INTERNATIONAL BUSINESS STRATEGIES BACKGROUND

- In business for 30 years
- Interface with most global leaders in electronics industry, with customers in U.S., Europe, South Korea, Japan, Taiwan, China, India, etc
- Interface with and support major global corporations such as Intel, Qualcomm, Broadcom, Microsoft, Nokia, Samsung, SK Hynix, Sony, Toshiba, Apple, Cisco, Huawei, IBM, Fujitsu, Canon, NEC, Hitachi, Renesas, TSMC, STMicroelectronics, TI, ARM, Cadence, Synopsys, Mentor Graphics, Seagate, Globalfoundries, SMIC, NXP Semiconductors, and others
- Interface with and support financial institutions such as Goldman Sachs, Carlyle, Blackstone, CitiGroup, Warburg Pincus, Walden, KKR, Morgan Stanley, Credit Suisse, BNP Paribas, Bain Capital, Bank of America, TPG, and others
- Strong expertise in China
  Published two books on China: China’s Globalization (How China Becomes No. 1) and Chinamerica (McGraw Hill) and contributed to Wall Street Journal, Economist, New York Times, Forbes blogs, China Daily, Global Times, EE Times, Xinhua, etc
- Support of strategic initiatives for number of global technology leaders

IBS HAS HIGH MARKET SHARE ON TECHNOLOGY AND STRATEGY BUSINESS
KEY ISSUES IN SEMICONDUCTOR INDUSTRY

- AI will be key driver for growth of semiconductor industry over next decade
- AI capabilities will transform many industries
  - Autonomous driving and autonomous transportation
  - Image enhancement for three-image-sensor-based smartphones
  - AR capabilities for smartphones, including support for ToF
  - Search engines in data centers
  - VR platforms for gaming and other applications
- Smartphones are largest consumer of semiconductor products
  - Smartphone volume is declining in 2018, but semiconductor content per phone is increasing
  - Largest smartphone vendors by unit volume in 2018 are Samsung, Huawei, and Apple followed by Xiaomi, OPPO, and Vivo
    (Four Chinese vendors are in top six global smartphone vendors)
KEY ISSUES IN SEMICONDUCTOR INDUSTRY (CONTINUED)

- Autonomous driving is building momentum
  - While Tesla is technology leader, largest market for autonomous driving in 2020 to 2027 will be China
  - Growth of ADAS infrastructure in China is supported by 5G
  - China is 12 to 18 months ahead of others in 5G technology
    Will have three million to four million 5G base stations in 2020 to 2021
- Electrification of vehicles is in high growth, with strong demand for silicon IGBT products
  SiC and GaN will be high growth, which will provide opportunities for substrates and foundry support
- Fan-out wafer-level packaging technology is also in high growth, with role of foundry vendors increasing in support of packaging
  OSATs will continue to grow and increase participation in high-density fan-out

SEMICONDUCTOR INDUSTRY CONTINUES TO HAVE HIGH LEVELS OF INNOVATION
WAFTER SUPPLY

- Three major technologies will dominate IC supply, including:
  - **FinFET**: Digital emphasis
  - **HKMG bulk CMOS**: Probable limit at 22nm
  - **FD SOI**: Limits at 12nm or potentially 10nm

- 7nm FinFET will be in high volume in Q4/2018 and is projected to represent 25% of TSMC’s revenues in Q4/2018
  - 10nm represented 25% of TSMC’s revenues ($2339 million) in Q4/2017 and 13% ($996 million) in Q2/2018
  - 5nm is scheduled for high-volume production in H2/2020
  - Samsung has similar schedule to TSMC and is potentially ahead of TSMC in process technology
  - FinFETs are highly effective for digital designs but marginal for RF and analog-centric mixed-signal designs
WAFER SUPPLY (CONTINUED)

▪ HKMG bulk CMOS is in high-volume production
  • 28/22nm revenues will be $11.5 billion in 2018
  • Bulk CMOS is also used for >28nm, where revenues will be $32.9 billion in 2018
  • Key limitation of bulk CMOS is difficulty with scaling below 22nm
    (Some volume production in past was at 20nm)

▪ FD SOI transistor cost can be lower than bulk CMOS and FinFET because of fewer mask steps
  • FD SOI has very low active and standby power consumption with use of back biasing
  • RF capabilities of FD SOI are superior to bulk CMOS and are much better than FinFET

SEMICONDUCTOR INDUSTRY SHOULD PLAN TO HAVE THREE MAINSTREAM PROCESS TECHNOLOGIES IN FUTURE
<table>
<thead>
<tr>
<th>Transistor density (M/mm²)</th>
<th>16nm</th>
<th>12nm</th>
<th>10nm</th>
<th>7nm</th>
<th>7nm Plus</th>
<th>5nm</th>
<th>3nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>20mm²</td>
<td>26.4</td>
<td>31.7</td>
<td>49.0</td>
<td>87.1</td>
<td>104.5</td>
<td>156.8</td>
<td>196.0</td>
</tr>
<tr>
<td>40mm²</td>
<td>528</td>
<td>634</td>
<td>980</td>
<td>1,742</td>
<td>2,090</td>
<td>3,136</td>
<td>3,920</td>
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<tr>
<td>60mm²</td>
<td>1,056</td>
<td>1,268</td>
<td>1,960</td>
<td>3,484</td>
<td>4,180</td>
<td>6,272</td>
<td>7,840</td>
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<tr>
<td>80mm²</td>
<td>1,584</td>
<td>1,902</td>
<td>2,940</td>
<td>5,226</td>
<td>6,270</td>
<td>9,408</td>
<td>11,760</td>
</tr>
<tr>
<td>100mm²</td>
<td>2,112</td>
<td>2,536</td>
<td>3,920</td>
<td>6,968</td>
<td>8,360</td>
<td>12,544</td>
<td>15,680</td>
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<tr>
<td>200mm²</td>
<td>5,280</td>
<td>6,340</td>
<td>9,800</td>
<td>17,420</td>
<td>20,900</td>
<td>31,360</td>
<td>39,200</td>
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</tbody>
</table>

CHIP (100mm² WITH 7nm PLUS) WITH 10.5 BILLION TRANSISTORS MAY COST $500 MILLION TO DESIGN
ADVANCED DESIGN COSTS

Limits number of participants in advanced technologies
### Lifetime of Waferfabs

<table>
<thead>
<tr>
<th>Number of years</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>12</th>
<th>13</th>
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<th>15</th>
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<tbody>
<tr>
<td>Planar (28nm)</td>
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<td>Mixed-signal (digital-centric)</td>
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<td>RF</td>
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<tr>
<td>Mixed-signal (analog-centric)</td>
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<td>Embedded nonvolatile memory*</td>
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<tr>
<td>Image sensors</td>
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<td>Other</td>
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<tr>
<td><strong>FinFET (16/14nm)</strong></td>
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<tr>
<td>Digital 16/14nm</td>
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<tr>
<td>Digital 10nm</td>
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</tbody>
</table>

**Note:**
* Includes automotive.

### FinFets will Continue to have Strong Demand for Digital Designs
TSMC’S REVENUES BY FEATURE DIMENSION (FY)

<table>
<thead>
<tr>
<th>($M)</th>
<th>2016</th>
<th>2017 (Dec 31, 2017)</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q1 %</td>
<td>Q2 %</td>
<td>Q3 %</td>
</tr>
<tr>
<td>10nm</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>20/16nm</td>
<td>1,449</td>
<td>23</td>
<td>1,580</td>
</tr>
<tr>
<td>28nm</td>
<td>1,891</td>
<td>30</td>
<td>1,923</td>
</tr>
<tr>
<td>45/40nm</td>
<td>882</td>
<td>14</td>
<td>1,030</td>
</tr>
<tr>
<td>65nm</td>
<td>630</td>
<td>10</td>
<td>824</td>
</tr>
<tr>
<td>90nm</td>
<td>378</td>
<td>6</td>
<td>343</td>
</tr>
<tr>
<td>0.13/0.11µm</td>
<td>126</td>
<td>2</td>
<td>137</td>
</tr>
<tr>
<td>0.18/0.15µm</td>
<td>693</td>
<td>11</td>
<td>756</td>
</tr>
<tr>
<td>≥0.25µm</td>
<td>252</td>
<td>4</td>
<td>275</td>
</tr>
<tr>
<td>TOTAL</td>
<td>6,302</td>
<td>100</td>
<td>6,869</td>
</tr>
</tbody>
</table>

7nm WILL REPRESENT 25% OF TOTAL REVENUES IN Q4/2018, WHICH WILL BE APPROXIMATELY $2.8 BILLION
PERSPECTIVE ON GATE COSTS

FD SOI IS COST COMPETITIVE
COST BENEFITS OF FD SOI

- Gate cost of 22nm FD SOI is comparable to 28nm HKMG bulk CMOS (depends on depreciation level)

- **12nm FD SOI will have lower gate cost than FinFETs**
  
  22.4% lower than 16nm FinFET, 23.4% lower than 10nm FinFET, and 27.0% lower than 7nm FinFET

  Key reason for lower gate cost of 12nm FD SOI is fewer number of mask steps, which compensates for higher substrate costs

- Present focus of FD SOI is on 28/22nm, but with roadmaps to 18nm and 12nm

FINFETS WILL CONTINUE TO EXPERIENCE GROWTH, WITH TSMC AND SAMSUNG AS FOUNDRY VENDORS FOR ≤10nm

INTEL WILL BE POTENTIAL CANDIDATE IN FUTURE
IMAGE SENSOR MARKET

ISP IS ONE POTENTIAL GROWTH MARKET FOR FD SOI
ISP WAFER REQUIREMENTS

- Volume will be 19.6 billion units in 2027
  With 30mm² chip size and 1950 good dies per wafer, will require 10.1 million wafers (842,000 WPM)
- Each image sensor will require ISP, which is bonded directly to image sensor
  **ISP will also require 842,000 WPM in 2027**
- FD SOI may provide better analog functionality (ADC), lower noise, and lower power consumption compared to 22nm HKMG bulk CMOS and 16nm FinFETs
  FD SOI may also give cost-competitive unit area with 22nm bulk CMOS due to fewer mask steps
  Cost per unit area of FinFET is too high at ≤16nm for ISP support
- ISP functionality will need to be optimized for specific applications such as automotive, security, and AR-based smartphones
  Result is that there will be many ISP products

EXAMPLE OF APPLICATION THAT MAY BENEFIT FROM FD SOI IS ISP
KEY FACTORS ARE 28nm, 22nm, OR 18nm AS WELL AS DIE COST
IOT SEMICONDUCTOR MARKET

IOT MARKET HAS GOOD GROWTH POTENTIAL AND IS GOOD CANDIDATE FOR FD SOI
KEY ISSUES IN IOT SEMICONDUCTORS

- IoT applications will experience strong growth because **efficient connectivity to cloud** is emerging.

  LPWA (primarily NB-IoT) will be key connectivity in short term and 5G in longer term.

- **Approaches for monetizing data** are being established by number of companies.

  AI technology for ADAS and consumer health is building momentum.

- Wearable health monitors also represent IoT devices that have high growth potential.

  Will have sensors, ADC, processors, and NB-IoT.

  Best technology option is FD SOI due to support of RF and low-noise analog functionality and low power.
KEY ISSUES IN IOT SEMICONDUCTORS (CONTINUED)

IOT BUILDING BLOCK FUNCTIONS

Sensing → Amplification → Processing → Transmission → Analytics → Implementation

- **Sensing**
  - Can be image sensors, MEMS, radar, LIDAR, and others
  - Value can be <$0.01 to >$1000.00

- **Amplification**
  - Can be amplifiers
  - Can also include filters

- **Processing**
  - Can be equivalent to Arm Cortex-M0 and up to 100TOPS for level 5 autonomous driving

- **Transmission**
  - Can be Wi-Fi, Bluetooth, ZigBee, LTE-M, NB-IoT, and Sigfox, and 5G
  - Can be deep learning with AI and very high performance
  - Can include training and inference

- **Analytics**
  - Can be deep learning with AI and very high performance
  - Can include training and inference

- **Implementation**
  - Key factor is in how data is utilized and monetized

EDGE DEVICES, WHICH INCLUDE IOT, HAVE HIGH GROWTH POTENTIAL

FD SOI IS BEST TECHNOLOGY BECAUSE OF LOW POWER CONSUMPTION AND RF CONNECTIVITY
PERSPECTIVE ON CHINA

- China is changing from being follower in many areas of technology to becoming leader
- China is leader in mobile 5G adoption and will have one billion 5G users in 2025 to 2028
- China will be volume leader in electric vehicles (40 million units in 2027 compared to one million units in 2017)
  Large battery capacity is being established to support electrification
- Autonomous driving is expected to increase rapidly in China, with Baidu being key driver
- Display capabilities are strengthening in China
  OLED technology of BOE is becoming competitive
- China is building wafer capacity for FinFETs (TSMC and SMIC) and bulk CMOS (SMIC, Huali, HHGrace, and CSMC)
  There is excess capacity in 28nm bulk CMOS in Q3/2018

IT IS IMPORTANT FOR CHINA TO ALSO BUILD LARGE WAFER FAB CAPACITY FOR FD SOI
NEAR-TERM SUPPLY COMES FROM GLOBALFOUNDRIES AND SAMSUNG
SEMICONDUCTOR CONSUMPTION PATTERN IN CHINA

CHINESE COMPANIES CONSUMED 15.8% OF TOTAL SEMICONDUCTORS IN CHINA IN 2010 BUT WILL CONSUME 64.2% IN 2027
SEMICONDUCTOR SUPPLY IN CHINA

Supply from Foreign Semiconductor Companies
Impact of China's $47 Billion Investments
Supply from Chinese Semiconductor Companies

Semiconductor Supply in China


Semiconductor Market in China

$114B $128.0B $129.5B $158.8B $170.2B $243.5B $276.6B $330.7B $396.8B $478.5B $527.0B


- $114B (2010) 4.5%
- $128.0B (2012) 7.6%
- $129.5B (2014) 8.9%
- $158.8B (2016) 11.2%
- $170.2B (2018) 11.7%
- $243.5B (2020) 14.6%
- $276.6B (2022) 17.1%
- $330.7B (2024) 20.2%
- $396.8B (2026) 25.6%
- $478.5B (2027) 29.6%

TOTAL SEMICONDUCTOR MARKET IN CHINA

- $128.0B (2010) 4.5%
- $158.8B (2016) 11.2%
- $243.5B (2020) 14.6%
- $330.7B (2022) 17.1%
- $396.8B (2024) 20.2%
- $478.5B (2027) 29.6%

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5G SMARTPHONE VOLUMES

CHINA IS LEADER IN SMARTPHONE VOLUME AND 5G
TAM FD SOI FOUNDRY

18/12nm TAM IS BASED ON ≤16nm FOUNDRY MARKET WHILE 28/22nm TAM IS BASED ON 28/22nm AND 45nm FOUNDRY MARKET

LARGE FOUNDRY TAM FOR FD SOI
FD SOI PRODUCT VALUE IS BASED ON LOWER COST, LOWER POWER CONSUMPTION, AND COMPETITIVE PERFORMANCE
CONCLUSION

- Semiconductor market is in growth mode, but there will be some volatility in 2020
- Smartphones are largest user of semiconductors
- Trade issues, however, could disrupt smartphone market
- AI is key long-term growth driver for smartphones and other applications

- China is leader in 5G, with installation of three million to four million base stations by 2020 or 2021
- Projection of one billion 5G users for 2025 to 2028
- Migration for digital designs to 7nm in 2018, 7nm Plus in 2019, and potentially 5nm in 2020
- TSMC and Samsung will likely be only foundry vendors at ≤7nm
- FD SOI, which includes 28nm, 22nm, 18nm, and 12nm, is best technology for many applications
- FD SOI supply comes from Globalfoundries and Samsung
CONCLUSION (CONTINUED)

- There are major benefits from China to support adoption of FD SOI for high-volume products that need low power consumption, RF connectivity, and analog-centric mixed-signal designs

FD SOI can provide product differentiation and optimize competitiveness of end designs, which is important in global markets as well as China market.

- It is important to develop new architectures that utilize ultra-low-power benefits of FD SOI at 12nm in order to give lower cost products than FinFETs for AR and other AI-centric mobile applications

VeriSilicon is already demonstrating leadership capabilities in new architectures

HiSilicon is one of global leaders in semiconductor design at 7nm for smartphones and other applications

THERE ARE MANY AREAS OF HIGH-GROWTH OPPORTUNITIES WITHIN SEMICONDUCTOR INDUSTRY, AND CHINA REPRESENTS KEY MARKET