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Harari et al.

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[54] **MULTI-STATE FLASH EEPROM SYSTEM WITH CACHE MEMORY**

58-215794	12/1983	Japan .
58-215795	12/1983	Japan .
59-45695	3/1984	Japan .
59-162695	9/1984	Japan .
60-076097	4/1985	Japan .
60-212900	10/1985	Japan .
A60178564	2/1986	Japan .
61-96598	5/1986	Japan .
62-283496	12/1987	Japan .
62-283497	12/1987	Japan .
63-183700	7/1988	Japan .
A01054543	3/1989	Japan .
2136992	9/1984	United Kingdom .
WO8400628	2/1984	WIPO .

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[73] Assignee: **SanDisk Corporation**, Sunnyvale, Calif.

[21] Appl. No.: **08/931,133**

[22] Filed: **Sep. 16, 1997**

Related U.S. Application Data

[63] Continuation of application No. 08/249,049, May 25, 1994, Pat. No. 5,671,229, which is a continuation of application No. 07/963,837, Oct. 20, 1992, abandoned, which is a division of application No. 07/337,566, Apr. 13, 1989, abandoned.

[51] Int. Cl.⁶ **G06F 11/00**

[52] U.S. Cl. **371/10.2; 711/136; 365/200**

[58] Field of Search **371/10.2; 365/200, 365/201; 395/182.04; 711/136**

[56] References Cited

U.S. PATENT DOCUMENTS

3,633,175	1/1972	Harper .
4,051,354	9/1977	Choate .
4,093,985	6/1978	Das .
4,210,959	7/1980	Wozniak .
4,250,570	2/1981	Tsang et al. .
4,272,830	6/1981	Moench .
4,279,024	7/1981	Schrenk .
4,281,398	7/1981	McKenny et al. .
4,287,570	9/1981	Stark .
4,295,205	10/1981	Kunstadt .
4,354,253	10/1982	Naden .

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

0557723	1/1987	Australia .
0086886	8/1983	European Pat. Off. .
0243503B1	7/1987	European Pat. Off. .
0300264B1	10/1989	European Pat. Off. .

OTHER PUBLICATIONS

Lucero et al., "A 16 kbit Smart 5 V-only EEPROM with Redundancy," *IEEE Journal of Solid-State Circuits*, vol. SC-18, No. 5, pp. 539-543 (Oct. 1983).

Torelli et al., "An improved method for programming a word-erasable EEPROM," *Alta Frequenza*, vol. 52, No. 6, pp. 487-494 (Nov.-Dec. 1983).

(List continued on next page.)

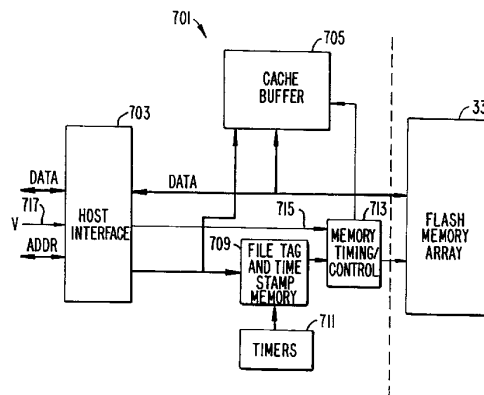
Primary Examiner—Phung M. Chung

Attorney, Agent, or Firm—Majestic, Parsons, Siebert & Hsue

[57] ABSTRACT

A system of Flash EEPROM memory chips with controlling circuits serves as non-volatile memory such as that provided by magnetic disk drives. Improvements include selective multiple sector erase, in which any combinations of Flash sectors may be erased together. Selective sectors among the selected combination may also be de-selected during the erase operation. Another improvement is the ability to remap and replace defective cells with substitute cells. The remapping is performed automatically as soon as a defective cell is detected. When the number of defects in a Flash sector becomes large, the whole sector is remapped. Yet another improvement is the use of a write cache to reduce the number of writes to the Flash EEPROM memory, thereby minimizing the stress to the device from undergoing too many write/erase cycling.

26 Claims, 5 Drawing Sheets



U.S. PATENT DOCUMENTS

4,355,376	10/1982	Gould .	5,226,168	7/1993	Kobayashi et al. .
4,380,066	4/1983	Spencer et al. .	5,297,148	3/1994	Harari et al. .
4,405,952	9/1983	Slakmon .	5,359,569	10/1994	Fujita et al. .
4,422,161	12/1983	Kressel et al. .	5,430,859	7/1995	Norman et al. .
4,449,205	5/1984	Hoffman .	5,488,711	1/1996	Hewitt et al. .
4,450,559	5/1984	Bond et al. .	5,546,351	8/1996	Tanaka et al. .
4,456,971	6/1984	Fukuda et al. .	5,606,532	2/1997	Lambrache et al. .
4,463,450	7/1984	Hausele .	5,671,229	9/1997	Harari et al. .
4,466,059	8/1984	Bastian et al. .			
4,479,214	10/1984	Ryan .			
4,493,075	1/1985	Anderson et al. .			
4,498,146	2/1985	Martinez .			
4,514,830	4/1985	Hagiwara et al. .			
4,527,251	7/1985	Nibby, Jr. et al. .			
4,530,055	7/1985	Hamstra et al. 711/136			
4,586,163	4/1986	Koike .			
4,601,031	7/1986	Walker et al. .			
4,612,640	9/1986	Mehrotra et al. .			
4,616,311	10/1986	Sato .			
4,617,624	10/1986	Goodman .			
4,617,651	10/1986	Ip et al. .			
4,642,759	2/1987	Foster .			
4,653,023	3/1987	Suzuki et al. .			
4,654,847	3/1987	Dutton .			
4,672,240	6/1987	Smith et al. .			
4,718,041	1/1988	Baglee et al. .			
4,733,394	3/1988	Burkhard .			
4,746,998	5/1988	Robinson et al. .			
4,785,425	11/1988	Lavelle .			
4,794,568	12/1988	Lim et al. .			
4,796,233	1/1989	Awaya et al. .			
4,800,520	1/1989	Iijima .			
4,805,109	2/1989	Kroll et al. .			
4,821,240	4/1989	Nakamura et al. .			
4,847,808	7/1989	Kobatake .			
4,882,642	11/1989	Taylor et al. .			
4,887,234	12/1989	Iijima .			
4,896,262	1/1990	Wayama et al. .			
4,914,529	4/1990	Bonke .			
4,916,605	4/1990	Beardsley et al. .			
4,920,478	4/1990	Furuya et al. .			
4,920,518	4/1990	Nakamura et al. .			
4,924,331	5/1990	Robinson et al. .			
4,933,906	6/1990	Terada et al. .			
4,942,556	7/1990	Sasaki et al. .			
4,945,535	7/1990	Hosotani et al. .			
4,949,240	8/1990	Iijima .			
4,953,122	8/1990	Williams .			
5,043,940	8/1991	Harari .			
5,051,887	9/1991	Berger et al. .			
5,053,990	10/1991	Kreifels et al. .			
5,070,474	12/1991	Tuma et al. .			
5,095,344	3/1992	Harari .			
5,136,546	8/1992	Fukuda et al. .			
5,163,021	11/1992	Mehrotra et al. .			
5,172,338	12/1992	Mehrotra et al. .			

OTHER PUBLICATIONS

Data Sheet: "27F256 256K(32Kx8) CMOS Flash Memory," *Intel Corporation*, pp. 1-24 (May 1988).

Preliminary Data Sheet, "48F512 512K Flash EEPROM," *SEEQ Technology, Incorporated*, pp. 2-1 through 2-12 (Oct. 1988).

Advanced Data Sheet, "48F010 1024K Flash EEPROM," *SEEQ Technology, Incorporated*, pp. 2-13 thru 2-24 (Oct. 1988).

Lai, Robert S., *Writing MS-DOS Device Drivers, The Waite Group, Inc.*, (Sep. 1987), pp. i-xi and 235-319.

Miller, "Semidisk Disk Emulator," *Interface Age*, p. 102, Nov. 1982.

Clewitt, "Bubble Memories as a Floppy Disk Replacement," *1978 MIDCON Technical Papers*, vol. 2, pp. 1-7, Dec. 1978.

Hancock, "Architecting a CCD Replacement for the IBM 2305 Fixed Head Disk Drive," Digest of Papers, *Eighteenth IEEE Computer Society International Conference*, pp. 182-184, 1979.

Wilson, "1-Mbit flash memories seek their role in system design," *Computer Design*, vol. 28, No. 5, pp. 30-32 (Mar. 1989).

Bleiker et al., "A Four-State EEPROM Using Floating-Gate Memory Cells," *IEEE Journal of Solid-State Circuits*, SC-22 (1987) Jun., No. 3, New York, NY, USA.

Intel Corporation, 27F256, 256K (32Kx8) CMOS Flash Memory, May 1988, pp. 1-21.

Krick, "Three-State MNOS FET Memory Array," *IBM Technical Disclosure Bulletin*, vol. 18, No. 12, May 1976, pp. 4192-4193.

Alberts C.S. et al., "Multi-Bit Storage FET EAROM Cell," *IBM Technical Disclosure Bulletin*, vol. 24, No. 74, Dec. 1981, pp. 3311-3314.

Horiguchi et al., "An Experimental Large-Capacity Semiconductor File Memory Using 16-Level Cell Storage," *IEEE Journal of Solid-State Circuits*, vol. 23, No. 1, Feb. 1988, pp. 27-33.

Furuyama, et al., "An Experimental 2-Bit/Cell Storage Dram for Macro Cell or Memory-on-logic Application," *Jan. 1988 IEEE*, pp. 4.4.1 to 4.4.4.

Stark, "Two Bits Per Cell ROM," *Jan. 1981 IEEE Catalog No. 81-CH1626-1*, pp. 201-212.

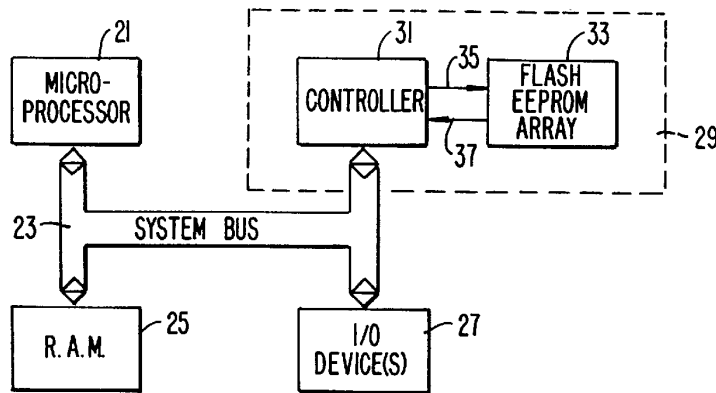


FIG. 1A.

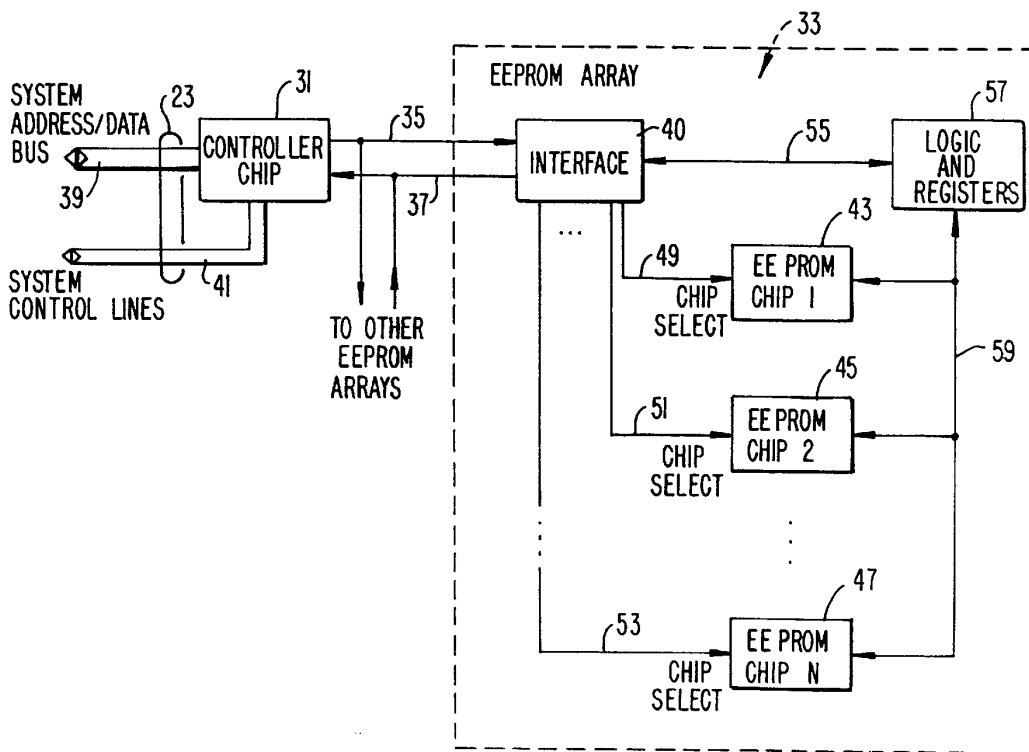


FIG. 1B.

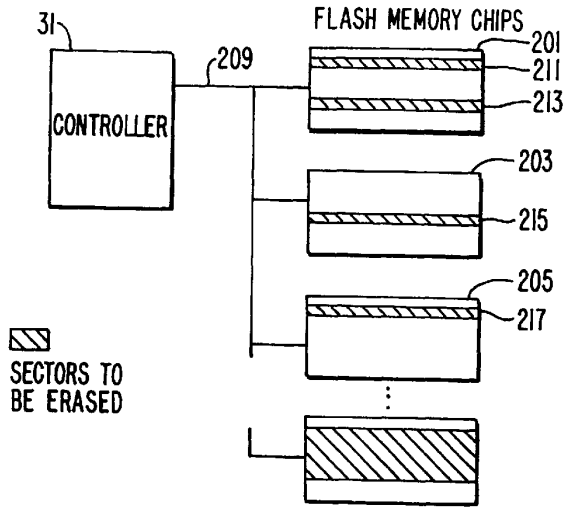


FIG. 2.

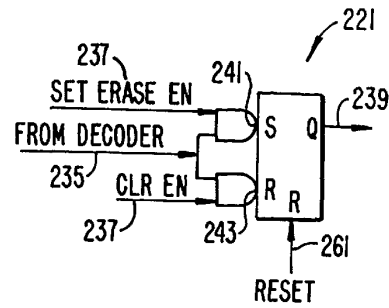


FIG. 3B.

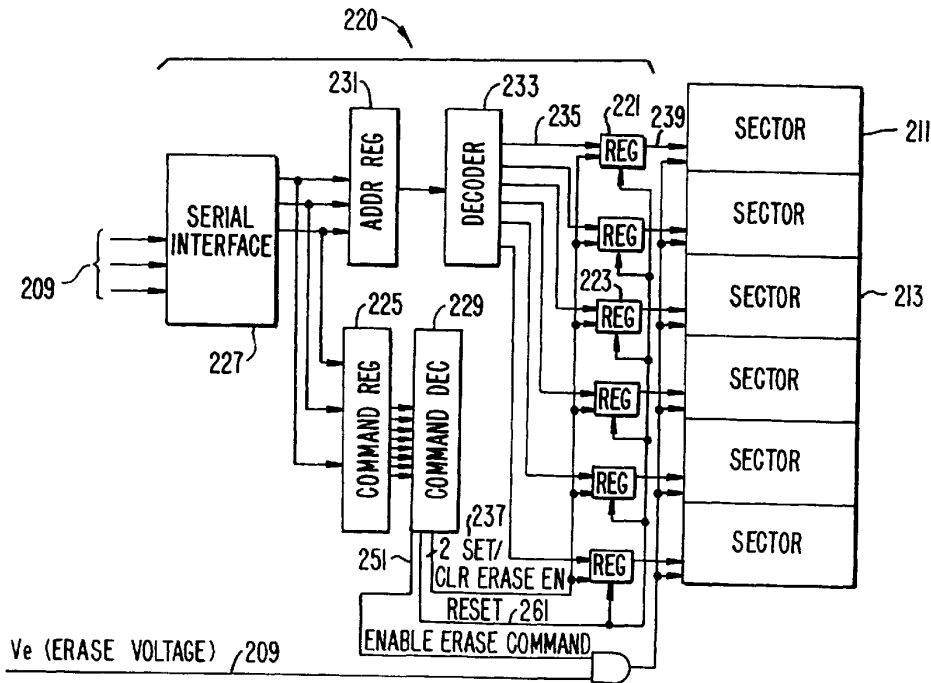


FIG. 3A.

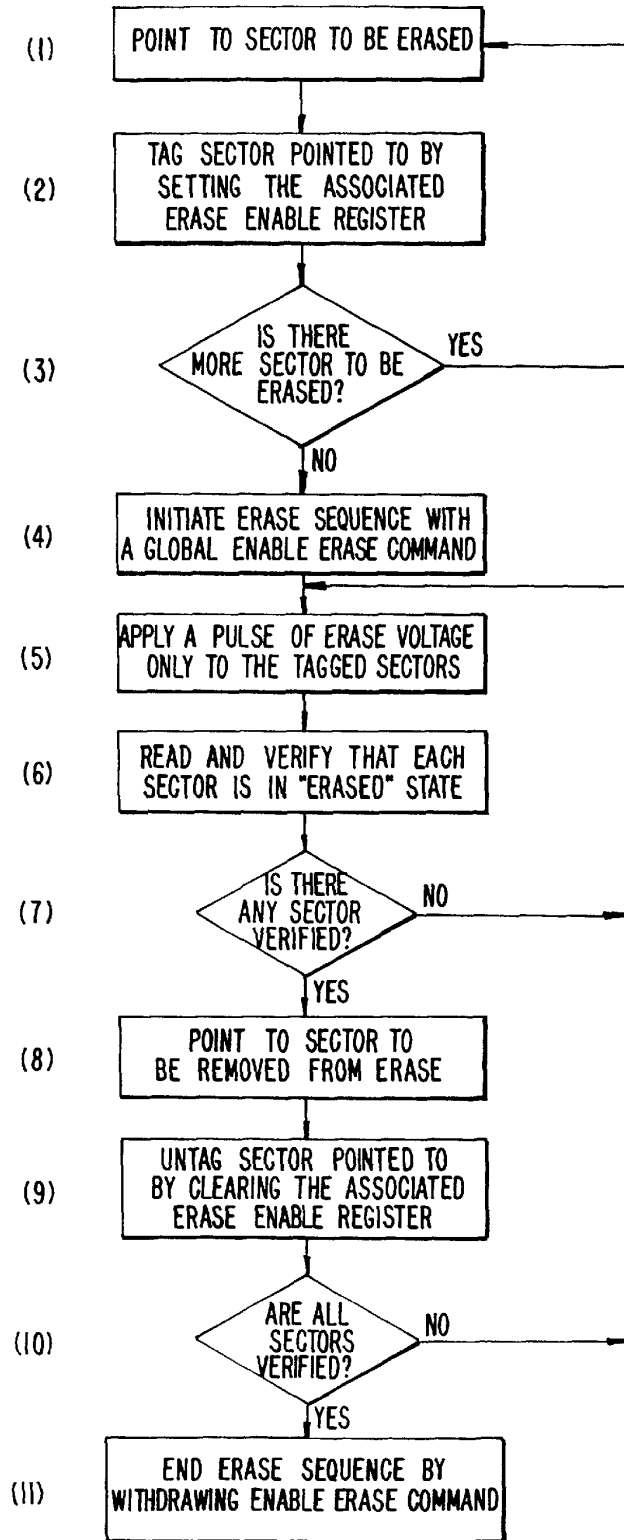


FIG. 4.

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