

Digital Memory Card Market and Technology

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Abstract

This paper provides a review of the NAND and NOR flash memory technology and the market trend. Details on the market share and providers of NOR and NAND are included. Key considerations are focused on the various memory storage card formats, flash IC packaging and card assembly process. Manufacturing issues in the latest trend of further reducing the card size to mini- and micro-formats are discussed.

1. Introduction

In recent years, the proliferation of portable consumer electronics such as MP3, digital camera, and 3G mobile phones created a tremendous appetite for digital memory cards that use nonvolatile flash memory for information and data storage. This paper provide a review of the progress in the flash memory technology for NOR (Not OR) and NAND (Not AND) flash memory integrated circuits (ICs). We will review the market application of memory combo and stacked die multichip packages (MCP) used in both low-end and high-end consumer electronics products. Packaging technology for memory chips, from die stacking to package-in-package and package-on-package stack, are also reviewed.

The second part of this paper is focused on the assembly of digital memory cards used for storage, including various types of card formats and designs such as Secure Digital (SD), mini-SD, Multimedia Cards (MMC) and *MMCmobile*. These cards are assembled by either a chip-on-board (COB) process using bare dice, or surface mount technology (SMT) using packaged flash and controller components. The last step in card assembly is accomplished by using either a pre-mold cover or an injection mold process over a PCA (Printed Circuit board Assembly). The pros and cons of these two approaches are discussed.

2. Flash Memory Types

The NOR (Not OR) type flash memory was invented by Fujio Masuoka of Toshiba in 1984 and Intel developed it further for initial mass production [1]. In 1987 Masuoka also invented the NAND (Not AND) type flash. [1]. Because these two kinds of flash function differently, their applications are suitable for different purposes. The fundamental reason is due to the cell design of the memory—a NAND cell size is smaller hence more density can be packed in an IC chip,

where as the NOR flash requires a larger transistor cell, hence lower density on the same sized IC. Table 1 summarizes the main differences between NOR and NAND in certain property features. Due to the faster speed and accuracy, NOR is typically used for code execution and NAND, being higher capacity but a little slower, is used more for data storage. The differences between the two types in functionality, however, are becoming smaller as their design and technology is merging together more closely in recent years.

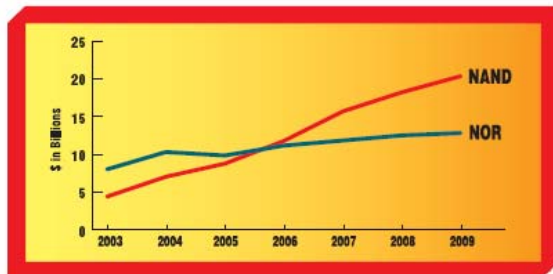
Table 1. NOR and NAND Properties

	NOR	NAND
Property	Fast access Low error Low density High cost Not scalable	Slow access More error High density Low cost Scalable
Application	Code execution	Data storage

2.1 Flash Markets

In 2004, the revenue for NOR flash memory was \$9.1 billion while for NAND, \$7.2 billion, according to Semico Research Corp. [2]. For 2005, the forecast revenue volume for NAND and NOR together will be over \$17 billion, a significant amount as compared to the total revenues for DRAM (\$26 billion) and semiconductor as a whole (\$206 billion). In recent years, the growth of NAND is expanding much faster than NOR, as shown in Fig. 1. The applications in portable data storage, the widely popular and growth in USB drives and digital still cameras all contribute to the need for more NAND memory. Whereas for NOR, its use in cell phones is now more limited to low-end and mid-range phones. For 3G and higher performance multimedia phones, or so-called smart phones, the trend is now using NAND and DRAM. In 2005, the revenue of NAND reaches parity with NOR for the first time, according to Semico [3]. Table 2 shows the gain in market shares between NAND and NOR. ISuppli predicts by 2009, the share of NAND will be 65% of the flash market. Table 3 lists typical memory packages used for code execution and memory usage for cell phones. For low and mid-range phones, NOR and PSRAM (Pseudo static random access memory) combination are used for initial phone registration to

the base station and code executions. For multimedia phones and smart phones, the trend is switching to use of SDRAM/NAND combination to increase the memory storage capability.



Source: Web-Foot Research Inc.

Fig. 1. Market Growth for NOR and NAND

Table 2 NOR and NAND Percent Revenues

Year	NOR	NAND
2000	91%	9%
2005	41%	59%
2009	35%	65%

(Source: iSuppli)

Table 3 NOR Mobile Phone Application

Phone type	Memory in package
Low-end	NOR/PSRAM (64Mb/16Mb)
Mid-range	NOR/PSRAM (256Mb/128Mb)
High-end	NOR/PSRAM (512Mb/128Mb) SDRAM/NAND (2156Mb/2Gb)

2.2 Current Technology

Table 4 lists the leading edge processing technology and the memory capacity for recent years and projected future progress. As recent as 2004, most suppliers use 110 nm process for 512 Megabit (Mb) density. In the current year, 2005, most have migrated to 90nm-process and 2-Gigabit (Gb) density. However, after 2009/2010, the process may reach 35 nm and the fabrication of flash transistors may no longer be scalable below 35 nm. At that time, other forms of memory may be developed to replace the silicon-based technology. One receiving the attention of many companies such as Intel and IBM is the phase change memory, or the Ovonic unified memory [4].

Table 4 Flash Memory Process

Year	Process	Density
2004	110 nm	1Gb
2005	90 nm	2Gb
2006	70 nm	4Gb
2007	55 nm	8Gb
2008	55 nm	8Gb
2009	35 nm	16Gb

2.3 Market Leaders and Price Erosion

The market share of major players who supply NAND is given in Table 5. The most dominating company is Samsung, followed by Toshiba/SanDisk. New comers Micron and Infineon are expected to have just minor shares according to RBC [5].

Table 5. NAND Market Shares

Company	2004	2005	2006
Samsung	60%	56%	54%
Toshiba/SanDisk	30%	29%	31%
Hynix/STMicro	5%	8%	8%
Renesas	4%	4%	4%
Micron	-	2%	2%
Infineon	-	1%	1%

The major NOR suppliers are Samsung, Toshiba, Intel and Spansion (AMD/Fujitsu); others are STMicro, Sharp, and Micron Technology. The market share as of the end of 2004 is given in Table 6. Intel's Sibley, due out by H22005, will use 90 nm process and offers 512Mb to 1Gb with a read speed of 500 kbs. The NOR market in 2004 was about \$10 billion. Semico forecasts that the 2006 market will be \$11 billion. The price decline per bit for NOR, however, would be less dramatic compared to NAND flash. For NAND, average price erosion per year for the last five years is nearly 40% per year.

Table 6. NOR Market Share

Company	Market share (%)
Samsung Electronics	25.1
Spansion	15.2
Toshiba	14.7
Intel	14.4
ST Microelectronics	7.7
Sharp	5.6
Renesas Technology	5.4
Silicon Storage Technology	2.8
Marconix International	2.1
Hynix Semiconductor	1.4

(Source iSuppli Corp 2/2005)

3. Digital Card Formats

Now we turn to the card formats using NAND flash memory for data storage, focusing on CompactFlash (CF), Multimedia Card (MMC), and Secure Digital (SD). Fig. 2 illustrates some commonly used cards. Currently, CF card market shares are gradually been taken over by thinner and smaller cards such as MMC and SD, as the memory density in these cards go up and increasing their storage capacity. In coming years, each card format may become to be specialized in certain applications. For example, CF cards may concentrate on very high capacity (4GB or higher) for use in high-resolution (>6 million pixel) professional, high-end digital still cameras or even camcorders for high volume recording and storage. On the other end of the spectrum, the thin form factor cards are moving even thinner and smaller for portable devices such as cell phones and multimedia phone or PDAs. The reduction in sizes in MMC—called MMC*mobile* and the miniSD that is about half the size of a regular SD card, are obviously intended for mobile applications. Most recently, there are microSDs (Fig. 3) and MMC*micro* (Fig. 4). The microSD card is based on SanDisk Transflash cards. Due to their minuscule sizes, initially, their memory densities are typically no more than 50% of their respective “mother” cards, or in the range of 128/256MB. With use of MCP (multichip package), however, stacked flash die inside the card will enable even the smallest cards to have memory density in the 512MB and even 1GB range.



Fig. 2. Various Card format and sizes



Fig. 3 SanDisk T-flash (microSD)



Fig. 4 MMCmicro (Courtesy Samsung)

3.1 Market Shares

As of 2004, the SD cards have become the most dominating format of choice with over 40% of the total card market, CF cards share, due to its relatively larger format, is declining with 26% and continue to drop. Sony's Memory Stick (MS) and MMC hold around 15% each. The competition is very dynamic as newer formats and versions with added features (security, biometrics, low voltage for mobile) become available. Some analysts predict that the various formats will consolidate eventually with SD, MMC and MS remain the main players.

3.2 MMC versus SD

When selecting the types of flash cards for application and devices, the performance and other factors such as license, royalty, security, and standards are all part of design considerations. Currently MMC and SD cards are the two more dominating format of choice, in Table 7 the special features of these two cards is compared. The design and performance difference between the two cards are now nearly equal. One useful factor to note is that, because both MMC and SD cards have the same outer envelop, the MMC cards can be used in the same slot for SD cards and most readers are designed to accept both MMC and SD cards.

Table 7. MMC and SD Comparison

Feature	MMC	SD
Dimension	32x24x1.4	32x24x2.1
Interface	7-and 13-pin	9-pin
Data security	High level (PKI)	Mid-level
License	No fee	Fees
DRM (digital right Management)	Mobile application	PC-centric
Low Voltage	1.8V	1.8V

4. Card Assembly Process

The assembly process for all the thin form factor cards is rather similar. Here we will cover the layout and assembly for CF cards, MMC cards and SD cards. As the cards migrate to mini and micro sizes, the card become essentially an SIP in MCP package. Therefore,

SIP and MCP processes are often used in the manufacturing of these miniaturized cards.

4.1 CF card assembly

The CF card is a shorter version of the PCMCIA card and the granddaddy of other thin cards that follow. However, for assembly process the CF cards are ideal with its relatively large dimensions of 43x36x3.3 mm. With overall body height of 3.3mm, the internal PCB subassembly can use laminates as thick as 0.5mm and standard TSOP packages for the flash on both sides of the PCB. Fig. 5 illustrates one simple layout with a single TSOP flash on one side and a controller (uC) in PQFP on the other side. It is possible to place four TSOPs inside and hence the total card capacity can be greatly enhanced, reaching 4 GB easily using today's 1Gb flash ICs. The CF card body is typically placed inside a plastic frame with either a plastic or a metal foil cover and sealed by thermosonic bonding.

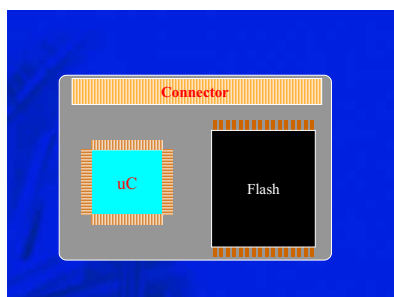


Fig. 5. CF Card Layout

4.2 MMC card assembly

For MMC cards the body thickness is reduced to 1.5 mm, this presents a severe challenge in the assembly of the PCB and the card itself in keeping the body flatness to within the specification of 0.2mm. For a PCB subassembly, there are two commonly used methods. One is using surface mount technology (SMT) to assemble the flash (in TSOP or WSOP) and controller (in LGA, land grid array). The other approach is use chip on board (COB), where the bare die flash IC and controller are wire bond to the substrate. Fig. 6 shows a TSOP design by AboCom Systems Inc. where the TSOP top surface is exposed because the combined height of the substrate and TSOP already reaches the card thickness limit of 1.5 mm. If, however, the TSOP is compressed to reduce its lead height, the substrate/die subassembly height may fit under a cover, as shown in Fig. 7. The choice for the controller chip package can be in other formats such as LGA or MLF (micro Leadframe) packages. For the SMT process, however, the combined package/substrate height must be limited to less than 1.3mm total. The top card cover uses a thin

metal foil to maximize the space allowable for the substrate subassembly height to about 1.3mm.

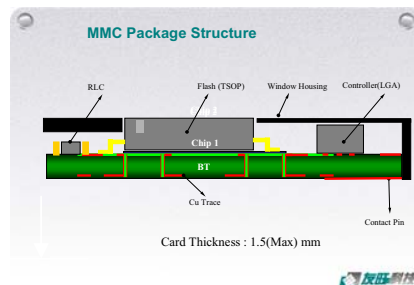


Fig. 6. MMC Card construction
(Source: AboCom Systems Inc)

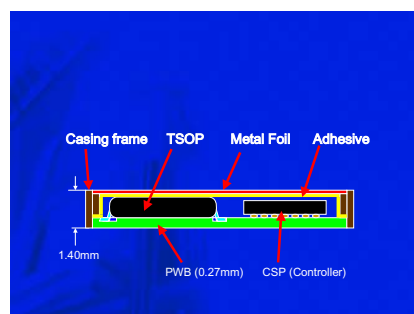


Fig. 7 MMC cross section with enclosed TSOP

When the COB approach is used, there should be more room for the IC since no semiconductor package is present. A glob top can be cast over the COB, or transfer mold is applied over the flash ICs. If necessary, stacked die may be used to increase the card density. Figure 8 illustrates a card with glob top and injection molded cover over the glob top.

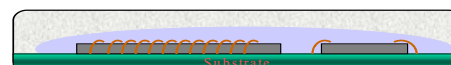


FIG. 8 MMC with flash and controller IC in glob top

4.3 Injection Molded cards

Instead of assemble the PCB subassembly in SMT with packages or COB by glob top or transfer mold, another method to incorporate the cover directly to the PCB subassembly is to use injection mold over the

subassembly. Injection molded covers offer several advantages over separately glued-on covers. In injection mold, the mold resin cover all the void space inside the card body, hence offering a more rugged card with more solid and stiffness. By sealing the substrate tight, the material also prevent moisture penetration, so when a card is accidentally dropped into liquid (coffee, water, toilet, rain, etc), the card interior would not be wet and become damaged.

4.4 SIP and MCP for miniature cards

Because of the thin thickness in the reduced sized cards (typically less than 1.0mm), and they must still contain high memory capacity, multichip package (MCP) must be used. Here, an MCP is considered as a package with multichip die stacking, while an SIP (system in package) is a package containing different components such as flash, controller, and passives. Thus, a miniSD or microSD card containing one flash die and other necessary components may be called an SIP. If the package contains also stacked die with two flash ICs, it may be an MCP, yet still in a SIP package. Fig. 9 illustrates an SIP layout containing one flash IC and a smaller controller die stacked on the topside of the flash IC. To conform to the overall card thickness, the stack height must be less than 1.0mm, and die thickness usually are thinned to 100 μm or less. Such chip-on-board (COB) assembly can then be molded to form final card finish size and appearance.

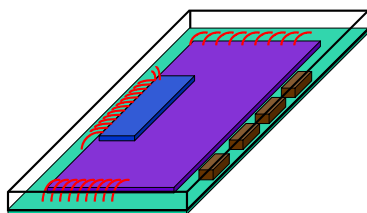


Fig. 9 SIP for Flash card

5. Summary

The growth of NAND and NOR type flash memory cards have been phenomenal in the past few years with the proliferation of consumer use of portable devices and digital storage. The flash market in 2005 is \$17 billion for both NAND and NOR, however, NAND growth is expected to outpace NOR and will have higher revenue in the years to come. Currently, many different card formats are all growing in popularity, but SD and MMC cards are the leading formats as their memory density increases while CF cards are becoming

more specialized in high-end professional digital photography. The fabrication process of MMC and SD cards are moving toward SIP and MCP, due to continued reduction in the card size and thickness. Of 1.0mm and lower Main manufacturing challenges include using thin die stack, thin substrates and method of forming the final card dimensions by either applying a thin cover or direct over mold.

References

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