THE FUTURE OF CT SCANS IS CLEARER THANKS TO NEW TECH

Semiconductor detectors that **DIRECTLY MEASURE THE ELECTRICAL SIGNALS PRODUCED BY X-RAYS** have hugely improved the resolution and contrast of computed tomography scanners.

In the 1970s computed tomography scanners, or CT scanners, transformed diagnostic medicine, allowing doctors to image the whole body in 3D. But the next major leap forward for the core detector technology didn't arrive until 2021, when Siemens Healthineers released its first high-definition photon-counting computed tomography system.

By harnessing new X-ray detectors, photon-counting CT hugely improves image quality and contrast. In addition, these machines can also provide results at a lower radiation dose, allowing vulnerable patients to be scanned.

LOOKING WITHIN

The typical CT scanners used in many hospitals today put patients at the centre of a doughnut-shaped structure containing an X-ray source and an array of detectors. This structure rotates around the patient emitting a narrow beam of X-rays as they pass slowly through it. The detectors on the other side of the doughnut measure the amount of radiation passing through the body, and a computer processes this information to generate multiple cross-sectional images.

These images can be combined to give a full three-dimensional reconstruction. Variations in the intensity of the transmitted beam allow different types of biological tissue to be identified, rather than just hard structures such as the skeleton. CT scanners don't just spot broken bones, they also enable doctors to identify cancers and the tissue swelling of infections.

The sharpness, or resolution, of the images produced by these conventional CT scanners is limited by the detector array. Most of today's CT scanners use so-called scintillation detectors. These are made from a solid ceramic material that absorbs incoming X-rays and converts them to visible light: a process called luminescence. This light is then detected by photodiodes to create an electrical signal.

The drawback is that the light produced during luminescence is emitted in all directions, which requires the introduction of septa of photo absorptive material to separate neighboring detector elements. This limits the efficiency of the detector.

Also, the luminescence from multiple X-ray absorption events is summed at the photodiode, so scintillation detectors can't distinguish between a single high-energy X-ray photon and several lower energy ones. This limits the contrast that is achievable between different parts of the body and leads to a loss of the information contained in the individual photon's energy.

Researcher, Ryoichi Ohno, has been on a mission to find a different approach to detectors. The president of Acrorad, a company developing X-ray detectors based in Okinawa, has been working to replace the luminescing ceramic with a semiconductor called cadmium telluride (CdTe).

NEXT-GEN DETECTORS

When an X-ray photon is absorbed by CdTe, it generates electrons and positively charged equivalents, called 'holes'. These charge carriers travel in opposite directions under the influence of an electric field, and electrons are collected by anode pixels. This allows X-ray absorption information to be deciphered from every single electrical pulse produced, removing the intermediate luminescence interpretation step. This process has been called 'direct photon counting'.

"When I visited CT manufacturers in the early 2000s and proposed the joint development of photon counting CT, they said it would be 10 years before the technology could reach the level achievable in the existing scintillator-based scanners," says Ohno. "And they simply didn't have the budget for that type of long-term basic research."

▲ A photon-counting CT system (left) uses a new type of detector containing cadmium telluride. This was only possible because of advances in producing high-quality cadmium telluride, pictured here being held by the detector material's developer Ryoichi Ohno (right).

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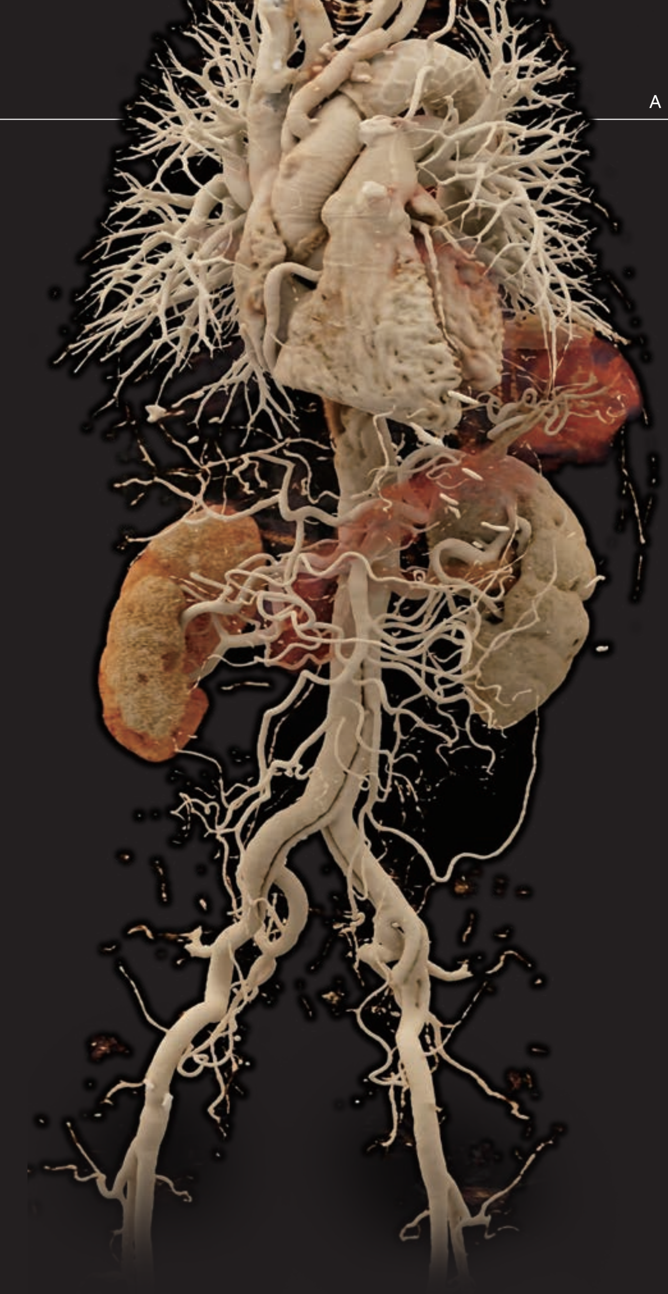
While CdTe X-ray detectors were in use at this time, they were limited to relatively simple tasks such as identifying unwanted fish bones in food products. The move from food to humans required detectors that could identify small changes in X-ray intensity while using a much more powerful X-ray source.

To achieve this, efficient semiconductor detectors need to be made from material with an atomic crystal structure free of imperfections and unintentional impurities. This required the development of a thoroughly improved "travelling heater method" to produce the high-quality CdTe.

This method involves moving a high-temperature heater across an ingot of imperfect polycrystalline CdTe. As the heater moves a molten zone travels through the ingot, dissolving the imperfect CdTe at the top and depositing it as a single crystal at the bottom, explains Ohno. The key to creating the perfect crystal is to move the heater very slowly. In fact, it can take weeks to several months to complete a single ingot.



▲ An image from a new photon-counting CT scanner. These scans offer highly precise spatial information using low radiation doses.

Eventually, Ohno took this technology and partnered with Siemens Healthineers. "I was very impressed by their strong commitment to innovative healthcare devices," he says. "And they had already started developing the necessary related technology: photon counting ASICs." ASICs (application specific integrated circuits) were the vital next step as they provided the electronic processing required to interpret the electrical signal from Ohno's novel detectors. This was a perfect partnership.

A FULLER PICTURE

In the end, it took more than 15 years for Siemens Healthineers to realize a clinically viable photon-counting CT, which they have called NAEOTOM Alpha. The localized electrical signal generated in the CdTe detectors gives the new system more precise spatial information, higher resolution, and less noise. These more efficient detectors also generate images with less intense beams of X-rays, which enables radiographers to reduce radiation exposure for sensitive patients, like children and young adults.

Moreover, the detectors provide information about the X-ray's energy spectrum. In other words, they can distinguish between X-rays of different wavelengths.

This is particularly important for differentiating between, for example, iodine based contrast media and calcium deposits. "To describe this in layman's terms, it's like going from a black and white image to a full-colour one; the depth of information that you get is a completely different world," says Philipp Wolber, the Global Product Marketing Manager for Siemens Healthineers' photon-counting CT systems, based in Germany.

With the technology now implemented in hospitals, Siemens Healthineers is keen to democratize their innovation by making it widely available. "Photon counting is clearly a major breakthrough in healthcare technology and medical imaging, so now we have to work toward getting it everywhere so it can be used by everyone," says Wolber.

And while the team are intensely focussed on expanding this technology, Wolber is keen to stress that access to such products is also about ensuring the systems are usable. "This is something we are building in right from the start, so that hospitals with fewer resources are able to be trained up to deliver all the advantages of this technology to their patients." ■

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