ams’ Direct ToF Proximity Sensor

First SPAD Time-of-Flight from ams in the Huawei Mate 20 Pro

IMAGING report by Stéphane ELISABETH
April 2019 – Sample
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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 ams' Proximity Sensor in the Huawei Mate 20 Pro.

In the Huawei Mate 20 Pro, the front optical hub is packaged in one metal enclosure featuring several cameras and sensors. The complete system features a red/green/blue (RGB) camera module, an ambient light sensor, a near-infrared (NIR) global shutter (GS) camera module, a flood illuminator, a proximity sensor and a dot projector.

This report focuses on analyzing the proximity sensor. Located in the front around the main speaker, the proximity sensor is contained in a Land Grid Array (LGA) package. The device is probably a custom version of the new TMF8701 component made specifically for Huawei, and is the first on the market from ams. The component includes a SPAD detector featuring a 15 µm-wide SPAD, with 128 pixel resolution, and a single Vertical Cavity Surface Emitting Laser (VCSEL). The structure uses innovative optical LGA packaging with polymer lenses produced using a transfer molding process.

This complete analysis of the proximity sensor includes detailed analyses of the SPAD detector and the VCSEL, along with a cost analysis and price estimation for the module. It also includes a physical and technical comparison with the custom proximity sensor from STMicroelectronics in the Apple iPhone 8 and iPhone X/XR/XS.
Huawei Mate 20 Pro Teardown

Overview / Introduction

Company Profile & Supply Chain
- ams
- 3D Sensing Market
- 3D Sensing Technology
  - Huawei Mate 20 Pro Teardown
- ams’ d-ToF Proximity Sensor

Physical Analysis

Physical Comparison

Manufacturing Process Flow

Cost Analysis

Selling Price Analysis

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Huawei Mate 20 Pro Front View – Sensing module
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Huawei Mate 20 Pro Back View – Opening
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d-ToF Proximity Sensor System Architecture

Features:
- HV process node
- Custom developed SPAD sensor
- on main sensor array
- TDC and histogram based distance detection
- Fully integrated power management
- Cortex M0 CPU
- Sub-ns pulse generating laser driver
- Multi-mesa VCSAP diode
Summary of the Physical Analysis

Module Assembly:
- Electronic components assembly
- Dimensions
- OLGA Package:
- Lens:
- VCSEL and SPAD Detector on OLGA Package
- Electrical Connections and support:

Sensor Die:
- Process:
  - Special Features:
    - Electrical Connection:
- Placement:

VCSEL Die:
- Process:
  - Electrical Connection:
  - Placement:
## Package View & Dimensions

<table>
<thead>
<tr>
<th>Package</th>
<th>Dimensions</th>
<th>Pin Pitch</th>
</tr>
</thead>
</table>

**Marking:**

- **ACVSF**

### Package Top View

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### Package Bottom View

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### Package Side View

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### Schematic View

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Package Cross-Section

Package total thickness:
- LGA PCB thickness:
- SPAD Detector thickness (with adhesive):
- VCSEL Die thickness (with adhesive):
- Optical blocking Package thickness:

Package Cross-Section Plan
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Package Cross-Section — SEM View
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  - Views & Dimensions
  - Cross-Section
- VCSEL Die
  - Views & Dimensions
  - Die Cross-section
- SPAD Die
  - Views & Dimensions
  - Delayering
  - Die Process
  - Die Cross-section

Physical Comparison
Manufacturing Process Flow
Cost Analysis
Selling Price Analysis
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SPAD Detector Die – Active Area

- An array is used for the reference.
- An array is used for the target.
- Resolution: 
- SPAD Target array dimensions: 
- SPAD dimensions: 

SPAD Detector Die Top View without Filters – Optical View
An additional filter added on top of the SPAD detector area.
SPAD Detector Die – Die Cross-Section – SPADs

**Overview / Introduction**

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- VCSEL Die
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**Physical Comparison**

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Comparison with STMicroelectronics Custom d-ToF – Package

<table>
<thead>
<tr>
<th>Component</th>
<th>Package</th>
<th>Pin Nb</th>
<th>Aperture Nb</th>
<th>Wire Bonding Nb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple iPhone 8 Plus D-ToF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apple iPhone X D-ToF &amp; Flood Illuminator</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huawei Mate 20 Pro D-ToF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Comparison with STMicroelectronics Custom d-ToF – SPADs

<table>
<thead>
<tr>
<th>Component</th>
<th>SPAD Array Area</th>
<th>Resolution</th>
<th>0% Attenuation</th>
<th>90% Attenuation</th>
<th>99% Attenuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple iPhone 8 Plus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huawei Mate 20 Pro</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Global Overview

SPAD Detector
- Transistors manufacturing
- Lithography steps
- Surface Micromachining manufacturing

VCSEL
- VCSEL diode manufacturing

Manufacturing Process Flow
- SPAD Die Front-End Process
  - SPAD Fabrication Unit
- VCSEL Die Front-End Process
  - VCSEL Fabrication Unit
  - Final Test & Assembly Unit

ToF Proximity Sensor Component
- Optical Blocking package with 2 aperture
- Molded Lens
- PCB Substrate
VCSEL Wafer Front-End process Flow (1/3)
### SPAD Detector 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 (Si)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clean Room Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment Cost</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Consumable Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield losses Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ASIC Front-End Cost</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foundry Gross Profit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ASIC Front-End Price</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The **front-end cost** for the SPAD Detector ranges from [value] according to yield variations.

The largest portion of the manufacturing cost is due to the [component].
VCSEL Wafer & Die Cost

By adding the probe test cost and the dicing, the VCSEL wafer cost ranges from [ ] according to yield variations.

The number of good dies per wafer is estimated to range from [ ] according to yield variations, which results in a die cost ranging from [ ].
Component Cost

<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>
<tr>
<td>ASIC Die Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VCSEL Die Cost</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Packaging Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final test &amp; Calibration cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield losses cost</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The component cost ranges from [ ] according to yield variations.

- The **SPAD Detector die** represents [ ] of the component cost.
- The **VCSEL die** represents [ ] of the component cost.
- The **package assembly** represents [ ] of the component cost.
- **Final test and yield losses** represent [ ] of the component cost.
Estimated Manufacturer Price

<table>
<thead>
<tr>
<th>Component cost</th>
<th>Cost</th>
<th>Breakdown</th>
<th>Cost</th>
<th>Breakdown</th>
<th>Cost</th>
<th>Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>ams Gross Profit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Component price</td>
<td></td>
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</tr>
</tbody>
</table>

We estimate that ams realizes a gross margin of ___ on the ToF Proximity Sensor, which results in a final component price ranging from ___

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

PACKAGING

• VCSEL in Smartphone – Comparison 2019
• Sony’s 3D Time-of-Flight Depth Sensing Camera Module
• STMicroelectronics’ Time of Flight Proximity Sensor & Flood Illuminator in the Apple iPhone X
• ams’ Spectral Sensor Portfolio: the AS726X Series
• STMicroelectronics Time of Flight Proximity Sensor in the Apple iPhone 7 Plus

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ADVANCED PACKAGING

• VCSELs – Technology, Industry and Market Trends 2018
• 3D Imaging & Sensing 2018
STMicroelectronics was the first company to provide Single Photon Avalanche Diode (SPAD) technology for proximity sensing. Back in 2016, Apple started to implement this technology for its high-end iPhone 7 Plus. At this time, the phone-making Original Equipment Manufacturers (OEMs) were looking for highly sensitive proximity sensors requiring low photon incidence to work. Several companies have followed this path and have developed their own SPAD technology. This year, ams started mass production of its proximity sensors based on SPAD technology and offer the solution to several customers. The very first customer is Huawei, with ams supplying a custom proximity sensor in the Huawei Mate 20 Pro. Following this, ams is expected to gain increasing market share with several design wins in other OEMs’ flagships this year.

In the Huawei Mate 20 Pro, the front optical hub is packaged in one metal enclosure featuring several cameras and sensors. The complete system features a red/green/blue (RGB) camera module, an ambient light sensor, a near-infrared (NIR) global shutter (GS) camera module, a flood illuminator, a proximity sensor and a dot projector.

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**COMPLETE TEARDOWN WITH**

- Detailed photos
- Precise measurements
- Materials analysis
- Manufacturing process flow
- Supply chain evaluation
- Manufacturing cost analysis
- Estimated sales price
- Comparison with STMicroelectronics’ d-ToF proximity sensor for the Apple iPhone 8 Plus and iPhone X
AMS’ DIRECT TIME-OF-FLIGHT DETECTION SPAD-BASED PROXIMITY SENSOR

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Estimated Price Analysis

AUTHORS

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RELATED REPORTS

Sony’s 3D Time-of-Flight Depth Sensing Camera Module
Deep analysis of the Sony’s 3D ToF Sensor and the VCSEL in the Oppo RX17 Pro. March 2019 - EUR 3,990*

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VCSEL in Smartphone – Comparison 2019
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