

A 3D-NAND and SSD Industry Update, and the HDD Roadmap

Summary

We hosted a call with an NAND industry expert, Jim Handy. Some takeaways include: 1) Samsung 48-Layer 3D-NAND is now available in the market; 2) MU is now showing 64-layer 3D-NAND; 3) enterprise SSDs with a 32% CAGR continue to be a big market for NAND; and 4) the HDD OEMs also continue to push areal density enhancements with shingled HDDs and HAMR. We believe increasing NAND supply will be a drag on the HDD industry, which is facing challenges with weak PC demand, a flat high performance market, and margin headwinds such as Toshiba.

Key Points

Samsung 48-Layer products are now available in the market. In line with our note last week, ([Link](#)), our industry expert noted Samsung's 48-layer 3D-NAND is now available as of last week (which assuming the 1.5-2 month production cycle would imply a January start to production).

Is Micron going from 32-Layer (L) to 64-L? The speaker also noted that at the International Solid-State Circuits Conference in San Francisco in February, MU showed what appears to be 64-L 3D-NAND. To put in perspective, 48-L drives 50% bit growth from 32-L and an ~30% cost reduction, with a much better ROI.

Soft NAND pricing in January, and the Toshiba operating margin guide, could point to soft NAND pricing in 2016. Jim also noted NAND pricing in January was weak, and appears to have stabilized. But we would note Toshiba (Covered by Takeshi Tanaka, Mizuho Japan) guided Apr'16-Mar'17 OM down 1000bps to 5%. As we show on the next page, SNDK and Toshiba operating margins trend similarly and could point to some weakness.

Enterprise SSDs, growing at a 32% CAGR, could be a headwind for 15K HDDs if cost reductions in 3D-NAND get aggressive. Jim noted enterprise SSDs will grow at a 32% CAGR into 2019, and any potentially significant ~40% 3D-NAND cost reduction could start to impact an already mostly flat growth 15K enterprise HDD market.

HDD OEMs continue to focus on Areal density enhancements to compete with SSDs. Key to note also, the HDD OEMs are following areal density enhancement. Near-term, the focus is on PMR and shingled HDDs to drive better capacities. But we believe soft NAND pricing and 3D-NAND could continue to pose a challenge to HDD OEMs.

Company	Symbol	Price (3/22)	Rating		
			Prior	Curr	PT
Cypress Semiconductor Corporation	CY	\$8.78	-	Buy	\$15.00
Intel Corporation	INTC	\$32.32	-	Buy	\$37.00
Micron Technology, Inc.	MU	\$11.44	-	Buy	\$13.50
SanDisk Corporation	SNDK	\$77.12	-	Neutral	\$78.50

Source: Bloomberg and Mizuho Securities USA

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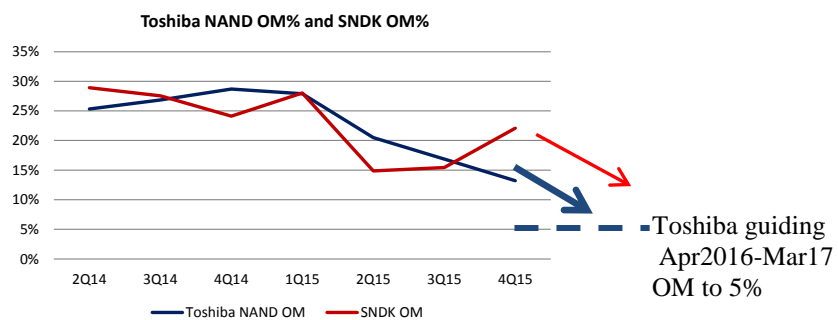
Enterprise SSDs, growing at a 32% CAGR, could be a headwind for 15K HDDs if 3D-NAND cost reduction gets aggressive. Enterprise SSDs are expected to grow at a 32% CAGR through 2019. But IT managers are starting to upgrade current PC systems with SSDs as opposed to refreshing an entire PC group, as it drives significant performance upgrade at a much lower cost. Jim noted SSDs are also treading on the heels of 15k mission-critical HDDs. SSDs are becoming a more viable option as opposed to the high priced, high speed HDDs, as IT can replace multiple HDD systems with a single SSD system of the same performance. The net result is the high end 15K high performance HDD market has flat lined. Key is if the SSD costs start to come down 40% y/y with 3D-NAND, there is a further risk to the HDD market. Nonetheless, HDDs have **proven to be reliable compared to relatively new SSDs and still favored in IT environments.**

China wants to get to 20% of the NAND market, and another key 3D-NAND player could be Cypress with CT. Jim also noted that China wants a local company to get to 20% share of the NAND market, and hence there could be substantial investments from China. Some key players noted were XMC. Another key supplier of 3D-NAND IP noted by the speaker is CY, with charge trapping 3D-NAND IP.

HDD OEMs have areal density enhancements techniques on hand. Near-term, the industry focusing on PMR (perpendicular magnetic recording) and shingled HDDs to drive areal densities and stay competitive with SSDs. In the long-term (many years away), we believe while costs reductions could plateau the HDD industry is working on: 1) HAMR (Heat Assisted Magnetic Record) into the 2019-21 timeframe, which would allow the bits per square inch to be multiplied by 10x; and 2) HDMR – heated dot magnetic recording in 2025.

Toshiba guiding Apr-2016 to Mar-2017 operating margins in NAND to 5% (versus 15% in FY3/16. We take a look at SNDK and Toshiba operating margins in NAND, and while SNDK margins have a lag, they seem to trend in-line with Toshiba. With Toshiba guiding Apr’16-Mar’17 operating margins in NAND to 5%, down 1000bps, could point to either weakness in NAND pricing or challenges in initial 3D-NAND ramps.

Exhibit 1: Toshiba NAND OM% and SanDisk OM% - a lag but similar Trends



Source: Mizuho Securities estimates, Company reports

Is Micron going from 32-Layer (L) to 64-L? Jim noted that MU showed what appears to be 64-L 3D-NAND at recent conferences. To put that in perspective, a 64-L 3D-NAND would increase output NAND bit substantially versus 32-L while also driving significant cost reduction (at 48-L it drives 50% bit growth from 32-L and a ~30% cost reduction). The MU/Intel design of FG(floating gate) 3D-NAND is initially easier to manufacture than CT (charge trapping) NAND.

A replay of the conference call is available **until 11:59 PM, Tuesday, March 29.**

Glossary

~ - approximately	eMCP - embedded multi-chip module using DRAM and NAND	IoT - internet of things	nm - nanometer	RSP - Renesas Semiconductor products/Drivers
1H/2H - first half/second half	EMV - Europay, MasterCard and Visa, a payment consortium	IP - intellectual property	NOL - Net Operating Losses	RSU - Restricted Stock Units
2G/3G/4G - 2nd generation, third generation, 4th generation wireless	EOY - end of year	ISM - Institute for Supply Management	NOR - a type of non-volatile storage memory	SAS - serial attached SCSI (small computer system interface)
3G/4G - Third generation / Fourth generation	EPS - earnings per share	ITU - International Telecommunication Union	NPV - net present value	SAW - surface acoustic wave filters
4G-LTE - Fourth generation, long term evolution	ET - envelope tracking	JPY - Japanese yen	NVMe - Non-volatile Memory Express	SDH - Synchronous Digital Hierarchy, mostly in Europe
ADAS - Automotive driver assist systems	ETD - Emerging Technologies Division	JV - joint venture	NYSE - New York Stock Exchange	SG&A - Sales, General and Administrative
APU - accelerated processing unit	EU - European Union	K - Thousand	ODM - original design manufacturer	SLAC - subscriber line audio-processing circuit
ARM - a family of instruction set architectures used for processors for computers, servers, etc.	EV - enterprise value	Kbps/Mbps - Kilobit per second/Megabit per second bandwidth	OEM - original equipment manufacturer	SLIC - subscriber line interface circuit
ASIC - application specific integrated circuits	EvDO - Evolution Data Only	KGD - Known Good Die	OFN - optical finger navigation	SMIC - Semiconductor Manufacturing International Corporation
ASP - average selling price	EVP - Executive Vice President	Kwpm - thousand wafer per month capacity	OLT - Optical Line Termination or Terminal	SoC - system on chip
ATM - Asynchronous Transfer mode	F - Fiscal	LIBOR - London Interbank Offered Rate	OM - operating margin	SONET - Synchronous Optical Network, used in North America
B - Billion	FASB - Financial Accounting Standards Board	LQ - last quarter	ONU - Optical Network Unit	SOX - Philadelphia semiconductor index
BAW - bulk acoustic wave filters	FBAR - film bulk acoustic resonator, a type of filter	LSD - low single digits	Opex - operating expenses	SRAM - static random access memory
BiDi - Bi Directional	FBAR/BAW - Film Bulk acoustic resonator/Bulk acoustic wave Filters	LT - long term	P/B - price to book value ratio	SSD - solid state drive
BOM - bill of materials	FCF - free cash flow	LTE - long term evolution, a 4th generation wireless protocol	P/E - price to earnings	TAM - total available market
bps - basis points	FDD LTE - Frequency Division Duplex Long Term Evolution	LY - last year	P/S - price to sales	TD - time division
CA - carrier aggregation	FP - finger print	m - Meters	PA - power amplifier	TDDI - touch display driver integration
CAGR - compound annual growth rate	FPGA - field programmable gate arrays	M - Million	PAD - power amplifier duplexer, essentially 2 filters and a Power amplifier	TDD-LTE - Time Division Duplex Long Term Evolution
CAPEX - capital expenditures	FT - force touch	M&A - mergers and acquisitions	PC - personal computer	TD-SCDMA - Time Division Synchronous
CDMA - code division multiple access	FTC - Federal Trade Commission	MB - megabyte	PCIe - Peripheral Component Interconnect Express	TLC - triple level cell
CEO/CFO - Chief Executive/Chief Financial	FY - fiscal/full year	Mbps - megabit per second	PMI - Purchasing Managers' Index	Tx/Rx - Transmit / Receive
CES - consumer electronics show	GAAP - generally accepted accounting principles	MCU - micro controller unit	PMIC - Power Management Integrated Circuit	USB - universal serial bus
CF - cash flow	Gb/GB - gigabytes/Gigabit	MHz - megahertz	PoE - Power over Ethernet	wpm - wafer per month
CFIUS - Committee on Foreign Investment in the United States	Gb/s - Gigabit per second	MIIT - China Ministry of Industry and Information Technology	PSD - Programmable systems division	x86 - Intel based processor architecture
COO - Chief Operation Officer	GF - Global Foundries	MIMO - multiple in, multiple out	PSoC - programmable system on a chip	XMC - Wuhan Xin Xin Semiconductor Manufacturing Corporation
CSP - chip scale packaging	GHz - gigahertz	MLC - multi level cell	PT - price target	y/y - year over year
CY - calendar year	GM - gross margin	MoE - merger of equals	Q - quarter	YE - year end
D/E - debt to equity	GPU - graphics processing unit	MOFCOM - Ministry of Commerce People's Republic of China	q/q - quarter over quarter	YTD - year to date
DCF - discounted cash flow	GSM - Global System for Mobile Communication	MSD - mid single digits	QCT - Qualcomm chip technologies	
DoD - Department of Defense	HDD - hard disk drive	MSM - multi station modems, QCOM's QCT chips	QTL - Qualcomm technology licensing	
DRAM - dynamic random access memory	HSA - heterogeneous system architecture combining x86 and ARM	NAND - "not and," a type of memory	R&D - research and development	
DT - desktop	HSD - high single digits	NB - notebook	Rev - revenues	
eMMC - Embedded managed NAND solution	I/O - input output operations	NDRC - National Development and Reform Commission in China	RF - radio frequency	
EBITDA - earnings before interest, taxes, depreciation and amortization	IC - integrated circuits	NFC - near field communications	ROI - return on investment	

Price Target Calculation and Key Risks

Cypress Semiconductor Corporation

Price Target: We believe CY is now a changed story, with a revenue focus on automotive and industrial, an automotive focused sales force, much less exposure to SRAM, continued fab consolidation with Fujitsu and Fab-4t on track with automotive qualifications and a dividend while you wait. CY's emerging technologies division is also starting to drive topline growth. Our PT of \$15 is based on 15.0x our F17E EPS of \$1.00.

Risks: CY competes in a cyclical, technologically intensive industry. Financial expectations and achieving future growth is subject to a number of risk factors, including, but are not limited to, the following:

Market Risks:

- Lumpiness in telecom and communication markets;
- Macro global slowdown, especially if the key U.S. economy is weak, impacting industrial, automotive and or weaker consumer spending; and
- Customer concentration, competition and pricing pressure from other low-cost OEMs, ODMs and suppliers and possible new market entrants from China, Asia-Pacific, or Taiwan.

Technology Risks:

- Potential loss of intellectual property and or commercialization of competing technologies,
- Successful integration and growth from Spansion acquisition
- Litigation Risks - adverse effects of potential existing and possible future patent or other litigation

Intel Corporation

Our 12-month price target of \$37 is based on 15.4x our 2017 EPS estimate of \$2.41 plus cash. In addition to competitive risks from a broad array of semiconductor and OEMs, macroeconomic risks and new product execution risks could impede the realization of our target price. INTC has traded between 10-16x forward P/E in the last 5-years.

Risks. We believe the risks to INTC are from a maturing PC market and limited traction in wireless and difficult comparables in tablets. Where we could be wrong is if INTC gets a significant foundry deal or makes a significant handset acquisition.

Micron Technology, Inc.

Price Target: We have MU rated Buy with a \$13.50 PT, ~9.9x our F17E EPS of \$1.36. MU has traded between 8-14x forward earnings over the last 5 years.

Risks: Micron competes globally in a highly cyclical and technology intensive market.

Key risks include:

- Memory ASP declines and cyclical;
- Competitive and market share pressures;
- Increased industry memory Capacity and increased Capex from Samsung, Hynix;
- Slower 20nm DRAM ramps, higher costs or yield issues;
- Slower NAND improvement and/or 3D-NAND yield issues affecting ramps; and
- Other macro-economic, litigation, competitive, currency and technology risks.

SanDisk Corporation

Price Target: Given some of the near-term challenges with customer share loss, 15nm ramps and 3D-NAND ramps ahead, we have SNDK with a Neutral rating and a \$78.50 price target, the value of the WDC acquisition (as of WDC Feb. 22nd closing price) and 34.3x P/E our F16E EPS of \$2.29. SNDK has \$2B in cash and short term investments and industry leading gross and operating margins in NAND by a wide margin. SNDK also has a strong Enterprise SSD portfolio with multiple strategic acquisitions that positions it well. As a result, we see limited downside risk in the stock from here.

On the other hand, even though SNDK is a leader in NAND, it still needs to regain its share loss, its 15nm/3D-NAND lead and revitalize retail. While estimates and expectations have come down substantially, as evidenced by GM consensus for 2015E now down 650bps y/y versus prior flat y/y, we will wait for some confirmation that: 1) 15nm yield issues are behind and 3D-NAND is moving to production; and 2) that SNDK can start to regain some of its enterprise-client SSD market share.

Risks: SanDisk competes in a cyclical, technologically-intensive business. The company's ability to meet our financial expectations and achieve future growth is subject to a number of risk factors, including, but not limited to, the following:

Market Risks

- SanDisk's continued success in its research and development efforts and timely introduction and execution of its new products.
- Slower demand growth in the retail and handset NAND market could leave a substantial supply overhang, further depressing pricing.
- Competition from Samsung, Hynix, Micron, and other large players in the SSD, NAND flash market with transition to 15nm and 3D-NAND.
- Unexpected changes in legal and regulatory requirements, tariffs, and exchange rates, political and economic stability, staffing and management issues, and potentially adverse tax consequences for its international operations.

Technology Risks

- Slower-than-expected NAND transition with 15nm and 3D-NAND and adoption of key SAS/3D/PCIe technologies.

- SanDisk gets ~70% of royalties from Samsung and the royalty comes up for renewal Aug-2016

Companies Mentioned (prices as of 3/22)

Cypress Semiconductor Corporation (CY- Buy \$8.78)
 Micron Technology, Inc. (MU- Buy \$11.44)

Intel Corporation (INTC- Buy \$32.32)
 SanDisk Corporation (SNDK- Neutral \$77.12)

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(As of 3/22)	% of coverage	IB service past 12 mo
Buy (Buy)	51.93%	36.17%
Hold (Neutral)	46.41%	25.00%
Sell (Underperform)	1.66%	33.33%

For disclosure purposes only (NYSE and FINRA ratings distribution requirements), our Buy, Neutral and Underperform ratings are displayed as Buy, Hold and Sell, respectively.

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