Panasonic 3D ToF Depth Sensing Camera Module

Panasonic MN3906 Time-of-Flight Image sensor and Flood Illuminator in the Vivo Nex Dual Display

IMAGING report by Stéphane ELISABETH
Physical Analysis by Nicolas RADUFFE
May 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 Panasonic MN34906 and the Flood Illuminator found in the Vivo Nex Dual Display.

- This report is focused on the analysis of the 3D depth-sensing camera, comprising the near-infrared (NIR) ToF camera module, and the flood illuminator. Relying on Panasonic’s knowledge of Charge Coupled Device (CCD) image sensors, the MN34906 has the smallest known pixel size for any ToF image sensor made with a CCD process on the market. Indeed, with a very low number of metal layers, Panasonic was able to produce a very cost-efficient image sensor with enough resolution and accuracy for a consumer application. Coupled with a standard flood illuminator based on vertical cavity surface emitting laser (VCSEL), the system has a very small form factor GS approach.

- This report analyzes the complete 3D depth sensing camera, provided along with cost analysis and price estimation for the module. It also includes a physical and technical comparison with other 3D sensing systems, such as the Infineon/pmd ToF image sensor in the Lenovo Phab 2 Pro, and the Sony BSI ToF image sensor in the Oppo RX17 Pro. The comparison looks at system integration, the NIR camera module and the illuminator architecture.
Vivo Nex Dual Display Teardown

Overview / Introduction
Company Profile & Supply Chain
- Panasonic
- Vivo Nex Dual Display Teardown
Market Analysis
Physical Analysis
Physical Comparison
Manufacturing Process Flow
Cost Analysis
Related Reports
About System Plus

Vivo Nex Dual Display Front View
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Vivo Nex Dual Display Rear View – Opened
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Summary of the Physical Analysis

NIR Camera Module Assembly:
- [Details]

NIR ToF Image Sensor:
- Dimensions:
- FSI
- Optical Features:
- Wire bonding on Rigid PCB
- CCD Technology

NIR ToF Image Sensor Die:
- Process:
- Electrical Connection:
- Placement in the package

Flood Illuminator Module Assembly:
- [Details]

VCSEL Die:
- Process:
- Electrical Connection:
- Placement in the package
VCSEL Die Overview & Dimensions

- Die Area:
  - Pad number:
    - Wire bonding:
      - Material:
        - Diameter:
    - Emitting Array:
      - Emitter Number:
        - Cavity Area:
        - Cavity Diameter:
3D ToF Camera Module – Sensor Die Overview & Dimensions

- Die Area:
- Nb of PGDW per 1-inch wafer:
- Pad number:
  - Connected:
- Pixel Array:
- NIR ToF Image Sensor resolution:
  - Pixel Area:
  - Pixel Size:
Sensor Die – Die Delaying – Pixels
Sensor Die – Die Cross-Section – Photodiode

Figure 1. (a) Pixel structure that consists with P-type substrate, photodiode is not separated in deep region. (b) Pixel structure of SDP, photodiode is completely separated.

Table 1. Characteristics summary of stacked deep photodiode

<table>
<thead>
<tr>
<th></th>
<th>Conventional photodiode</th>
<th>Stacked deep photodiode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photodiode depth</td>
<td>4.7μm</td>
<td>10μm</td>
</tr>
<tr>
<td>QE (850nm)</td>
<td>16%</td>
<td>30%</td>
</tr>
<tr>
<td>MTF (850nm at Nyquist frequency)</td>
<td>40%</td>
<td>40%</td>
</tr>
<tr>
<td>Dark current 60 °C</td>
<td>17ele/sec</td>
<td>17ele/sec</td>
</tr>
<tr>
<td>Read out voltage</td>
<td>4.6V</td>
<td>4.7V</td>
</tr>
</tbody>
</table>

Source: H. TAKAHASHI et al., IEEE, 2015, Symposium On VLSI Tech.
# Vivo vs. Oppo vs. Lenovo – NIR Camera Module

## Overview

- **Company Profile & Supply Chain**
- **Market Analysis**
- **Physical Analysis**
- **Physical Comparison**
  - Vivo vs. Oppo vs. Lenovo
- **Manufacturing Process Flow**
- **Cost Analysis**
- **Related Reports**
- **About System Plus**

## Table: Comparison of NIR Camera Modules

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Lenses Number</td>
<td></td>
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</tr>
<tr>
<td>Spacer Number</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>FOV (°)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module Height (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filter thickness (µm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Substrate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Image Sensor Assembly</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Pixel Array Circuit Process Flow

- **n-type buried Layer**

**Manufacturing Process Flow**
- Global Overview
- NIR Sensor Die Front-End Process
- NIR Sensor Process Flow
- NIR Sensor Fabrication Unit
- NIR VCSEL Process Flow
- NIR VCSEL Fabrication Unit
NIR Camera Module – Pixel Array 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 (p-epi Si)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clean Room Cost</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>
</tr>
<tr>
<td>Yield losses Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pixel Array Front-End Cost

The **front-end cost** for the Pixel array Die ranges from **according to yield variations**.

The largest portion of the manufacturing cost is due to the **...**
## Flood Illuminator – NIR VCSEL Front-End Cost

<table>
<thead>
<tr>
<th>Wafer (Epitaxy + Metal Layer)</th>
<th>Low Yield</th>
<th>Medium Yield</th>
<th>High Yield</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Cost</td>
<td>Breakdown</td>
<td>Cost</td>
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<tr>
<td>wafer with epitaxy</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Clean Room Cost</td>
<td></td>
<td></td>
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<tr>
<td>Equipment Cost</td>
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<td>Consumable Cost</td>
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<td>Labor Cost</td>
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<tr>
<td>Yield losses Cost</td>
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</tbody>
</table>

### Front-End Cost

The **front-end cost** for the NIR VCSEL ranges from according to yield variations. The largest portion of the manufacturing cost is due to the...
### Complete System Price

<table>
<thead>
<tr>
<th></th>
<th>Low Yield</th>
<th>Medium Yield</th>
<th>High Yield</th>
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</thead>
<tbody>
<tr>
<td><strong>3D ToF Module Cost</strong></td>
<td></td>
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<tr>
<td>Gross Profit</td>
<td></td>
<td></td>
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<tr>
<td>3D ToF Module Price</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Yield</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium Yield</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>High Yield</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>3D System Cost</strong></td>
<td></td>
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<tr>
<td><strong>Main Camera Cost</strong></td>
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<tr>
<td><strong>Wide Angle Cost</strong></td>
<td></td>
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</tr>
</tbody>
</table>


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

REVERSE COSTING ANALYSES - SYSTEM PLUS CONSULTING

IMAGING
- Sony’s 3D Time-of-Flight Depth Sensing Camera Module
- Huawei Mate 20 Pro’s 3D Depth-Sensing System
- Mobile Camera Module Comparison 2019
- Orbbec’s Front 3D Depth Sensing System in the Oppo Find X
- STMicroelectronics’ Near Infrared Camera Sensor in the Apple iPhone X
- Apple iPhone X – Infrared Dot Projector
- Lenovo Phab2Pro 3D ToF Camera

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IMAGING
- 3D Imaging & Sensing 2019
- VCSELs - Technology, Industry and Market Trends
- Consumer Biometrics: Market and Technologies Trends 2019
- Status of the Camera Module Industry 2019 – Focus on Wafer Level Optics
- Status of the CMOS Image Sensor Industry 2018
Panasonic’s 3D Time-of-Flight Depth Sensing Camera Module

For 3D depth sensing, three approaches have been considered in consumer applications: active stereo vision (AS), structured light (SL) and Time-of-Flight (ToF) sensing. SL was developed by Apple, which brought it to the market for the first time in 2017. It’s based on a complex system requiring several components, including a Global Shutter (GS) image sensor and a dot projector. The latter has been considered difficult and expensive to make due to the precision required. The ToF approach could be less complex and less expensive. You just need a ToF image sensor and a flood illuminator to bring depth sensing to a system. In this field, only three known companies have solutions. In 2016, Infineon was the first to bring out its 3D ToF image sensor, developed with pmd, for the Google Tango Project. Today, Sony has the major share of the market with several design wins starting from low-end smartphones, such as the Oppo RX17 Pro in 2018, to high-end ones, such as the Samsung S10 5G and Huawei P30 Pro in 2019. This year, Panasonic has surprised the market with a new ToF image sensor in the Vivo Nex Dual Display.

This report is focused on the analysis of the 3D depth-sensing camera, comprising the near-infrared (NIR) ToF camera module, and the flood illuminator. Relying on Panasonic’s knowledge of Charge Coupled Device (CCD) image sensors, the MN34906 has the smallest known pixel size for any ToF image sensor made with a CCD process on the market. Indeed, with a very low number of metal layers, Panasonic was able to produce a very cost-efficient image sensor with enough resolution and accuracy for a consumer application. Coupled with a standard flood illuminator based on vertical cavity surface emitting laser (VCSEL), the system has a very small form factor GS approach.

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  • NIR Camera ToF Sensor Die
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Manufacturing Process Flow
  • Die Fabrication Unit: NIR Image Sensor, NIR VCSEL
  • NIR Image Sensor and VCSEL Process Flow

Cost Analysis
  • Cost Analysis Overview
  • Supply Chain Description and Yield Hypotheses
  • NIR Image Camera Module Cost
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    o Wafer and die cost
    o Lens module and assembly cost
  • NIR Flood Illuminator Cost
    o Front-end (FE) cost
    o Front-end cost per process step
    o Wafer and die cost
    o Assembly cost

Estimated Price Analysis: NIR Camera Module, Flood Illuminator Module, and Optical Hub

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RELATED REPORTS

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Deep analysis of the Sony’s 3D ToF Sensor and the VCSEL in the Oppo RX17 Pro.
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Huawei Mate 20 Pro’s 3D Depth-Sensing System
The complete system includes a 3D camera, flood illuminator, and DOT projector featuring a DOE.
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