

1990s

Multi-level and larger-capacity flash memory

~ Integrated Circuit ~

To cope with advancement of PC and the development of applications, memory capacity continuously increased with the pace of 4 times in every 3 years. However, the increase of memory capacity has been a battle against miniaturization. Research on multilevel memory cells advanced as a technique for increasing the memory capacity. The multi-level memory cell means storing signals in four states of “00”, “01”, “10”, “11” or more, instead of binary states of “0” and “1”.

Regarding the multi-level technology, there was an announcement of 16-states/cell DRAM at ISSCC in 1984 from Hitachi, and several others were seen thereafter, but they did not become actual products. Application of multilevel technology to flash memory was realized with the delay of 10 years from DRAM, for NOR flash in 1995 (ISSCC: Intel) and 1996 (ISSCC: NEC 64 M), and for NAND flash in 1995 (VLSI Symposium: Toshiba) and 1996 (ISSCC: Samsung 128 M), respectively.

Early development of multilevel technology was mainly focused to NOR type, aiming to compete with the NAND type which was suitable for large capacity but not suitable for multi-level scheme.

Actual multilevel flash products were commercialized by SanDisk and Intel in 1997 as 64Mbit NOR flash. Later, in 1998, an AND type 256 Mbit flash memory based on multilevel technology was announced at ISSCC from Hitachi in 1999, and Mitsubishi also announced a 256M product, and mass production using multilevel technology was started in substantial manner for the first time. As a result, the flash capacity increased drastically, and flash cards became multilevel AND and NAND types as mainstream. Multilevel NOR type flash was not actually commercialized. As a capacity increase technique of NOR flash, 2bit/cell mirror bit method was devised (AMD) and applied to the actual product.

Capacity expansion of flash memory advanced with the pace of twice every year by the multilevel AND and miniaturization of NAND. 1 Mbit was the main product around 1990, and it advanced to 256 Mbit at the end of 1990. In recent years, the demand for large capacity flash memory (flash card) has dramatically increased, and multilevel technology is also adopted in NAND type flash in order to realize the capacity increase rate of twice per year.

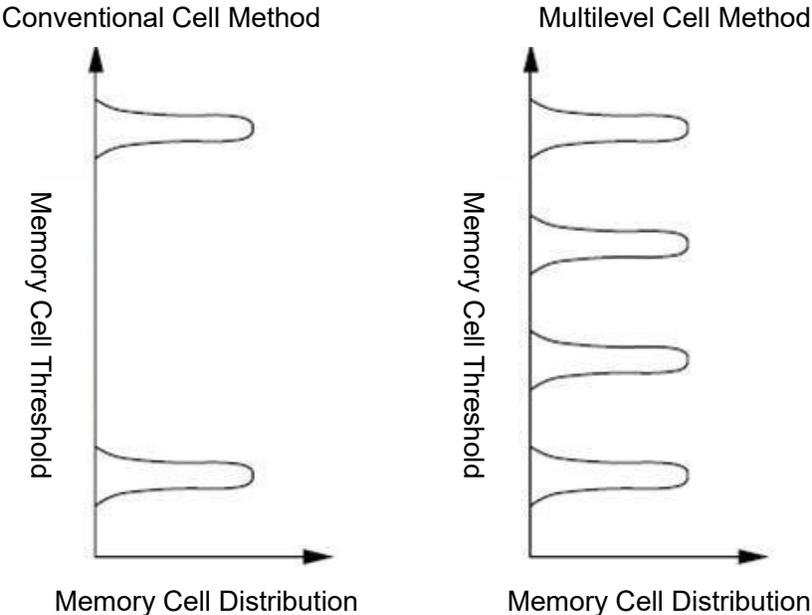


Fig.1: Threshold Level Distribution of Multilevel Memory

In the conventional cell system, two threshold values of “0” and “1” are stored, whereas in the multi-level cell system, by controlling thresholds at four levels, corresponding to “00”, “01”, “10”, “11”, data for two equivalent cells are stored in one cell.

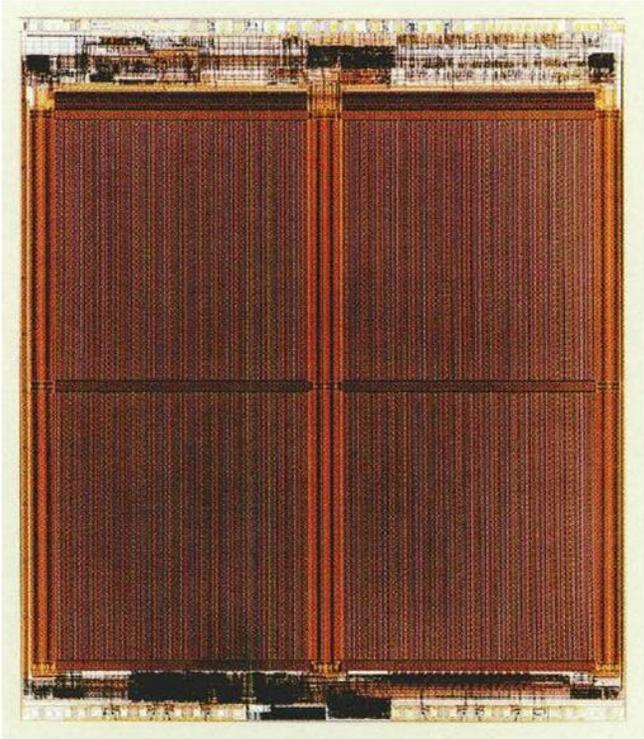


Fig. 2: 256Mbit multilevel AND Flash memory (Hitachi)