3D Will Revolutionize Mobile Industry

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NAND Product Planning Office
SK hynix
Contents

1. Corporate Overview
2. IoT & Mobile Trends
3. 3D NAND
4. Mobile Storage Solutions
5. Summary
Corporate Overview
SK WORLD WIDE

The continued growth of SK through the various business success stories

Global Networks

277 Affiliates/Branches

Global Assets

$U\$ 85 Billion

Global Talents

81,667 Talents

(As of 2014)
M14 introduction & Product Portfolio

The size of seven football fields, 200K of 300mm wafers per month

M14 (New Fab.)

<table>
<thead>
<tr>
<th>Gross Area</th>
<th>53,000 m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wafer size</td>
<td>300 mm</td>
</tr>
<tr>
<td>Start up</td>
<td>Q3 ‘15</td>
</tr>
<tr>
<td>Products</td>
<td>DRAM / NAND</td>
</tr>
<tr>
<td>Technology</td>
<td>-</td>
</tr>
</tbody>
</table>

Product Portfolio

<table>
<thead>
<tr>
<th>Applications</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC / Server</td>
<td>DDR4, DDR3</td>
</tr>
<tr>
<td>Graphics</td>
<td>GDDR5, DDR4, DDR3</td>
</tr>
<tr>
<td>Consumer</td>
<td>DDR4, DDR3, DDR2, DDR</td>
</tr>
<tr>
<td>Mobile</td>
<td>LPDDR4/3/2 (MCP, PoP)</td>
</tr>
<tr>
<td>Consumer</td>
<td>TLC, MLC, SLC</td>
</tr>
<tr>
<td>Mobile</td>
<td>eMMC (eMCP), UFS</td>
</tr>
<tr>
<td>SSD</td>
<td>SATA, PCIe</td>
</tr>
<tr>
<td>Mobile</td>
<td>VGA/2M/3M/5M/8M</td>
</tr>
</tbody>
</table>

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Hong Kong
IoT & Mobile Trend
By 2020, 50B+ things will be connected… and they will all need NAND Flash

The Explosion of Connected Devices

NAND Demand Forecast

50B+ Devices
35ZB Data

Source: SK hynix

Source: Cisco, IDC
Mobile Trends & Technical Requirement

Mobile Industry will require the better & cheaper storage solution

- Higher Performance
- Higher Density
- Better Reliability
- Low Power
- Small Package

- Fast boot up, Web browsing, Downloads, etc.
- More & Richer apps, High Resolution photos, 3D graphics
- Data Retention, Endurance
- Longer battery life
- More contents, Small & Slim Form Factor
3D NAND
Benefits of SK hynix 3D Technology

Much Better

Reliability

2D NAND 3D NAND

> x1.5 thru tPROG

Performance

2D NAND 3D NAND

> 30% Net die

Bit Growth

2D NAND 3D NAND
Better Bit Growth

Supporting industry demand through reasonable bit growth with 3D technology
**Better Reliability**

Bit Line Interference Free & Word Line Interference almost Free

Reduced Number of Stored Electrons

How to Overcome Cell Interference?

Small Cell Interference
due to lower capacitive coupling
between neighboring cells

Scaling down

2ynm

1ynm

Sub-1znm

Need Breakthrough!

Better Reliability

 DSL

 CSL

 SSL

 Bit Line Interference Free & Word Line Interference almost Free

Reduced Number of Stored Electrons

How to Overcome Cell Interference?

Small Cell Interference
due to lower capacitive coupling
between neighboring cells

Nitride

Channel

N

N+1

Sub-1znm

Need Breakthrough!
Better Performance

Small cell interference & narrow cell distribution enabling one-shot program

3D tPROG

2D TLC ~ 2.0ms

2D MLC ~ 1.2ms

3D MLC < 0.6ms

3D TLC < 1.0ms

Performance @ Mobile Application

Seq. Write
200 MB/s

3D MLC

2D MLC

140 MB/s

≒ 50%↑
(vs 2D MLC)

QDP Configuration / Data transfer size : 512KB / OS Level test

Better Performance
Continue to Advance thru 3D technology

- 2D
- 3D V1: Q4. 2014
- 3D V2: Q3. 2015
- 3D V3: Q4. 2015

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SK hynix 3D NAND Everywhere

Mobile 2015

Client SSD 2015

Raw Nand 2015

Enterprise SSD 2016

Retention

S/W

Others

P/E

QoS

Others
Mobile Storage Solutions
NAND Flash portfolio

Technology

Solutions

Year
2014
2015
2016
Future

3DV1
3DV2
3DV3
3DV4
3DV5
3DV6

eMMC5.0
eMMC5.1
UFS2.0
UFS2.1
UFS3.0

SATA SSD
NVMe SSD
SATA SSD
NVMe SSD
SATA SSD
NVMe SSD
**World’s Best performance Mobile storage solutions**

SK hynix UFS solution – AVAILABLE TODAY

<table>
<thead>
<tr>
<th></th>
<th>eMMC5.0</th>
<th>UFS2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sequential</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5X</td>
<td></td>
<td>&gt; 750MB/s</td>
</tr>
<tr>
<td><strong>Random</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3X</td>
<td></td>
<td>&gt; 30KIOPS</td>
</tr>
</tbody>
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World’s First 3D NAND based Mobile Storage Solution

- **3D V1**: eMMC5.0 (Prototype) in **2015 (Q1)**
- **3D V2**: eMMC5.1 in **2015**
- **3D V3**: UFS2.1 in **2016**
## Qualcomm & SK hynix Alignment

SK hynix Mobile storage solution is well aligned with Qualcomm

<table>
<thead>
<tr>
<th>Year</th>
<th>Qualcomm</th>
<th>SK hynix</th>
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</thead>
<tbody>
<tr>
<td>2013</td>
<td>MSM8974</td>
<td>eMMC4.5</td>
</tr>
<tr>
<td>2014</td>
<td>MSM8994</td>
<td>eMMC5.0</td>
</tr>
<tr>
<td>2015</td>
<td>MSM8996</td>
<td>1st UFS eMMC5.1</td>
</tr>
<tr>
<td>2016</td>
<td>Post MSM8996</td>
<td>2nd UFS eMMC5.x</td>
</tr>
<tr>
<td>2017</td>
<td>Post MSM8956</td>
<td>TBD</td>
</tr>
</tbody>
</table>
## Mobile Storage Solution with Mobile DRAM, LPDDR

SK hynix can provide mobile DRAM having high-performance, low power, various types of pkgs

<table>
<thead>
<tr>
<th>Package Type</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flagship</strong></td>
<td>PoP</td>
<td>PoP</td>
<td>PoP</td>
</tr>
<tr>
<td><strong>High</strong></td>
<td>PoP</td>
<td>eMCP</td>
<td>PoP</td>
</tr>
<tr>
<td><strong>Mid</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Entry</strong></td>
<td>MCP (SLC NAND)</td>
<td>eMCP</td>
<td>eMCP</td>
</tr>
</tbody>
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Summary

- Share 3D Benefits with all industry partners
- World 1st 3D Mobile Storage Solutions
- “Working Together” with Qualcomm