

Spectral Imaging using Hybrid Integrated, Large-Area High Resolution X-ray Detectors

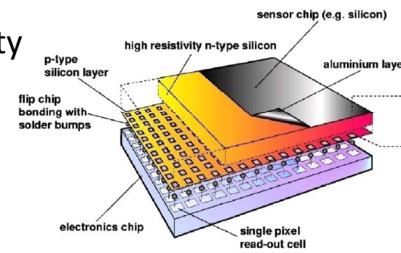
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Introduction

In X-ray imaging, e.g. for Medical or Security applications the ultimate image quality is obtained when the energy of each incoming photon is measured:

- Increased discrimination between different materials.
- Significantly better image contrast can be achieved.
- Significant enhancement in image quality with reduced radiation dose.
- Reduction of noise for the same quantum efficiency.



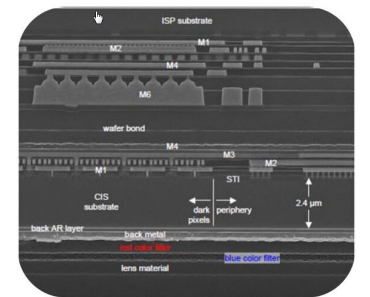
K. Taguchi et al, *Med Phys*, vol. 40, no. 10, Oct. 2013.

State-of-the-Art of X-Ray Spectral Imaging

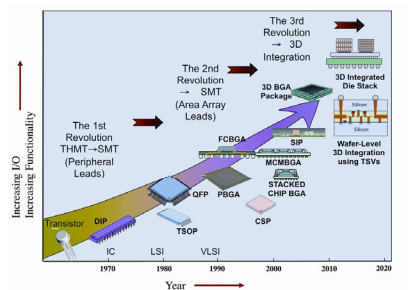
Current approaches, like Medipix & Timepix, typically use a combination of direct detection and ROIC's (read-out IC's). However, direct detection requires high voltages, and the materials typically used for spectral X-ray imaging for medical applications (CdTe and a-Se) are expensive, and suffer from degradation. Also, image sizes are currently typically limited to a few square centimeters, with ~ 256x256 pixels, while medical X-ray imaging size requirements are typically between 13x13 to 45x45cm².

Technology Enablers for Spectral Imaging v2

1. Indirect detection using state-of-the-art structured and fast scintillators will meet the requirements for spectral X-ray imaging at lower costs, higher reliability and easier system integration (no high voltages) than current direct-detection approaches using CdTe or a-Se.
2. Fast, low-noise and affordable wafer-scale CMOS imagers for medical indirect X-ray detection have become available.
3. 3-D integration using bump bonding was limited to high-end applications like space and particle physics. Recently, low cost solutions for direct wafer-to-wafer bonding have been developed for consumer imaging applications (e.g. in mobile phones). This batch-process hybrid packaging (wafer-to-wafer bonding of imager IC and ROIC) can now be also applied to spectral X-ray detectors to connect the CMOS imagers to the ROIC.
4. Scaling: Continuous increase in computing power/area for the ROIC.
5. Assembly: New assembly technologies to enable smaller/lighter overall device sizes (e.g. 3D printing).



OmniVision OV23850 PureCel-S General Structure

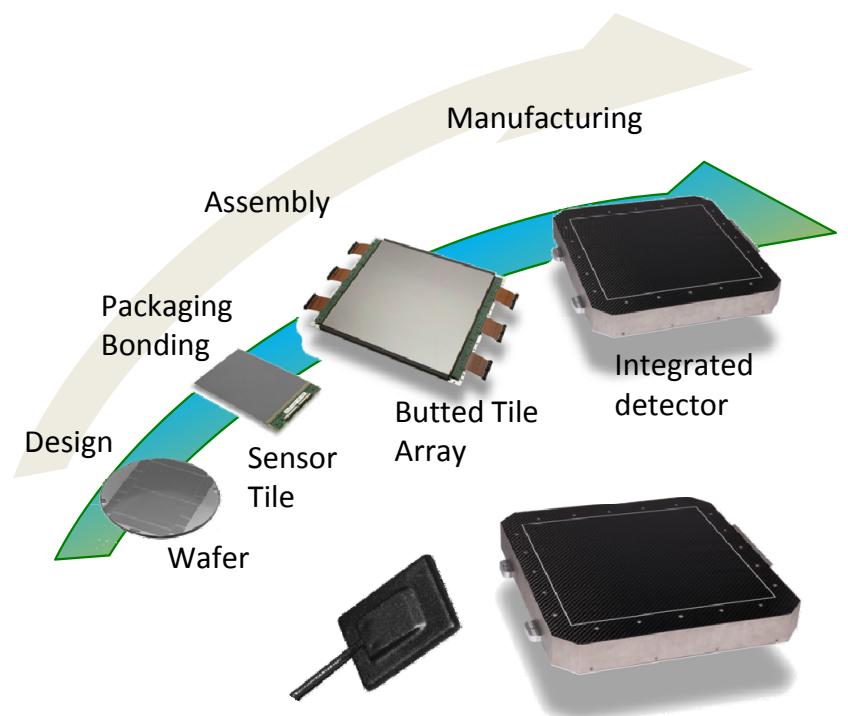


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The Idea/Concept

Make a new generation of X-ray spectral imaging devices based on photon counting using indirect detection in combination with a large-area CMOS imager wafer-bonded to an advanced ROIC. This will be achieved by exploiting the technological advancements in scintillators, advanced assembly technologies and further scaling of IC's. The new generation detector will have a better performance and higher reliability at lower cost, compared to the current solutions. The main points are:

1. **Increase detector Size:** Applications call for several cm². Yield values 80 to 90% minimum for 8 to 12 inch wafers. Need for alternative IC architectures.
2. **Reduce Cost:** Trade-off between Size and Yield. Need for large area detector Assembly Technologies. Research for (new) Hybrid Device Architectures. Wafer Processing, Packaging and Assembly reduction needed. 3D printing potentially beneficial.
3. **Improved Scintillators:** Scintillators with a high light output, high resolution, small decay times and high stopping power.



Potential Impact

Medical:

- Patient examinations: quicker, sharper images and lower doses.
- Medical diagnostics: bone densitometry and mammography, tissue or material identification:

Security:

- Identify dangerous or forbidden substances hidden in closed containers, suitcases and bags.

TDPI Competences and Possible Contributions

- Application Knowledge
- Leader in wafer-scale CMOS imagers
- Expertise in high-speed low-noise ROIC's
- In-house advanced assembly process development
- X-ray conversion: modelling, optimization and evaluation