# Insider's Guide to Medical Imaging Sensors and Arrays:

## The Five Things You Must Know


by

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White Paper

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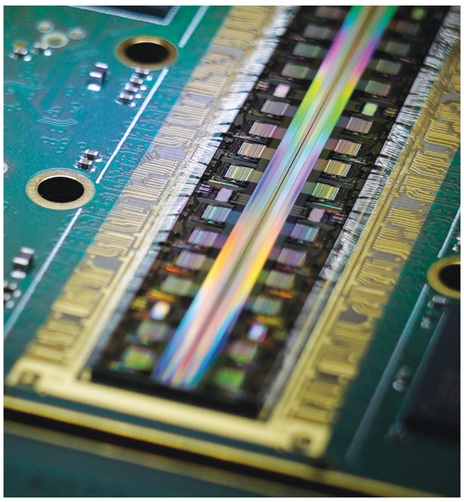
## Introduction

The packaging of high-end optical imaging sensors for medical devices is undergoing a transformation. In the past, these sensors consumed large amounts of power that not only rapidly drained batteries, but also required active cooling to retain image quality. Packaging solutions were developed to cope with these challenging thermal properties. For example, large ceramic cavities with thermo-electric cooling (TEC) layers were applied to imaging sensor assemblies to improve heat transfer. These packages provided the desired thermal conductivity, stability, and flatness — but were costly and large.



Custom line scan CIS board, sensitive to particles

These solutions bucked industry trends that were driving medical imaging manufacturers to build smaller, lighter, and less energy-intensive systems. It was clear that new imaging sensor technologies must be applied to the revolutionary 3D imagers, CT scanners, digital X-ray machines, and endoscopes that were transforming patient care.

In recent years, high-resolution medical imaging sensors and assembled sensor arrays have been developed to meet these industry trends. These components required new packaging technologies as semiconductor technology advanced, chip sizes grew, and devices became more compact. As a result, the designers of new sensor packaging face a host of new challenges.

- As dies get bigger, new technology is required to die bond and wire bond properly.
- Different and more expensive materials must be used in the connections. These materials require longer curing times and engineering oversight to be performed correctly.
- For endoscopes, optics can be put directly on the chip. That means the glass fiber that transports the image from the tip of the endoscope to the camera must be aligned perfectly with the optic on the chip.
- For PET and CT scanners and X-ray systems, imagers are assembled in large arrays to make very large detector surfaces. A sensor array is placed on a substrate with SMD components on the back. Then a central layer is placed on the top, calibrated, put into a ring, and sold as a finished PET scan module.

These challenges place new burdens on medical imaging OEMs to specify correctly, make good material selections, and build components and assemblies with experienced processing people — all while producing systems at the highest quality and at competitive costs.

The good news: technologies are on the horizon that will cut imaging sensor power consumption and heat generation, reduce size, and lower cost.

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The Five Things You Must Know

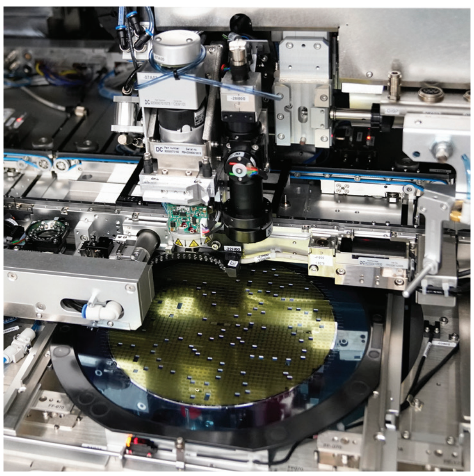
## The Five Technical Challenges

There are five technical challenges that must be overcome to build a superior medical imaging sensor or assembled sensor array.

### 1. Placement Accuracy

High-precision placement of the components to the die surface is critical process. Attached chip optics such as prisms, apertures, frames, etc. must be placed with a few µm accuracy. Imager dies normally require 5- to 10-micrometer accuracy in the X and Y directions. For medical devices such as endoscopes, it may be necessary to glue a prism directly on top of the imager. This requires precision at the pixel size — about 5 to 15 microns.

It is important to recognize that a supplier's existing die placement equipment might not be accurate enough to process new designs. In the future, medical imaging structures will continue to get smaller — demanding finer placement machines, plus considerable supplier knowledge and expertise in areas such as adhesives, covering materials, and die-bonding quality.



Customized die bond equipment, for precise die placement

### 2. Flatness

Highly accurate placement also means that flatness and tilt are essential. Sensors must be packaged without warp or bow to guarantee sharp imaging in the flocal plane. The larger the chip becomes, the more difficult it is to achieve flatness levels below 100 µm to 50 µm. A supplier must guarantee flatness over the device's complete temperature range — making its material and processing capabilities extremely important.

Optics that can tolerate warped imagers would be too expensive to produce. It is much more economical to invest in packaging with the appropriate flatness than in applying more sophisticated optics.

### 3. Cleanliness

High-end medical imaging sensors and arrays must be constructed in an ultra-clean environment. Dirt on a pixel or dust in the production process will cause quality issues and lower yields. Dicing chips out of a wafer is a dirty process that will generate plenty of dust. These particles can accumulate on the chips leading to significant product loss. A supplier must know how to dice chips without creating dirt.

As pixels become smaller, the handling and packaging processes need to be extremely clean and typically require Class 100 clean room facilities. Assembling imagers with several chips on one carrier requires a very high number of contacts. This process also must be kept very clean. If one die is lost due to dirt or contamination, the entire module must be discarded.

### 4. Product and Material Handling

To enable clean imager packaging, it is advantageous to have all the handling steps — dicing the substrates and semiconductor wafers, assembly, and test — in one location. When this work is performed in one clean room, there is no chance of contamination. When wafer dicing is done at a remote location, then shipped half way around the world, there is great risk of damage during transportation. Doing electro-optical final testing on site shortens feedback loops and guarantees the product quality needed for high-end medical imaging applications.

A good supplier should have the competencies to process and singularize semiconductor wafers, glass, ceramic, and organic materials all under one roof — eliminating the potential for product defects.

### 5. Material Interconnection

In the assembled sensor array, every connection must work perfectly, otherwise the module will be defective and must be scrapped. Material interconnection expertise is essential to perform this work. The wire bonds have to be reliable, and their gaps must be as close as possible. Sound material interconnection can mean the difference between a high-quality, cost-effective solution out of the box, or expensive and time-consuming trials that delay commercialization.

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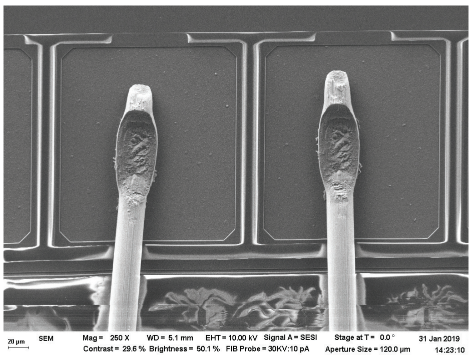
## The Right Packaging Partner

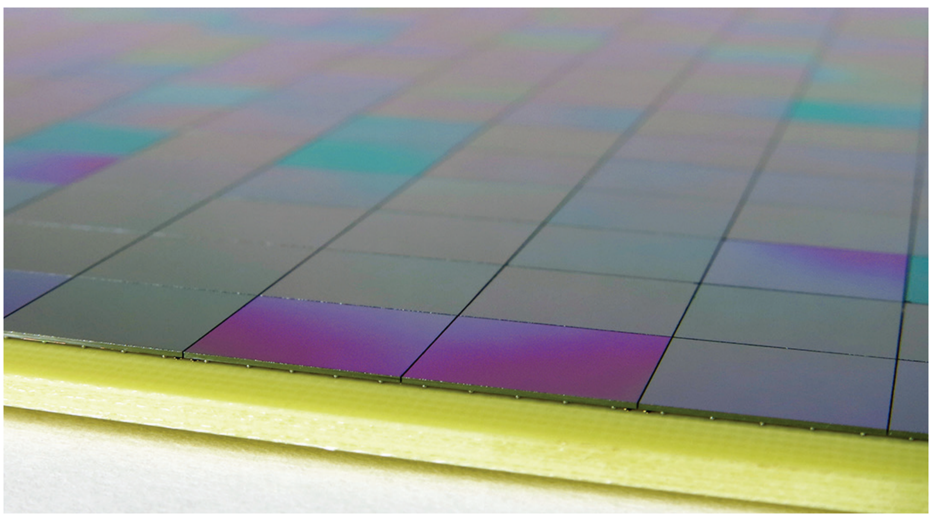
Medical imaging OEMs search for packaging partners with the knowledge, expertise, and production processes that ensure the best cost and quality. Packaging suppliers should be evaluated on the following criteria:

- **Scalability in product volume and size:** The supplier must have the capability to scale its volume using industrial panel level production techniques on automated equipment with acceptable development costs. It also should be equipped to accommodate the trend to larger and larger semiconductor dies – up to 10 cm and beyond.




Wire bonding reliability analysis with a REM inspection

- **Knowledge and expertise:** Choose a long-term partner with the engineering capability to jointly develop imager design and packaging technologies. Designing these components together will result in a superior technical solution.
- **Technology transfer:** The sooner the OEM submits its product idea to a trusted manufacturing partner, the better and more efficient the development and production process will become. In this collaboration, the OEM lays out the device’s design, explains the type of die, reviews the dimensions, and explains the operating conditions (temperature and humidity). Then the packaging partner can ensure it uses the proper adhesive, subset, ceramics, and printed circuit boards (PCB) to achieve the OEM’s goals. The two work together to develop a technical solution that is designed for manufacturability.
- **Quality systems:** Supplier partners must have a strong quality system, experienced people, and the appropriate quality certifications. These external audits prove the supplier’s processes are aligned with given quality norms. Quality certifications ensure the supplier’s processes will produce good yields at attractive cost levels. Quality systems must be designed at the beginning of the production process to ensure that all involved employees embrace responsibility for quality.



Large flip chip arrays for medical imaging using self-aligning soldering process

## New Solutions

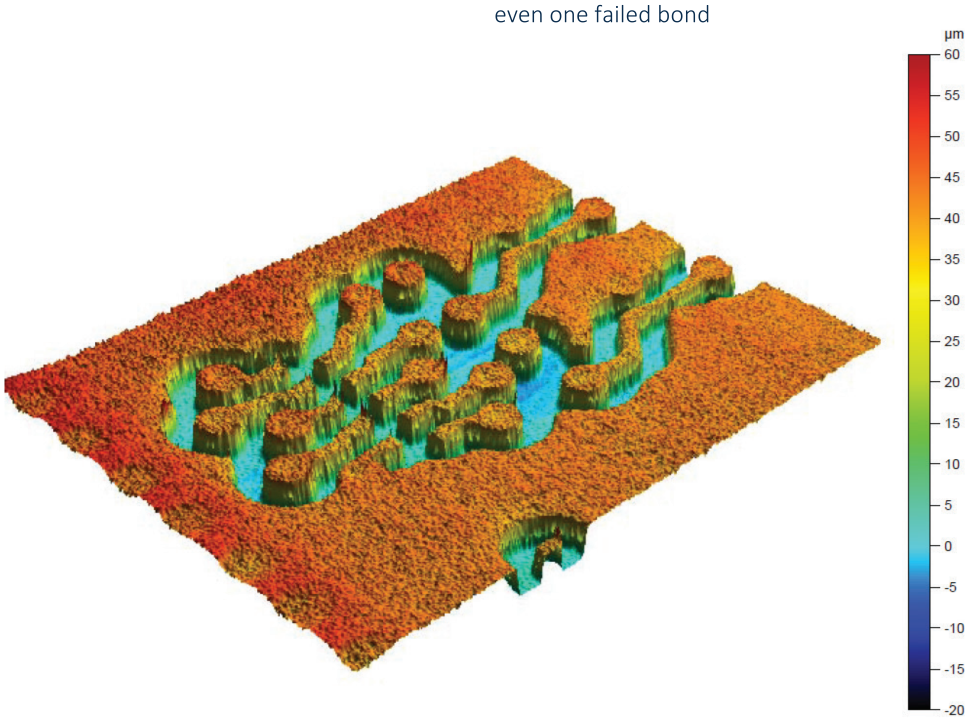
There are new technologies entering the market that will dramatically enhance the development of next-generation imaging sensors and arrays and improve device performance.

Higher-efficiency CCD and CMOS structures will reduce power consumption so dramatically that even high-end applications will not require active cooling. Lower thermal restrictions will permit different packaging technologies and organic substrate materials. By placing the naked chip on the PCB, chip on board (COB) technology will help reduce cost and size significantly: equal or less than industrialized panel production. Ceramics, while less flexible and more costly than COB, also will be used.

PCB substrates with COB imagers will allow the combination of imaging with other electronic surface mount device (SMD) components to build even more compact products and shorten electrical signal path lengths to reduce noise.

Development costs for individual packaging solutions should decrease, allowing optimized sensor array packaging for the low- and mid-level production volumes found in medical equipment markets.

Chips will be front-side illuminated with classical bond wire connections or back-side illuminated requiring flip-chip soldering technologies and a more complex material mix. These high-resolution sensors have a high number of connections and no tolerance for even one failed bond




Laser scan of wire bond pad topography

## Conclusion

The packaging of high-end optical imaging sensors for medical devices is in transition. New imaging sensor technologies are being applied to create revolutionary 3D imagers, CT scanners, digital X-ray machines, and endoscopes that are dramatically enhancing patient care.

Designers of these new products are facing technical challenges in placement accuracy, flatness, cleanliness, product handling, and material interaction. These challenges will require knowledgeable and experienced packaging partners that can scale in product volume and size. True supplier-OEM partnerships will be required to realize the most efficient technology transfer and products that are designed for manufacturability.

These partnerships will leverage the many new solutions entering the market that will reduce the size and power consumption of sensor array assemblies while lowering development costs.

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## About First Sensor

First Sensor is one of the world's leading suppliers in the field of sensor systems. In this growth market, First Sensor develops and produces standard products and customer-specific solutions for the ever-increasing number of applications in the industrial, medical, and mobility markets. With the most innovative sensor solutions, our goal is to identify, meet, and solve the challenges of the future — today.

## About the Authors

**Georg Hegewald, First Sensor AG**
Georg started his 10-year career within Supply Chain Management and foreign trade before developing into a sales role within First Sensor. Throughout his career, he developed an affinity to technical and production processes. He holds a degree in business economics earned at Dresden IHK Business Academy.

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Mike received his Mechanical Engineering Technology degree from Purdue University followed by earning his MBA from California State University. He has had has various technical sales roles throughout his 15-year career and specializes in automation.

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