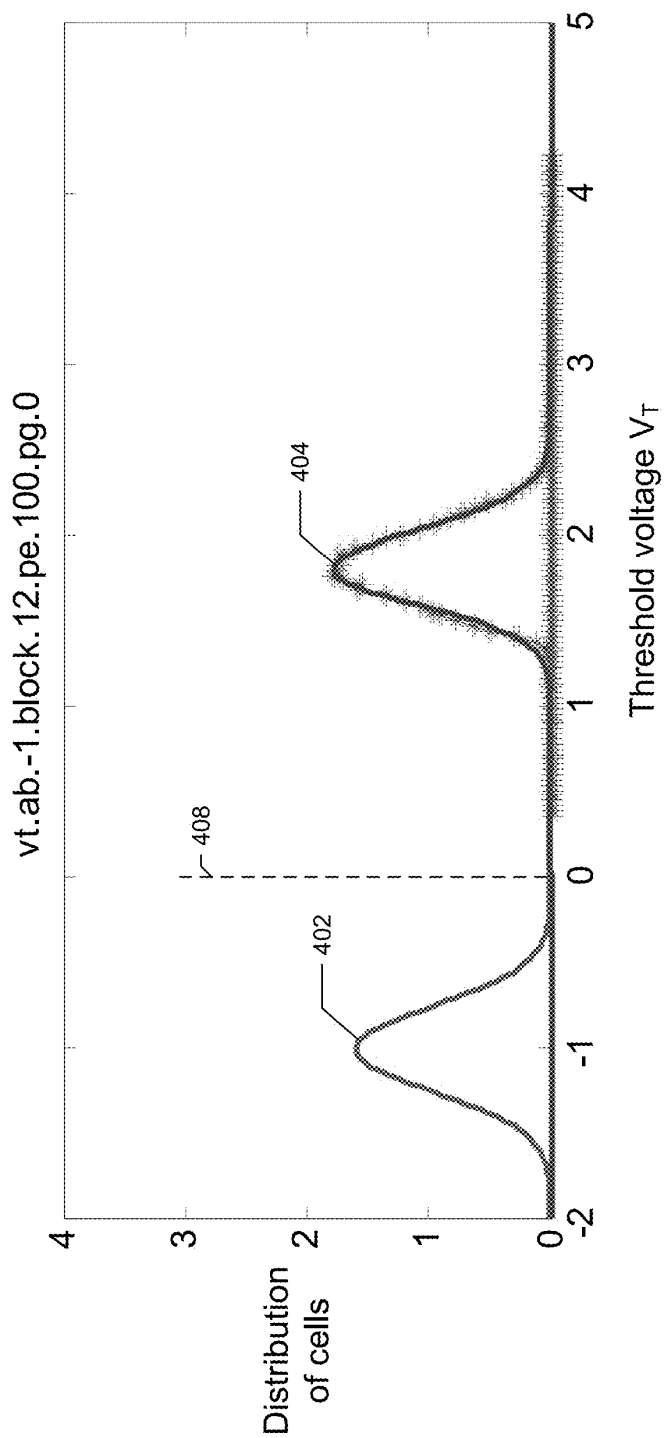


FIG. 3

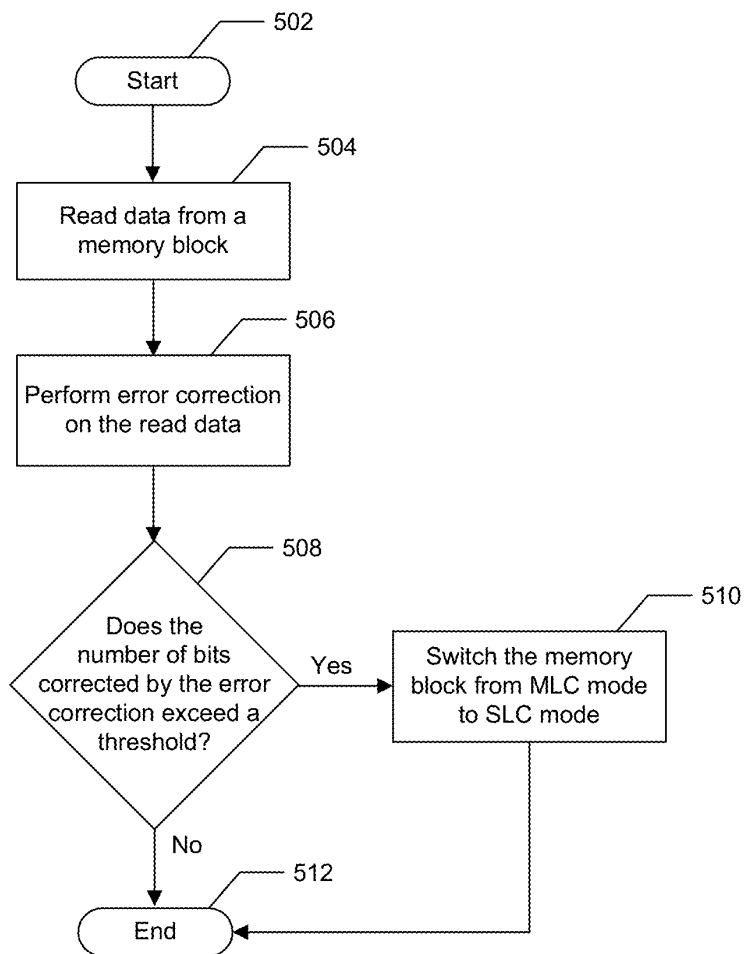


FIG. 4

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