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Executive Summary

- This full reverse costing study has been conducted to provide insight on technology data, manufacturing cost and selling price of the **NIR Camera Sensor in the Apple iPhone X** supplied by **STMicroelectronics**.

- Located in the iPhone X’s front, around the main speaker, the True Depth system is packaged in one metal enclosure. The system features a dot projector, a red/green/blue camera and a NIR camera sensor. The latter device, provided by STMicroelectronics, is a NIR camera sensor based on an **Imager-SOI substrate**, involving multiple innovations.

- The SOI substrate allows **high quantum efficiency** and **reduces noises** from the substrate. Combined with STMicroelectronics’ knowledge of NIR sensing technology, the sensor die has very **small pixels**, less than 4 μm long, and **high resolution** of almost two megapixels, thanks to **STMicroelectronics’ new technology node**, reaching below 140 nm on SOI. This allows the sensor to precisely detect faces to unlock the smartphone in a very short response time. The use of deep trenches coupled with SOI substrates provides **high dynamic range pixels**. This camera assembly uses **stud bumping** to connect the sensor die in flip-chip configuration, along with an optical module comprising **four lenses**.

- This report analyzes the complete NIR camera sensor, including a complete analysis of the module and the sensor die, along with a cost analysis and a price estimate for the device. It also includes a **physical and technical comparison** with other NIR image sensors for 3D sensing, such as those from Infineon, pmd and Tower Semiconductor for consumer applications, Melexis for automotive, and Texas Instruments for industrial applications.
Apple iPhone X Teardown

Apple iPhone X Opened View
©2017 by System Plus Consulting
TrueDepth Module
Module Views & Dimensions

NIR Camera Sensor Bottom View ©2017 by System Plus Consulting

NIR Camera Sensor Side View ©2017 by System Plus Consulting

NIR Camera Sensor – Flex Marking ©2017 by System Plus Consulting

NIR Camera Sensor Global View ©2017 by System Plus Consulting

NIR Camera Sensor Top View ©2017 by System Plus Consulting
Module Disassembly

Overview / Introduction

Company Profile & Supply Chain

Physical Analysis
- Module View
  - Module Cross-Section
  - Sensor Die View
  - Sensor Die Cross-Section

Physical Comparison

Manufacturing Process Flow

Cost Analysis

Selling Price Analysis

Feedbacks

About System Plus

NIR Camera Sensor – Disassembly – Bottom View
©2017 by System Plus Consulting

NIR Camera Sensor – Disassembly – Global View
©2017 by System Plus Consulting
Module Cross-Section
Module Cross-Section – Filter

NIR Camera Sensor – Cross-Section
©2017 by System Plus Consulting
Sensor Die – Die View & Dimensions

Die Area:

Nb of PGDW per 12-inch wafer:

Pad number:
  - Connected:

Pixel Array:

NIR Image Sensor resolution:
  - Pixel Area:
  - Pixel Size:

Die Top View – Optical View
©2017 by System Plus Consulting
Sensor Die – Die Delayering – Pixels

- **Pixel Area:**
- **Photodiode Area:**
- **Fill Factor:**
Sensor Die – Die Cross-Section – Pixels

Sensor Die – Cross-Section Plan
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Sensor Die – Die Cross-Section – Pixels – SEM View
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Sensor Die – Die Cross-Section – Pixels

Sensor Die – Cross-Section
©2017 by System Plus Consulting

Sensor Die – Die Cross-Section – Pixels After Doping Revelation – SEM View
©2017 by System Plus Consulting

Sensor Die – Die Cross-Section – Pixels – Schematic View
Estimated Pixel Performance
## Sensor Front-End Cost

<table>
<thead>
<tr>
<th>Front-End</th>
<th>Low Yield</th>
<th>Medium Yield</th>
<th>High Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost</td>
<td>Breakdown</td>
<td>Cost</td>
</tr>
<tr>
<td>Raw Wafer Cost (SOI)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clean Room Cost</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Equipment Cost</td>
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<td></td>
<td></td>
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<tr>
<td>Consumable Cost</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Labor Cost</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Yield losses Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Sensor Front-End Cost Breakdown (Medium Yield)

The **front-end cost** for the Sensor ranges from according to yield variations.

The largest portion of the manufacturing cost is due to the
Total Front-End Cost

<table>
<thead>
<tr>
<th>Raw Substrate (SOI)</th>
<th>Low Yield</th>
<th>Medium Yield</th>
<th>High Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost</td>
<td>Breakdown</td>
<td>Cost</td>
</tr>
<tr>
<td>NIR Image Sensor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microlenses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield Losses Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The **total front-end cost** for the NIR Image sensor ranges from [ ] to [ ] according to yield variations.

The largest portion of the manufacturing cost is due to the **[ ]**.
Sensor Wafer & Die Sensor

By adding the probe test cost and the dicing, the **Sensor wafer cost** ranges from $\text{[value]}$ to $\text{[value]}$ according to yield variations.

The number of **good dies per wafer** is estimated to ranges from $\text{[value]}$ to $\text{[value]}$ according to yield variations, which results in a **die cost** ranging from $\text{[value]}$ to $\text{[value]}$. 
# NIR Image Sensor Estimated Manufacturer Price

<table>
<thead>
<tr>
<th>Component cost</th>
<th>Low Yield</th>
<th>Medium Yield</th>
<th>High Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost</td>
<td>Breakdown</td>
<td>Cost</td>
</tr>
</tbody>
</table>

We estimate that STMicroelectronics realizes a gross margin of 40% on the NIR Image Sensor, which results in a final component price ranging from $X to $Y.

This corresponds to the selling price for large volume to OEMs.
Related Reports

REVERSE COSTING ANALYSES - SYSTEM PLUS CONSULTING

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Ref.: SP17378

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