Managing the paradigm shift to Mobile platforms in the semiconductor industry

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SUBMITTED TO THE MIT SLOAN SCHOOL OF MANAGEMENT IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTERS OF SCIENCE IN MANAGEMENT STUDIES
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE 2012

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Abstract

In the recent years we are seeing a significant shift from the PC & Laptop, so called EDP (Electronic Data Processing) to the mobile devices such as smartphones and tablet PCs. Driven by strong customer demands and the technological advancements on the supply side which enable companies to fulfill them, this is a trend which is expected to continue for the near future, at least, and the future of the conventional devices do not seem so bright.

This trend has a significant influence on the overall life of anyone living in this environment, but it is even more obvious to the semiconductor industry which is not only fundamental to all the devices, but also is critically influenced by the major changes in the application trends. The shift to mobile devices will not only have influence on the quantity of semiconductors but due to the different characteristics required by the devices, the overall industry is expected to undergo notable adjustments.

The thesis analyzes the current wave of change in the use and development of computing devices and foresees how the mobile devices will influence the conventional ones and eventually change the strategies and competitive structure in the semiconductor industry.

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Chapter 1 Introduction

The semiconductor industry all started when Walter Brattain and John Bardeen, scientists at the Bell Telephone Laboratories in Murray Hill, New Jersey, first invented the transistor. Their research aimed to replace vacuum tubes as mechanical relays in telecommunications and were researching the behavior of germanium crystals as semi-conductors. Vacuum tubes enabled long-distance calls by amplifying voices but the tubes consumed a lot of power which resulted in creation of heat and rapid burn-outs. So the tubes required high maintenance which was not only inconvenient but also very costly. [1] For their work on the transistor, the three inventors shared the 1956 Nobel Prize in physics.

Interestingly the fate of the semiconductor industry has come back to where it all began, Telecommunications.

*This is a day I've been looking forward to for two-and-a-half years. Every once in a while, a revolutionary product comes along that changes everything.*

... 

*So, three things: a widescreen iPod with touch controls; a revolutionary mobile phone; and a breakthrough Internet communications device. An iPod, a phone, and an Internet communicator. An iPod, a phone are you getting it? These are not three separate devices, this is one device, and we are calling it iPhone.*

*Today, today Apple is going to reinvent the phone, and here it is.*

- Steve Jobs at the Macworld Conference & Expo 2007 introducing the iphone
Some would say that the mobile revolution began with the above keynote speech at the Macworld Conference & Expo 2007 by Steve Jobs. After Steve shocked the world with his usual motivational speech the first iphone came to the market in June of 2007. People did not mind sleeping in the open and as a reward they were able to be the ones to possess the first iphone. The media spotlighted the iphone as something totally different from anything previous and this was the beginning of the mobile revolution.

The first phase of the mobile revolution can be defined as the ‘Innovation’ phase led by Apple. Everything was new and innovative and the life style of people changed dramatically adjusting to the new environment. But the paradigm shift to mobile platforms has changed not only the everyday life of people but also most of the global hardware industry. Dramatic changes which were not even imaginable merely 2~3 years ago have been happening within months and weeks.[2]

Nokia has been the leader in the mobile phone market since 1998 and their position seemed to be extraordinarily strong. But with the emergence of the smartphones their market leadership is in extreme danger and they are struggling to survive the change. Motorola, who was the market leader prior to Nokia and is called the matrix of mobile communication is now a part of a search company called Google. And who would have imagined that Hewlett-Packard would be seriously considering the spin-off of its industry leading Personal Systems Group (PSG) - which includes PCs - and would kill its new tablet computer as part of a major revamping away from the consumer market.

But now, coincidently at almost the same time as the pass away of Steve Jobs, the mobile revolution is moving into its 2nd phase. And the new phase can be defined as the ‘Growth and
Evolution’ phase.[2] According to Gartner, the smart device market which is the total of smartphones and tablets, in 2012 is expected to be over 730 million units which is almost two times the PC unit shipments.

Figure 1: PC and Smart Device Shipment Forecast

<table>
<thead>
<tr>
<th>Year</th>
<th>PC</th>
<th>Smart Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>308M</td>
<td>172M</td>
</tr>
<tr>
<td>2010</td>
<td>351M</td>
<td>316M</td>
</tr>
<tr>
<td>2011</td>
<td>353M</td>
<td>537M</td>
</tr>
<tr>
<td>2012</td>
<td>368M</td>
<td>735M</td>
</tr>
<tr>
<td>2013</td>
<td>412M</td>
<td>973M</td>
</tr>
<tr>
<td>2014</td>
<td>462M</td>
<td>1,201M</td>
</tr>
<tr>
<td>2015</td>
<td>520M</td>
<td>1,463M</td>
</tr>
</tbody>
</table>

Source: Gartner

As the size of the smart device market becomes significant, the importance of key components of the devices is expected to emerge and the other hand that of the user interface or applications to shrink. This is due to the fact that during the growth of the industry, the followers have caught up with the innovators, Apple, and the differences among these factors have diminished rapidly.
But the growth of the smart devices do not only influence shipments of hardware products. It is dramatically changing the OS (Operating System) and CPU (Central processing) markets.

In the PC hardware world, Intel was the dominant player not only in their field but throughout the entire PC supply chain since they had, and still has, such dominant market share in one of the key components. But as the AP (Application Processor) market becomes significant with the growth of the smart devices market, players who are strong in the AP field such as, Samsung, Apple, ARM, are growing very rapidly.

If Intel was the powerhouse of the hardware side of the PC era, Microsoft was the counterpart on the software side. Microsoft has maintained its monopolistic market share in the PC OS but in the mobile smart device market it is a totally different story. As you can see in the below graph, although Microsoft is expected to grow from 2012 due to the introduction of its Windows 8, they are trailing by far to Android and iOS.

**Figure 2 : Market Share of Smart Devices by OS**

Source: Gartner
In short terms, with the growth of the mobile smart device market, the era of WINTEL (Windows+Intel) seems to be fading away. [2]
Chapter 2 Analysis of the Key Applications’ trends

In this chapter, I will analyze how the trends of the key applications are changing and how the mobile devices are affecting the demands and uses of conventional computing devices.

2.1 Personal computers

According to IDC’s 2011 Consumer PC Buyer Survey, among the US participants of the survey who at least had one PC, 87.8% of respondents said they have at least one desktop in their home; another 41.5% said they have at least one notebook. [3] In a worldwide survey, 83.1% of the respondents said they have a desktop PC at home and 58.9% said they have a note PC.

Figure 3: Current Desktop PC and Notebook PC Ownership
Although currently more people possess a desktop PC, among the US respondents who said they anticipated buying a new PC in the next 12 months, 44.0% said they'd likely buy a new desktop PC, 58.8% said they'd buy a notebook and 17.8% said they would buy a tablet such as the iPad or other Android devices. [3]

Figure 4: Future PC purchase form factor

This trend of going mobile can be seen in the recent years of PC shipment and forecasts of following years. Since notebook PC shipment first exceeded the desktop PC in 2008, the trend has never slowed down.
According to the forecast of Gartner, the compound annual growth rate (CAGR) of the mobile PC will be 12.1% between 2009 and 2016. But the desktop is expected to only mark a 1.5% CAGR during the same period. And the growth of mobile PC and sluggish of the desktop PC is more obvious in the consumer sector than the professional sector.

2.2 Mobile Devices

2.2.1 Smartphones

In 2011, the worldwide smartphone market exceeded most people’s already aggressive predictions and shipped nearly 480 million units. This is nearly 60% increase from that of 2010 which was slightly under 300 million units.
2.2.1.1 Smartphone shipment trends in 2011

The smartphone market once again proved one of the main drivers of the overall mobile phone market, which grew 11.7% year over year. In 2011 smartphones accounted for 32% of all mobile phone shipments for the year, up several percentage points from the 22% proportion in 2010. [4]
In 2011, there were major changes in the three traditional powerhouses of the mobile phone and smartphone industry.

First, Nokia discarded their long time smartphone operating system, Symbian. In the second month of 2011, Nokia's new CEO and former Microsoft executive Stephen Elop, announced a partnership with Microsoft that will pair Microsoft's less-than-successful Windows Phone 7 OS with Nokia's flagging handset business. The move was a dramatic shift for the Finnish handset maker, which seemed to completely abandon what was still the market-leading, albeit declining, mobile phone operating system. [5] And at the same time Nokia also added Bing, the Microsoft search engine, as its default engine in its phones. By October, Nokia announced its first devices running on Windows Phone and by the end of the fourth quarter, Nokia had quickly become the worldwide leader of Windows Phone smartphones worldwide. [4]

Research In Motion had its own issues. The company released few new devices during the first half of the year, waiting until the official release of its new BlackBerry OS 7 to launch refreshed smartphones. While these presented "fresh but familiar" experiences to users, overshadowing their success was a slowly creeping nearly worldwide outage of its proprietary network. Although RIM was able to remedy the outage within a matter of days, it was enough for users and companies to rethink their decision to use BlackBerry smartphones. [4]
Figure 8: Smartphone shipment share by top 5 vendors

![Smartphone shipment share by top 5 vendors](image)

Source: IDC

And as the year passed its mid-point, in August, Google announced its largest M&A projected of all time to acquire Motorola Mobility for $12.5 billion. Google stressed repeatedly that the acquirement’s main objective was to secure the extensive library of patents of the target company. But the consolidation of the largest smartphone OS and at one time the leader of mobile devices was more than enough to catch serious attention of smartphone makers mainly using the Android as their operating systems such as Samsung and HTC. And this attention led to the partnership of Samsung and Microsoft.

Microsoft and Samsung announced at the end of September that they had signed a definitive agreement with Samsung Electronics, to cross-license the patent portfolios of both companies, providing broad coverage for each company’s products. Under the terms of the agreement, Microsoft would receive royalties for Samsung’s mobile phones and tablets running the Android mobile platform. In addition, the companies agreed to cooperate in the development and marketing of Windows Phone. [6]
And at the end of the year Apple announced the iPhone 4S and took the most shipping of a smartphone title from Nokia thanks to a delayed release schedule compared with previous years and more operators offering the iPhone, despite the lack of 4G LTE connectivity or a different sized screen. [4]

2.2.1.2 Smartphone overall trend forecast

Not only more people are buying smartphones as their new mobile communication device, but more and more people are using their smartphones in tasks which traditionally desktop or notebook computer used to do. The traditional form factors of computers will not totally go away but smartphones, with tablets, will take a lot of tasks away from them. Already there are more mobile phones than computers connected to the internet [7] and the difference will widen up faster with the growth of the smartphone market. As smartphones gain widespread adoption, the desktop computer will be relegated to the specialist and elite professional, much as the mini-computer and supercomputer are today. Many of the routine tasks we currently perform on a desktop or laptop, we will be able to accomplish on a smartphone. More importantly, new applications will meet the needs of people who don’t use a computer today. [8] As easily predicted by IDC and Gartner, and basically any research organization, end-users’ interest in smartphones will increase and it is difficult to believe this trend will change direction in the near future.

IDC predicts the economic recovery will continue from 2012 to 2016 led by the mature markets, followed by emerging markets and this will have a very positive impact on the
smartphone market. Mobile phone vendors will shift resources from feature phones to smartphones as revenue and profit drivers. Strong demand for smartphones has caused vendors to shift their product portfolios to include more smartphones. In some cases, this has led to making the smartphone the cornerstone of the overall mobile phone business. This will increase shipments of smartphones. The likelihood of switching back to feature phones is unlikely. [4]

2.2.1.3 Smartphone operating system trend forecast

![Smartphone shipment share by OS (2008-2015)](image)

One of the biggest issues in the smartphone industry will be how the operating system war will end up. As mentioned in the begging of this thesis the operating system area is one of the biggest differences the mobile era has with the PC era. There will be less dominancy in the mobile operating system whereas in the PC Microsoft had a near monopoly dominance.

As you can see in the above graph, in the beginning, Nokia’s Symbian was the dominant operating system in the market. But as Apple’s iOS and Google’s Android started to penetrate
the market the situation changed very quickly and with Nokia abandoning Symbian and working with Microsoft’s operating system, it seems like the market will mostly be a three sum game. Both IDC and Gartner are forecasting the market to settle down at around 50% Android, 20% iOS, 20% Microsoft and the rest by minor players.

Android is most likely to be the leading operating system in the smartphone market for a while. Due to its open source and customization, Android’s flexibility is the best among the competitors. So in order to take advantage of these characteristics, major smartphone makers will deploy Android on their smartphones and make it the leading operation system of their strategies and many will try to reach out to the fast growing emerging market. The only real possible threat to the Android is itself. This meaning that according to how Google positions itself after the acquisition of Motorola, major vendors might consider adjusting their operating system strategies. The alliance between Samsung and Microsoft can be seen in this perspective. But since it is quite obvious that it would be a both sides losing game if it actually occurs, the possibility of Google making a decision radical enough to chase away the major vendors should be very low. Total Android-powered smartphone shipments are expected to reach 370.8 million units in 2012, up 52.4% from the 243.2 million units shipped in 2011. By 2016, total Android-powered smartphone shipments are expected to reach 551.1 million units, resulting in a CAGR of 17.8% from 2011 to 2016. [4]

Demand for the iOS, in other words iphone, has never slowed down since its first appearance in 2007. The current users are very loyal to the brand and product and seldom switch. At the same time new customers are always flowing in. But having only one company make smartphones with the iOS is a serious limitation and very difficult to be a sustainable strategy, especially without the man who led the whole thing in the beginning. It would be
interesting to watch how Apple goes about its smartphone strategies. The key points to watch would be how long they will maintain a premium brand strategy and how long they will stick with the one screen size strategy when other competitors have several different screen sizes which serve different needs of different customers. Total iOS-powered smartphone shipments are expected to reach 134.4 million units in 2012, up 44.3% from the 93.1 million units shipped in 2011. [4]

Adding the majority of Nokia and a part of Samsung on their side will spur shipments of the Windows operating system smartphones. And if the relationship with Google and the acquired Motorola seem to become closer and closer, the Microsoft operating system is the one that would most benefit from it. Symbian smartphones will steadily decrease throughout our forecast period. Other vendors will still ship Symbian devices, but will not be enough to sustain growth from previous years. [4]

Total Windows Phone-powered smartphone shipments are expected to reach 41.3 million units in 2012, up 353.8% from the 9.1 million units shipped in 2011. 2012 will be the first full year that Windows Phone will have Nokia as a smartphone partner. With more markets launching Nokia Windows Phone devices, the upward trajectory of Windows Phone is assured. By 2016, total Windows Phone–powered smartphone shipments are expected to reach 233.8 million units, resulting in a CAGR of 91.4% from 2011 to 2016.

Total Symbian-powered smartphone shipments are expected to reach 40.7 million units in 2012, down 50.0% from the 81.5 million units shipped in 2011. With many of its longtime supporters moving to other operating systems and Nokia's announcement to more aggressively execute on its Windows Phone strategy, Symbian powered smartphones will
experience a faster decline and reach an eventual end. By 2016, total Symbian-powered smartphone shipments are expected to reach 0.8 million units, resulting in a CAGR of -60.3% from 2011 to 2016. [4]

2.2.2 Tablets

_Last time there was this much excitement about a tablet, it had some commandments written on it._

–The Wall Street Journal–

On the 27th day of January two years ago Apple introduced the iPad to the market. It was not the first time a tablet PC was introduced to the market but as the above comment of The Wall Street Journal said, it was different. Maybe because of Apple or Steve Jobs but definitely it was different. And in a timeframe of just over two years, it has proved to be much more different than anyone first anticipated it to be. Tablets transformed from a small, niche and unexciting market to a hot-selling, aspirational consumer phenomenon. Tablets have changed not only the computing hardware industry but have significant impact on
consumer behaviors and content consuming activities. But it is now just the beginning. Up to now, Apple and the iPad is the strong leader in the market and others are following. But as in PCs and smartphones they will catch up on features and the war will be real from there on.

2.2.2.1 Tablet shipment trends

From 2010 through 2016, the unit production of media tablets will emerge aggressively at a CAGR of nearly 55%. The market size will be over 90% of that of regular mobile PCs which is expected to be near 370 million units in 2015. Although Android and Windows based tablets will grow at a significantly faster pace than the currently over 60% dominant player Apple, the iPad will continue to dominate the media tablet market through 2016.

Figure 10: Media Tablet Shipment Forecast (2010–2016)

![Media Tablet Shipment Forecast](image)

Source: Gartner

The media tablet is not, currently, a replacement for a regular mobile PC and should be viewed differently. It is primarily a content consumption device with some minimum features that can replace those on a regular mobile PC. Though Gartner predicts that the media tablet market won't rapidly expand its features to compete with regular PCs by 2012, it is obvious
that the media tablet PC has replaced part of the mini-notebook PC market with better service content and a user friendly interface. We expect to see more media tablets to become available during 2012. [9]

2.2.2.2 Tablet market trend forecast

Apple’s success in the tablet market with the iPad can be considered as the high end bar for media tablets. Among many competitors no one really has challenged to compete with a higher end product. And with the introduction of the Kindle Fire, Amazon effectively set the lower end bar of the market. Now it seems like other vendors’ battle field has been set. The higher end vendors, such as the Samsung Galaxy Tab, have mostly competed directly with the Apple iPad at a price range of $400–$700. The high-end devices are equipped with powerful hardware features such as dual core processors and larger displays. On the other hand the lower end devices with price range of $150–$250 have been mostly covered by lower end vendors.

Many have tried but Apple is a tough competitor to compete with. They are not just the first to deliver to the market. Adding to their already strong brand image and extremely loyal customer base, they have proved to the market in a short time that they add much value to the user’s everyday life and have a strong eco-system of supporting applications. Due to the promising future of the market many have tried but it seems no one really has been very successful in competing with the Apple iPad, yet.

HP would probably be the most obvious failure story. They launched the TouchPad running their own operating system, webOS, but eventually discarded the category just in few months due to extremely slow user adoptions.
Samsung has the Galaxy tab series with Android operating systems in the market. Many consider Samsung as the strongest competitor of Apple also in the tablet market as they are in the smartphones, up to now they have not been able to be as effective as they are in the smartphones. As the Android operating system evolves to a more optimized format for the tablets and its ecosystem develops, eventually Samsung will be the biggest threat for Apple.

HTC, another strong smartphone vendor, has the Flyer which offers the stylus input system and some creative features but has not much presence. Similar to Samsung HTC will also be much better off in the segment with the development of the Android OS and ecosystem.

Other vendors such as RIM, Lenovo, Asus and Acer have tried in the market with various form factors without any notable success. When Microsoft enters with its own Windows 8 version of tablet, although it will have its limitations due to the late arrival, it might change the market dynamics quite a bit. Especially it will have a great chance when enterprises really begin to integrate their whole systems with existing Microsoft software and OS environment.

In order for the followers to chase Apple there are several things in the tablet eco-system they must seriously consider.
First, one of the most important parts of the tablet eco system is the application. Apple’s iPad will probably keep the leadership in numbers and quality of the applications for a while. This can be very critical. More and better apps mean better user experience which leads to more customers. Good apps create customer loyalty which makes customer to come back. I would be a critical point for the Android side to secure the quantity and also the quality of apps.

Secondly, another very important part of the tablet eco-system, especially in the consumer side, is the content base it can provide. Apple has an excellent ecosystem and leads the market today. Amazon has a similarly robust ecosystem. Google’s ecosystem is still evolving, which puts vendors relying on it at a bit of a disadvantage. To succeed, these vendors may need to forge partnerships with new entities. [11]

Finally, although media tablets continue to be a consumer purchase category up to now, and that won’t change dramatically in the near term, it has already begun to gradually change and can be a great chance for the follower to make up for their late start. There will a beginning of a shift in 2012 as an increasing number of companies particularly enterprises begin to roll out supported media tablets for key employees. As a result, the percentage of
media tablets shipped into the commercial segment actually appears slightly lower than in our previous forecast. We expect about 6.7% of shipments in 2012 to be commercial, growing to 10% by 2015. [11]

2.3 Pressure is on the PCs

The Smartphone is no longer an advanced mobile phone. It seems like the only reason it is still called as a variety of the phone is not because of its calling functionality but because it was called a phone in the beginning. Calling today’s smartphones a phone is not much different than calling a laptop computer a phone since we can call someone with it.

The market penetration of the media tablet is still quite low but no one can call it a niche market anymore. Users who are very used to the smartphone touch interface have adapted to the similar media tablet experience very easily and the category is growing fast.

Today people are using their smart devices for almost everything they do with their conventional computers and sometimes even more. These activities include emailing, gaming, reading, watching videos or TV, listening to music, as an alarm clock, banking, stock trading, web-surfing, social networking, using it as a GPS both walking and in a vehicle and of course, making calls.

And people are changing their computing behaviors due to the portability and convenience of the smart devices, despite the fact that the functionalities are still limited compared to the conventional computing devices. People are enduring the inconveniences and making ways to use their mobile devices over the computer they used to use. In this section, I will analyze how the new mobile devices are actually putting pressure on the conventional PCs.
The motivation to purchase mobile devices varies, including peer pressure, the "cool" factor, early adopter experimentation, mobility needs and e-book reader substitution. Media tablets are regarded as extensions of smartphones and as mobility and media consumption devices. They are not typically purchased as direct PC (desktop and laptop) replacements. However, tablet users noted that they use tablets beyond media consumption only and the tablet's "instant-on" capability represented considerable convenience in the minds of some users. Consumers reported using tablets in a variety of places especially the living room, the bedroom and, with surprising frequency, the bathroom. [12]

2.3.1 More Screen Viewing through smart devices

According to the above graph, users are using the smart mobile devices for screen viewing throughout the day. Interestingly the graph shows a difference in screen viewing
device according to the timeline of the day.

We can see that in the early morning time, the portion of the smart mobile devices is the highest. This is due to two major factors. First it is the commuting time and people prefer to use their smart devices over their PC. For the same reason the 5 to 7 pm timeframe shows a high usage of smart mobile devices. The second factor is that in the morning time, people the information people want to seek are quite simple, such as weather, traffic and simply scanning through their inbox, and people use their smart devices rather than booting their computers.

During the daytime, people tend to use their conventional computers more since many of them are in working environments and even at home their computers are already booted and ready to use. And finally in the late hours, the usage of computers become higher because many of the people who are using any kind of screening device is possibly working on a task which is probably urgent or important and require more computing functionalities or reliabilities.

But interestingly, although there is a flow and variance of usage throughout the timelines, we can see that people are constantly using their smart devices for at least near 50% of all of their screen viewing throughout the day. Screen viewing by phone is high throughout the day and even in the evening when many users are back home. This implies that phones are not being used simply for wide-area access, but everywhere consumers go, including within their own homes where they have phones next to them and view them as needed while using other devices like PCs, TVs and tablets. [12]
2.3.2 Smart devices taking place of PCs

People are using less time on their PCs due to the tasks that their smart devices are capable of doing instead of the PCs. There are heavy tasks that PCs are much effective of doing and some only capable of doing but in other tasks smart devices are even more effective that the PCs due to their mobility and instant boot time. In a survey conducted by Gartner research, consumers expressed a wide range of views as to the extent that smart devices are superseding PCs in their daily lives. [12] People are still using for heavy functions such as productivity-related tasks or entertainment involving large file sizes such as the HD videos. And some are using their PCs just because they are more used to them. But interestingly, some use their smart devices during their rest time more because they use their PCs for most of their working hours and it has a work related image which makes them want to avoid them off of duty. Some comments from the survey include:

- "Once I got this (smartphone) it's like I barely touch the computer anymore. I do have my gaming computer and that's totally separate, I'll spend hours and hours on that, but as for stuff you do on the phone, like your email and all that stuff, once I got my phone I barely touch the computer." (Male, 20s, aspirer, San Jose.)
- "I find that iPad is very entertaining. The primary reason for its purchase is entertainment, but for desktop or laptop PCs, they are mainly for work." (Male 44, young fun seeker, Shanghai.)
- "At home, I really don't sit in the office anymore (to use PCs), I'd rather sit in the living room with my feet up and surf or play a game or watch a video (on a tablet)." (Female, 54, tech savant, Boston.)
- "I've noticed that my PC and laptop usage have gone way down. My laptop has one of those carry-along cases. (Now) it sits in the case sometimes for a couple of weeks." (Male, aspirer San Jose.)
- "I often use my iPad at home because you don't want to sit beside the desk anymore. You are
exhausted after a day's work and you need to relax. Playing on the iPad when lying on the couch is comfortable." (Male, 36, aspirer Shanghai.)

- "I still use my laptop at night. I feel I am using my laptop less, but it would never be replaced 100%." (Male, 27, aspirer, Taipei.) [12]
Chapter 3 Analysis of the Influence on the Semiconductor Market

Up to the previous chapter, we have seen how the computing world is shifting from the PC platform to the smart mobile device platforms. In this chapter I would like to analyze how this hardware application shift will impact the semiconductor industry.

3.1 From CPU to AP

Due to the explosive growth in the smart device market, we can expect the AP market to show similar growth. If the smart device market grows to nearly 1.5 billion units by 2015 it will be 4 to 5 time more than the PC market which uses the CPU.

3.1.1 Growth of the AP and penetration into PC territories.

**Figure 13: Comparison of CPU and AP market**

The current AP market size is around 8 billion dollars which is significantly smaller than that of the CPU market which is around 40 billion. Although the smart device unit shipment
is already larger than PC shipments, this is due to the fact that the average price of AP is still about 20% of that of CPU. But as can be seen in Figure 13, when the AP shipment becomes 4 to 5 times larger than the CPU shipment in 2015 the total dollar value of the AP market is estimated to be about 38 billion dollars which is a result of a nearly 50% compound annual growth rate from 2010. Of course the AP market is not limited to the smart devices and will be expanded to other devices such as navigation systems, automotive and even PCs, but the growth pattern will be explainable with just the main demand drivers which are the smart mobile devices.

Figure 14: Semiconductor Consumption by Device Category

Based on the steep growth, AP are expected to develop better processes and evolved through increased number of cores and higher speeds. The core of AP is evolving from single to Dual to Quad which will mean higher cost and higher price for the AP. And with the development of the ARM based CPU, the speed of AP is expected to grow up to 2.5GHz from the end of 2012. So with the combination of Windows 8 which is known to support not only the CPU but also AP, we can expect AP to be used in more PCs from the second half of 2012.
Since the price of AP is less than 50% of CPU, [2] the adoption of AP into the PC will be fastest in the lower end PCs where low price is valued more than higher performance.

3.1.2 Possibility of a leadership change in the new AP world

In the PC world and in other words, CPU world, Intel was the king of the jungle that no one was even close enough to really compete. But in the mobile, AP world, there might be a regime change.

Samsung currently has over 50% of the AP market share [2] monopolizing Apple’s iPhone’s and Samsung’s smartphone’s APs. And it seems that there is a high possibility of this trend to continue for a while and there are several reasons.

First Samsung is aggressively increasing their capital expenditure into the non-memory semiconductor business. In 2012, Samsung announced that 8 trillion won out of 15 trillion won of semiconductor CAPEX will be in the non-memory business. As a result Samsung will have over 50% extra capacity allocated to the production of AP. [2]

Secondly, Samsung’s process technology in AP is not much behind Intel or TSMC as it was in other non-memory productions. The 32nm High-K Metal Gate process Samsung used to make their recent 2Ghz dual core Exynos 5250 is known to be better in low voltage features than the 28nm TSMC products. Samsung also shares common platforms with IBM, TI, Global Foundries in developing non-memory processes.

Finally the synergy effects with the memory semiconductor business will increase the cost competitiveness of Samsung’s AP. In the smart devices are made as a form of POP
(Package on Package) with Mobile DRAM and MCP (Multi Chip Packaging). So Samsung, as a leader in the memory mobile DRAM industry, has an advantage over other AP vendors who do not have memory production capabilities in house.

Figure 15: Comparison of Standard Silicon and HKGM

![Comparison of Standard Silicon and HKGM](http://www.maximumpc.com/article/features/fast_forward_hkmg_masses)

3.1.3 Current AP competitors for Samsung: Qualcomm and TI

The current leaders in the stand alone application processor market with Samsung are Qualcomm and Texas Instruments. Each has approximately 20% of market share. [2]

Qualcomm is especially strong in producing integrated architecture application processors which integrates baseband chipsets with the applications processors. Qualcomm’s application processor called Snapdragon, is based on the Scorpion CPU which is based on ARM v7 architecture and proprietary GPU. The Snapdragon is designed asynchronously which enables it to be very efficient in power usage. But on the other hand, the data processing per
clock is relatively low. And although it has been improved since Adreno 20, the Snapdragon’s GPU capability is known to be not very competitive. From Snapdragon S3, which uses 45 nanometer technology, Qualcomm is producing dual core 4.2~1.5Ghz CPU and is expected to introduce 28 nanometer based 2.5Ghz quad core CPU in 2012. [2]

**Figure 16 : AP Architecture (Integrated vs Discrete)**

![AP Architecture Diagram](image)

*Source: Semiconductor Insight*

The Snapdragon is mainly used in smartphones from Sony-Ericsson, HTC and LG but recently due to the limitation in LTE baseband chips, other LTE models including Samsung’s are using it also. Currently in order to support LTE services, Qualcomm MDM 9600 is required. But because the MDM 9600 only supports 3G voice communication combined with Snapdragon AP, smartphone makers have no choice but to use it. For instance, if Samsung want to use their own AP, they would have to have both 3G and LTE baseband processor in their smartphones. Qualcomm is planning to introduce MDM 9615 in the short future which will enable other APs to support 3G voice communications but until then LTE smartphones will inevitably have to use Snapdragon. [13]
Texas Instrument OMAP's largest customer base is Nokia. Same with Samsung, OMAP is a discrete architecture application processor which is not integrated with baseband chipsets.
The OMAP is based on ARM v7 architecture using Cortex A-8, A-9 CPU and uses Imagination’s PowerVR SGX series GPU which Apple also uses. The OMAP is very good in CPU overclocking but is relatively inferior in video decoding due to the lack of ARM’s NEON instruction queue.

Beginning from OMAP 4, TI started to produce 1.0~1.5 Ghz dual core CPU based on 45 nano technology and is expected to move to 28 nano technology from the third quarter of 2012. OMAP is being used in the Kindle Fire and Samsung’s Galaxy Nexus.

3.1.4 Future potential AP competitors for Samsung: TSMC and Intel

In the long run, Samsung’s biggest potential competitors would be TSMC as Apple tries to diversify their AP production from Samsung and Intel as they penetrate the AP market more aggressively. But it does seem like risks from either competitors will not be realized within a year or two.

For TSMC, Apple would probably love to diversify their supply of AP to TSMC and even maybe wish to change their major supplier to them. But this seems to be very difficult to happen in a very short time for several reasons.

First, Samsung and TSMC are totally different companies with different business models. Samsung is not simply a foundry company, as TSMC, and possesses design capability and many AP related intellectual properties. So, for instance, if Apple really wants to switch to TSMC for their AP, they would have to also change many Samsung IPs which are applied in the design of current Apple APs coming from Samsung.
Figure 19: Gate first vs Gate last methods

Second, the AP production process of Samsung and TSMC are very different. Samsung’s AP production process is based on the ‘Gate First’ technology which is relatively simple to produce, has smaller chip size and is more energy efficient. This makes ‘Gate First’ process basically better for AP production. On the other hand, TSMC and Intel both use the ‘Gate Last’ process which is better in making higher speed. Although this process is faster in processing speed, it is more complex to make, the chip size is larger and is less efficient compared to the ‘Gate First’ approach. It is true that even Samsung might change its process to ‘Gate Last’ after the 28 nano technology, but currently the advantages of ‘Gate First’ seems big and will be an major obstacle for Apple to switch AP suppliers in the near term. [14]

Thirdly, in order for Apple to switch their major supplier, TSMC would have to secure sufficient capacity fulfill the requirements. For this TSMC would have to either pre-invest to increase their capacity or reallocate significant amount of capacity from other customers to Apple. In either case both companies will face very difficult questions to answer. Apple will have to figure out whether TSMC will be able to provide the quantity at a cost level as low as Samsung even after major investment or capacity reallocation from other customers. On
TSMC’s side, they would have to think whether Apple is willing to provide high enough margins as other customers or whether it is a good decision to support Apple despite the negative effects on margins and customer relationships. The problem is that it seems very difficult for TSMC and Apple to meet at any point of interest which will make the decision very difficult to make. And during the delay, the smartphone and AP market will be changing even faster regardless.

Intel is expecting to launch its new CPU called Ivy Bridge late 2012 or early 2013. [15] Ivy Bridge uses a new design structure called 3D Tri-Gate which changed the 2D transistor design method, after 52 years since first developed by Fairchild in 1959. Especially the new method can lower the power usage by 50% which is revolutionary. [16] But still it is expected to take at least more than a year for the newly designed chips to reach 0.5W level of AP which will delay Intel’s penetration for at least the length of that timeframe.

Figure 20: Intel’s new 3-D approach

The chip maker breaks from conventional approaches to make transistors. Conventional transistor: Electrons flow between components called a source and a drain, forming a two-dimensional conducting channel. A component called a gate starts and stops the flow, switching a transistor on or off. Intel’s new transistor: A fin-like structure rises above the surface of the transistor with the gate wrapped around it, forming conducting channels on three sides. The design takes less space on a chip, and improves speed and reduces power consumption.

Source: Intel
3.2 Memory Semiconductor Analysis

The paradigm shift to mobile platforms is not only influencing the processor market but it has significant influence on the memory semiconductor market also. In this chapter I will analyze how the shift is influencing the NAND and DRAM market, and also take a look into some current technical issues the memory industry is facing.

3.2.1 NAND

![Figure 21: DRAM, NAND monthly revenue and NAND portion](image)

According to the World Semiconductor Trade Statistics (WSTS), NAND monthly revenue preceded that of DRAM for the first time in history. Part of this is due to the price drop of the DRAM but a major portion is because the NAND market is beginning to grow much more thanks to the growth of the smart devices. As you can see in the graph above, the NAND
portion in the memory semiconductor used to be very volatile but since 2010 when the smart devices began to ship aggressively, the portion has been on a steady increase trend. And from 2012, the NAND overall market is expected to exceed that of DRAM. From 2011 to 2016, NAND demand is expected to grow over 55% every year. Although the growth rate will become lower as the key applications become more mature in the market, the strong growth of NAND, which will be pulled by smart devices and SSD, will remain strong for the next 5 years.

![Figure 22: NAND total demand and annual growth rate](image)

If we look at the NAND demand by application, already in 2011 mobile devices are using up over 50% of the NAND. And thanks to the smartphones and media tablets, this trend has no sign of slowing down and in 2016, it is expected to pass 65% of the whole usage of NAND in the world. And especially as the media tablet market continues its high-growth trajectory, it will significantly pull the NAND usage especially in the high end media tablet segment.[17]
3.2.2 DRAM

The DRAM market has been a highly competitive market for a long time. But as it comes through one of the, not if the, worst downturn of all time, this might change.

The most significant thing that happened during the downturn period is that the gap between
tier 1 and tier 2 vendors has widened wider than ever before. This is mainly due to differences in process technology and product portfolio. The tier 2 vendors are trying their best in all possible ways including technology development and capital raising but the difference might widen even more due to the increase in mobile DRAM and also the need of new equipment for further process development.

3.2.2.1 Limited PC growth

With the strong growth of the smart devices, the conventional PC devices are expected to grow much more moderately than they used to. This means that the conventional PC market will grow around 5% in good years and -5% in bad years. This is very different from the +10% which used to be the growth rare for a long time. [2] But if the media tablets are added to the conventional PC numbers, the personal computing device market will maintain its +10% growth trend. The problem is that when conventional PCs use 4GB of DRAM the media tablets mostly use only 1GB of mobile DRAM which will have a negative effect on the overall DRAM demand.

**Figure 25: PC shipment trend by form factor**

![Graph showing PC shipment trend by form factor.](source: IDC, Gartner, KDB research center)
3.2.2.2 Key factors in PC in 2012

In 2012, there are several factors that could have positive impact on the PC shipments. First Intel will introduce their new CPU, Ivy Bridge. Second Microsoft will introduce their new operating system, Windows 8. And finally, thin and light ultrabooks have potentials to increase PC shipment. But these factors are expected to have more positive effect on the mobile DRAM than the conventional PC DRAM.

Ivy Bridge will be able to embed low power DDR3 mobile DRAM and from Intel’s Haswell CPU which is expected to come in 2013, it is expected to have strong positive impact on mobile DRAM.

Figure 26: Intel Roadmap

Windows 8 will have the fastest boot up speed up to now, expected to be 8 seconds, a new user interface and will be compatible between CPUs and ARM based APs. And the compatibility will bring many low end PCs to use APs over CPU which are lower in price and energy efficient.
3.2.2.3 Mobile DRAM vs PC DRAM

With the rise of the smart devices and increased use of mobile DRAM in embedded applications, DRAM growth is expected to be led by mobile DRAM growth.

**Figure 27: DRAM growth rate by type**

![Bar chart showing DRAM growth rate by type from 2007 to 2012.](chart)

Source: KDB research center

For example in 2012, following 2011, the growth rate difference between PC DRAM and mobile DRAM is expected to be nearly 60%. And moreover, due to the higher profit levels and accelerated demand of mobile DRAM, top vendors are expected to change their production portfolios into mobile DRAM more which will have a decrease impact on the normal PC DRAM.
3.2.3 Competitive landscape in the mobile memory semiconductor

In the mobile DRAM market the two Korean memory companies, Samsung and Hynix, are dominating. According to DRAM exchange, in the fourth quarter of 2011 Samsung semiconductors took 54% and Hynix 21% which adds up to 75% of the total market. Of the remaining 25% Elpida took 17% and Micron 7%. And due to the bankruptcy of Elpida last March and the anticipated take-over of Micron the number of companies competing in the Mobile DRAM market is down to three.

![Figure 28: Comparison of Total and Mobile DRAM market share](image)

Micron Technology and Elpida used to be the number 3 and 4 DRAM companies before the bankruptcy of Elpida. So the integration of the two companies is sure to have a significant impact on the competitive structuring of the memory semiconductor industry. Numerically adding the market share of the two companies, it becomes larger than that of Hynix and becomes the number 2 DRAM company in the world. Micron’s best scenario is to maximize this economies of scale effect and become a more powerful factor in the DRAM industry. But it will be very difficult for Micron to take the best scenario for granted. It is anticipated that
Micron will pay approximately 2.5~3 billion US dollars. It will cost Micron around 1.5~2 billion dollars to upgrade Elpida’s Hiroshima fab and they also have to worry about Elpida’s debt which is over 5 billion dollars. And even if Micron is able to overcome all the financial issues the market share of the combined company is not expected to match the sum of the pre-acquisition due to overlapping capacities. Historically, the DRAM industry has gone through numerous consolidations between companies and most of the efforts were between the non-leading companies trying to catch up with the leader. But the results were never as good as the consolidators expected. In the case of the anticipated Micron-Elpida consolidation, the uncertainty is even higher due to the geographical and cultural distances between the two companies. It will be a difficult challenge to realize the synergy between the two companies and become a major memory semiconductor force in the mobile era.

Figure 29: Mobile DRAM Technology portion by company

Source: DRAM exchange
Meritz securities research center
The reason behind such an oligopolistic market lies the characteristics of mobile products. The mobile semiconductor products must be low power, on-board products and built-to-order and these characteristics set the quality bar very high and customers prefer trusted suppliers much more than conventional PC DRAMs where many quality issues can be solved simply by changing the memory modules.

In the design category, Samsung semiconductors is way in front of their competitors. Samsung’s portion of 3x nm in Q1 2012 is estimated to be around 32%. Hynix applied its 38nm technology initially in their PC DRAMs and is beginning to apply to mobile DRAM from Q1 2012 and Elpida is in process of transiting into 3x nm but became very questionable with the current financial issues. [18]

**Figure 30 : Mobile DRAM design portion trend (Samsung)**

![Mobile DRAM design portion trend (Samsung)](image_url)

Source : DRAM exchange

Meritz securities research center
Figure 31: Mobile DRAM design portion trend (Hynix)

Source: DRAM exchange, Meritz securities research center

Figure 32: Mobile DRAM design portion trend (Elpida)

Source: DRAM exchange, Meritz securities research center
3.2.4 Current Technical Issues in the Memory industry

Top memory vendors such as Samsung, Hynix and Toshiba are planning to mass produce under 10nm beginning from the end of 2012. The transition to sub-10nm requires a holistic change not only in designing of the chip, but also in equipment, materials. And the biggest change might be the change in equipment which is not controlled by the vendors themselves and requires enormous capital investment. In order to go sub-10nm, additional the immersion ArF lithography equipment makers must have new EUV(Extreme Ultra Violet) equipment.

Figure 33: Evolution of light source

Based on the Rayleigh’s law, the theoretical resolution of ArF immersion stepper is $R = k \frac{\lambda}{NA} = 0.25 \frac{193 \text{ nm}}{1.35} = 35.7 \text{ nm}$. With the device, there should be additional process to implement line and space of less than 20nm. In the case that the yield of additional process is less than previous processes, it would negatively affect to the cost efficiency. Therefore, the other exposure devices could solve the fundamental limitations of previous devices. For instance, EUV devices use refraction index of 0.25 but, the significant decrease in wavelength ($\lambda$) used in the devices would enable the theoretical resolution, $R = k \frac{\lambda}{NA} = 0.25 \frac{13.5 \text{ nm}}{0.25} = 13.5 \text{ nm}$.[2]
The major NAND manufacturing companies continue to develop 3D stacking technology. Toshiba published BiCS(Bit-Cost Scalable) 3D cell technology in VLSI conference, 2007 and also developed P-BiCS 3D cell technology advanced from BiCS in 2009. Vertically stacking the memory cells composed of films and Si electrode, the technology forms a hole with U-shape pipe structure. On the other hand, Samsung Electronics announced the technologies: 1) NAND cells with horizontally arrayed vertical gate(VG) and 2) NAND cells with vertically arrayed Terra-bit cell array transistor(TCAT) placing oxide film and metal electrode out of cylinder shaped Si electrode. The technology competition of manufacturing 3D memory would impact on the market share of NAND memory. [2]

Currently the only equipment manufacturer that can make the EUV equipment is ASML. According ASML roadmaps, mass EUV equipment is to be introduced from the third quarter of 2012. The anticipated price of the equipment is around 100–150 million dollars. Therefore, due to the large amount of investment, limited supply and long delivery time over 10 months,
the requirement of EUV to advance production technology can be the next big hurdle for the non-tier1 memory semiconductor vendors and if they are not able to jump over it somehow, it might lead to the next big restructuring of the memory semiconductor industry.
Chapter 4 Conclusion

As reviewed in the previous chapters it is next to impossible to deny the paradigm shift from the PC platform to the Mobile platform. Conventional PCs will not disappear and hang on to task that they are more appropriate, but many tasks will be shifted to smart mobile devices with smaller but various screen sizes for customers to choose from. Smart devices are generally cheaper than conventional PCs and more convenient because of their portability, and more and more useful with context optimized for the platform.

And the semiconductor industry players will have to cope with the trend in order to survive. The 3 biggest trends are the shift from PC CPU to Application processor in the logic semiconductors, the overtake of the leading memory industry of NAND and the increased importance of Mobile DRAM. So companies must concentrate their resources in these three areas to be a competitive player in the semiconductor market.

And currently, one company seems to exceptionally stand-out in this trend and that is Samsung electronics. In other words, the paradigm shift from PC to mobile might also be called the shift from Intel to Samsung, at least in the semiconductor industry. In the PC to mobile paradigm shift, Samsung seems to be leading in all categories of the necessary areas. The most outstanding characteristic of Samsung is that they have a very efficient vertical integration structure in the industry. They are not only leading all areas, AP, NAND and Mobile DRAM, but they are also the worldwide leading smartphone maker. They might not be as innovative as Apple and their position in the minds of the customers might be less competitive than Apple, but nevertheless, they are the leading Android phone maker and this isn’t a title that they will allow to move to anyone else anytime soon. Moreover, Samsung is the leading AMOLED vendor which strengthens their position even more. The only area that
another player seems to be physically leading is the media tablet sector. But even in this area, Samsung's aggressive strategy with the widest range of products will enable them to threaten the leader.

So everyone else's position might be defined as how to compete with Samsung strategy. Intel, TSMC, Qualcomm and TI must find ways to compete with the aggressive investment, intellectual properties and even the relationship with Apple and Samsung mobile phones in the AP semiconductor sector.

Hynix and Toshiba must find ways to compete with the NAND and also mobile DRAM leader despite the current differences in process technology and the risk of transitioning to sub-10nm process. One of the biggest key points of this battle will be who secures the EUV lithography equipment and smoothly transits to the sub-10nm nodes.

4.1 Key considerations of the Application Processor makers

Considering the different characteristics of the mobile devices from the conventional EDP ones, there are several areas that the AP manufacturers must seriously consider designing their products as well as their market strategies.

The first factor would be the pure performance of the processors. Although mobile devices are used much heavier towards contents consumption and entertainment, smartphone and media tablet users are utilizing their devices more and more similar to the conventional PCs. More contents and software applications are being developed to match the growing usage of the consumers. People and programmers are both requiring higher performance. The reason is simple: from being able to play games, surf the Internet, browse, download / upload movies / videos and songs, to being able to make and receive clear voice and video calls, the
device needs to be able to multitask.

Figure 35: Power performance sweet spot for application processor architecture

![Power performance sweet spot for application processor architecture](image)

Note: Figure 5 is designed to show only the progress the three architectures are expected to make in the next five years in terms of improving performance and lowering power consumption. It is not meant for comparing the actual positions of the various offerings of the architectures, either in terms of power consumption or performance measures.

The second factor which could be as basic and critical as the pure performance is the power consumption. The most important and critical difference of the new devices compared to the conventional ones is self-explained in the category. It is mobile. As mentioned above as more people use their smartphones and tablets for more complicated tasks the performance of the application processors and also the displays will also need to improve. But unfortunately this is bad news for the power consumption factor of the devices. Smartphones and media tablets will have to be able to perform all the sophisticated requirements with an extremely thin power budget to be truly mobile. No matter how powerful the device is and how many
awesome applications are available for it, if the user has to go through the hassle of searching for a power outlet every half an hour and be stuck to it, the mobility of the device is eliminated and this will not bode well for the user experience. Hence, the ability of the AP to operate at an acceptable level with a very low power usage is a critical factor the AP makers must consider more in the mobile era.

The third factor the AP maker should consider is the OS compatibility of their products. Although the industry is growing at a very high speed, the smartphone and tablet device market is still evolving and is yet to mature. The market is still very dynamically evolving and the final winner is yet to be decided. The user experience, which is critical for next generation smartphones and tablets, is related to the design of the OS/user interface and the Eco-system. The ability of an application processor to support multiple OSs is, therefore, critical, as the system vendor will then be able to customize its product and user interface design to the product’s target audience. For a business user, the system vendor may choose an OS that has a mature ecosystem of software providers catering to the business user's needs, whereas, for an end consumer, the system vendor may choose another OS that has a mature ecosystem of software providers catering to the entertainment needs of the end consumer. [19] So if the AP is compatible of supporting different operating systems, system vendors will be enabled to switch to their optimal operating systems to their targeted market without having to worry about investing and designing for a different processor. And for the AP maker, the compatibility will naturally make the reachable customer base much broader which will enable them to have many more strategic options to penetrate the market.

The next factor of consideration would be the design flexibility. For the system vendors to match and catch up with the ever rapidly changing customer requirements is an extremely
difficult task and challenge. Customers nowadays are not only very individualized and unique but are also interacting with so many different features and technologies through various media and this leads to a very short lasting of affection to a feature or models. So the system vendors are under never-ending pressure of introducing new models and features into the market. In order to match this need, the application processor must require minimal design variation and at the same time must be able to be expandable to as many as features and functions possible.

The last factor for the AP manufacturers to consider will be the cost. As more and more the mobile devices are sold and become a part of everyone’s life, it naturally will become a kind of commodity. And as we have seen so many times in the past and especially in the PC industry, this commoditization will make the price competition in the industry very high. This trend is actually already beginning in some regions and segments of the market. Therefore, the application processors not only have to be as low cost as possible but they also have to help the system makers lower their development costs the same way.

4.2 Key considerations of the Memory makers

The switching over to the mobile era will also require memory makers to consider different factors from the PC era.

The most important thing the memory semiconductor companies must consider and manage carefully is the product portfolio. The move into the mobile era is directly influencing the individual product lines but now it has become much more difficult to forecast and balance the portfolios to maximize profits for the memory companies. Adding more difficulty to this is the limited investments in the semiconductor industry due to the
historic downturn it has been through the past several years.

In the NAND market, not only the increase usage of NAND memory in the mobile devices but also the growth of the SSD demand will be a critical trend to watch for the memory vendors. Although the growth of the PC market is expected to be limited in the future, due to the smaller form factor such as ultrabooks will definitely increase the demand for NAND memory. And moreover, as consumers get used to the mobile devices which are basically boot-free and have instantaneous reactions, they will required more speed in their conventional PCs which can generate growth in the SSD market.

In the DRAM market, it is no more of use to simply compare the expected growth of the demand and supply of total DRAM capacity combining PC DRAM and Mobile DRAM because the growth rate of the two different types is very far apart. In other words, the Mobile DRAM is no longer a tiny type of DRAM that can almost be neglected. Due to the higher growth and margins of the mobile DRAM, the top tier DRAM makers are likely to increase the mobile DRAM portions in their product portfolios which can result in a decrease of overall PC DRAM capacity.

So the leading memory companies with capabilities of producing all product line-ups from NAND, DRAM and mobile DRAM should be very careful in analyzing not only the change in application shipments and usages but also what the effect of their own change of product portfolio will be on the overall capacity of each line of product. In this way they will be able to not only maximize their profits but also limit the opportunities for the weaker vendors to take advantage of the top vendors’ decision.

For the Tier 2, Tier 3 vendors, their own fate seems very much out of their own hands. The competitiveness gap between the top and Tier2, 3 vendors have widen during one of the
worst downturn of the industry and it seems almost impossible to make up. And as the paradigms shift to the mobile devices which require memory semiconductors that the Tier2, 3 vendors are even worse at, the situation even worsens more. Adding to this is limited access to the extremely high cost equipment such as the EUV (Extreme Ultra Violet) that will make it even more difficult. So the Tier2, 3 vendors should keep an eye on how the leading vendors are doing, more than how the application is changing. The vendors that are able to catch the decisions of the Top vendors and who are able to act appropriately to them will be the candidate to survive the hyper competitive market.
Bibliography


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