Driving the paradigm shift in innovative flat-panel detector technology, introducing CMOS on mobile full-size C-arms

Technical overview, advantages and comparison of two FD technologies

Every day, Ziehm Imaging employees dedicate their work and expertise in researching and developing innovative hard- and software, clinical applications and other solutions to enhance clinical benefits in daily clinical routine.

One of these innovations came to life in 2006 with the first introduction of flat-panel detectors (FD) to a mobile C-arm. Ziehm Imaging started the paradigm shift of innovative detector technologies for mobile X-ray imaging from image intensifiers (I.I.) to flat-panel detectors. Other C-arm competitors followed and reconfirmed the trend of implementing amorphous silicon (aSi) flat-panel detectors to their mobile systems.

Since then, Ziehm Imaging continuously reaffirms this step in further driving innovations for mobile X-ray imaging systems with the latest flat-detector technology.

By introducing CMOS technology as an alternative detector technology to aSi detectors, Ziehm Imaging pushes the trend of innovative flat-panel technologies even further and closes the gap without compromising image quality of FD technologies and cost efficiency of I.I. systems.

Flat-panel detector technology

For a number of reasons – including shrinking reimbursements and an ever-increasing aging population – the demand for efficient high-quality care is rising. In parallel, the demand for minimally invasive procedures is growing and posing increasing requirements on the development and equipment of imaging technologies.

This is why Ziehm Imaging started the shift from I.I. technology to FD technology in 2006. Therefore, Ziehm Imaging could offer a solution that enhances image quality and improves workflow in the daily clinical routine of outpatient facilities and hospitals.

Ten years on, the flat-panel detector has been established as a mature technology for mobile C-arms, providing multiple advantages over the I.I. systems, such as smaller detector housing, extended dynamic ranges, no image distortion and a greater sensitivity for improved image quality as well as better patient coverage.[1]

The technology behind FD

Compared to image intensifiers, the flat detector's more direct signal conversion path with no optical lens results in uniform image brightness and no geometric distortion. The solid state detector provides more reliability and no image degradation over time. In addition, FD systems do not require a television camera to produce an electronic signal for the image processing and display. By its design, the flat-panel detector produces a digital signal, which offers the possibility of further image processing. This leads to a reduction of image noise caused by analog electronic components usually used in I.I. systems. Typical sizes of each pixel size are, depending on the manufacturer, around 150 µm - 200 µm.

Benefits of FD technology

With significant bigger field of view (FOV), less noise and distortion-free imaging, FD technology offers much better image quality with a higher dynamic range of up to 16 times more shades of gray. This enhances the visualization of more details, which brings advantages, especially in demanding procedures, while complying with dose-saving ALARA principles.

Image quality wasn't the only reason to drive the shift. The larger C-arm opening and a much more compact detector housing allows for more flexible positioning and ensures better communication of the staff during procedures.[1] The mobile C-arms with FD technology thereby enable surgeons and technicians alike a greater ease of use. Thanks to its rectangular images, FD technology takes advantage of a larger field of view and offers better patient coverage. This makes it possible for Ziehm Imaging to visualize both hip joints in just one image, allowing for a reduced applied dose. Furthermore, higher image quality and better workflow opportunities lead to improved performance capabilities and ultimately lower time consumption in the OR. This may decrease overall hospital costs.

Ziehm Imaging established the trend of FD technology for mobile C-arms back in 2006. Since then, more than 80 % of all developed systems have been equipped with flat-panel technology.

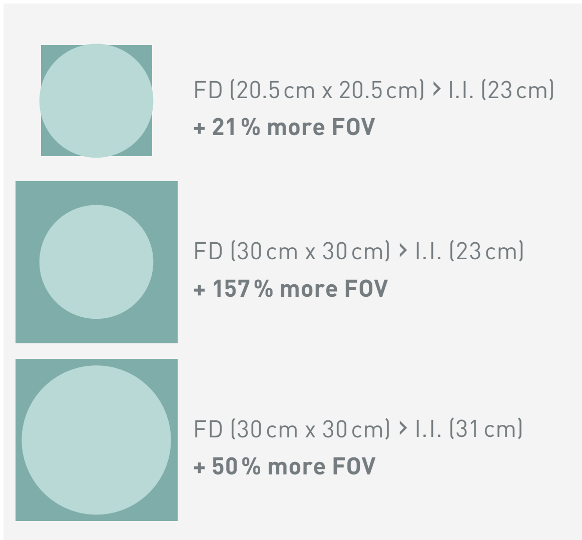

Fig. 1: Gain in FOV comparing I.I. and FD technology

Going one step further with CMOS

With the aim of developing cost-effective and high-quality imaging technology, medical and industrial suppliers have shown increasing demand for a different kind of flat-panel detector technology known as CMOS (Complementary-symmetry metal-oxide-semiconductor). In response, Ziehm Imaging wanted to drive the paradigm shift in detector technologies for mobile C-arms even further to answer this demand.

The wafer-based CMOS imager has grown in popularity. This initially occurred in the industry of small-area medical X-ray imaging applications such as dental, mammography and extremity imaging. On the basis of knowledge from Ziehm Imaging's cooperation partner OrthoScan, CMOS imagers have already been integrated with efficiency and at a reasonable cost into mobile Mini C-arms. Ziehm Imaging has been investing time and money in the research and development for several years to make it available for mobile full-size C-arms. It has been transformed into a market-ready product that closes the gap without compromising the high image quality of FD technology and the cost efficiency of image intensifiers.

The technology behind CMOS

The CMOS technology is based on a crystalline silicone atom structure, which differs from the uneven atom structure of amorphous silicon (aSi) (see Fig. 2 and 3).

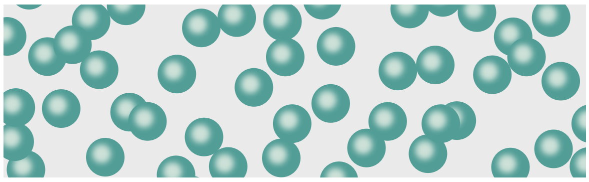

Fig. 2: Amorphous silicon atom structure

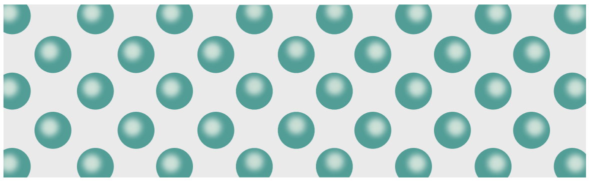

Fig. 3: Crystalline silicon atom structure

This uniform silicon structure of crystalline silicon in the CMOS detector leads to an improved transfer of electrons, generated by incoming X-ray photons, through the crystalline structure to the read-out electronics. This allows the X-ray photons to pass more quickly through the structure with fewer power requirements, resulting in a general lower noise level compared to the aSi technology.

Due to the smaller pixel sizes of the CMOS detector (100 µm x 100 µm) with less dark current, a higher spatial resolution as well as a greater sensitivity can be achieved, which leads to images that are less grainy and dim. Using pixel binning, the noise floor and thereby also the dynamic range can be improved considerably. By combining the signal in four adjacent pixels into 1 pixel cluster of 200 µm x 200 µm and performing a single read-out of the summed signal, the output signal-to-noise-ratio (SNR) can be significantly improved.

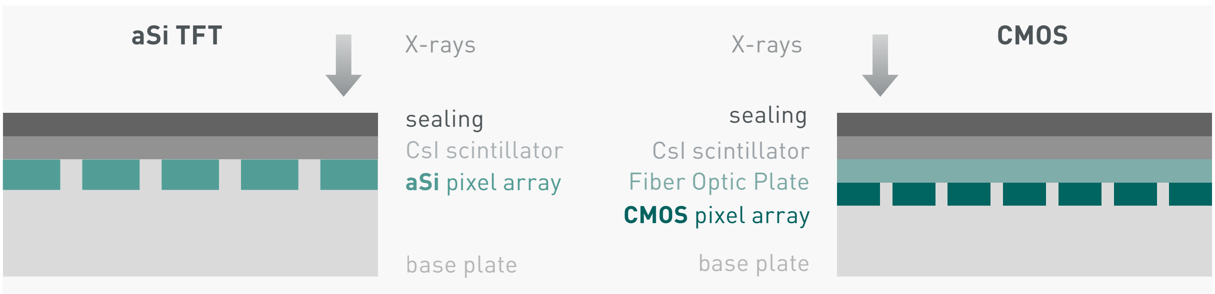

Fig. 4: Technical principle of the aSi and CMOS detectors

Advantages of CMOS technology

The most important advantage regarding image quality of the CMOS detector can be seen in the magnification modes. CMOS benefits from its true resolution especially in the magnification modes by making use of the initial pixel size of 100 µm x 100 µm. With the potential to display more than 4.0 line pairs / mm, the CMOS detector achieves up to a doubled spatial resolution. In combination with lower noise levels in the magnification modes, CMOS shows its direct advantage. Higher sensitivity enables the visualization of smaller pixels with lower dose rates but with the same image quality. In the end, this means that with the same dose a higher resolution or with the same resolution a lower dose rate can be achieved. The high-resolution imaging dramatically improves image quality – to display even the smallest anatomical structures, especially in the magnification modes.

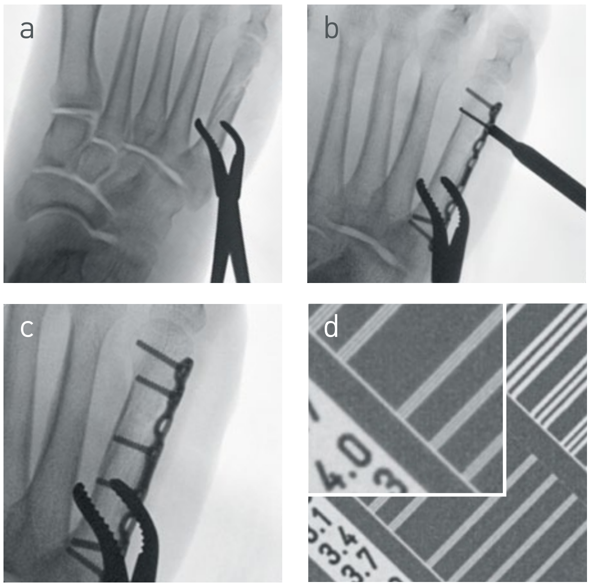

Fig. 5: Clinical images acquired with CMOS flat-panel for detail-rich resolution in all magnification modes: a) full size (20 cm x 20 cm), b) MagMode 1 (15 cm x 15 cm), c) MagMode 2 (10 cm x 10 cm), d) spatial resolution phantom with more than 4.0 lp / mm visible

In addition, the basic, more uniform structure of the CMOS detector enables a higher read-out speed of the X-ray photons due to direct pixel access and a faster communication link with 9 GBit / s allowing full native resolution (true resolution) of up to 30 frames per second.

The wafer-based CMOS technology is also currently more cost-efficient in smaller detector sizes compared with current aSi detectors. It improves the overall cost-efficiency ratio by closing the gap between the high image quality of the mature aSi detector technology and the cost efficiency of I. I.-based fluoroscopy systems.

Two detector technologies side by side

With aSi FD technology, Ziehm imaging possesses a mature technology with many years of excellent clinical experience in combination with outstanding dose-management technologies such as pulsed operation modes.

Experience with aSi technology as well as its proven reliability are certainly strong arguments for using X-ray imaging technologies in mobile C-arms. In larger FOVs of 30 cm x 30 cm, aSi technology still has a cost advantage over CMOS. This is due to the complexity of comprehensive tiling procedures and the need to combine a higher number of CMOS wafer tiles in order to achieve bigger FOVs. As a result, aSi technology will continue to show its advantages in fixed and mobile C-arms with bigger FOVs. In addition, Ziehm Imaging recognizes further development opportunities for this mature technology, to help it remain competitive in the future.

CMOS-based flat-panel detectors offer an excellent alternative to image intensifiers with higher image quality and all the common advantages of FD technology, including distortion-free imaging, more space at the detector and better patient coverage.

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In addition to that, CMOS is expected to show further advantages in the magnification modes with higher spatial resolution, lower noise ratios and a higher read-out speed, which also enables higher frame rates to deliver better image quality in smaller FOVs compared with aSi FD technology. Furthermore, the gap in cost-effectiveness between flat-panel technology and image intensifiers is starting to close.

It can therefore be concluded that both technologies will have reasons to exist side by side in the relevant application fields over the next few years.

Advantages at a glance

Advantages of amorphous silicon (aSi) FD technology
- long clinical experience
- efficient cost-performance ratio for bigger FOVs
- proven dose management with comprehensive SmartDose concept
- broad application portfolio thanks to bigger FOV

Advantages of crystalline silicon (CMOS) FD technology
- higher spatial resolution compared with aSi due to smaller pixel sizes
- significantly more details in the MagModes
- lower dark noise levels lead to less noise in general, which improves dose management even further and increases the dynamic range
- possibility of higher frame rates at full resolution

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[1] AAPM /RSNA Physics Tutorial