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DATASHEET

Electron Microscope Pixel Array Detector (EMPAD)

High dynamic range direct electron detector for 4D STEM application

Direct electron detector solution for high dynamic range diffractive mapping at any high tension.

A superior solution

The classical process of scanning transmission electron microscopy (STEM) imaging records the scattered electron intensities by integration of fixed ring or disk detectors that may or may not be segmented. Only structural information via the dark or bright field images is obtained, and the full annular distribution is not resolved. The Thermo Scientific™ EMPAD Detector samples the diffraction plane with 128x128 pixels in each STEM image point, thereby enabling detailed access to additional information on strain, orientation, electric or magnetic fields (center of mass analysis). It even potentially allows for resolution enhancement via Ptychography methods. Once data is acquired, contrast can be optimized by utilizing the full diffraction pattern or by applying masks to provide quantitative information on materials properties.

High dynamic range mapping

Typical diffraction patterns contain some intensities that are very high and uneven in their overall distribution, which determines the need for a fast high dynamic range sensor to suit mapping applications. The EMPAD Detector design provides the unique ability to record 2 pA/pixel with 1100 fps to record fast, high-quality diffraction patterns for ultimate results in 4D STEM, from high to low convergence and collection angle applications (nano- or microbeam methods).

Integration and documentation of experiments

The EMPAD Detector is retractable, with the insertion/retraction, beam scan, and diffraction pattern recording being controlled by software via a dedicated PC. Four different user-defined masks can be applied to the data during operation to obtain vital live feedback on the quality of the incoming data. All the information is obtained in one scan and, therefore, perfectly correlated. Both the diffraction pattern and the scanned area are calibrated to allow for for quantitative data analysis.

Key Benefits

Highest dynamic range of 1 to 1 million primary electrons per pixel / per readout to retrieve low-signal dark field and high-signal bright field information with a large field of view of 19.2x19.2 mm and the highest DQE, MTF, dynamic range and speed.

Ptychography methods allowing resolution improvements beyond the diffraction limit of optical lenses.

High tension flexibility for operation from 30–300 keV to optimize the voltage to match the diffraction application's needs or the stability needs of the materials examined.

Highest current per pixel of up to 2 pA in combination with 1100 fps readout speed. The high dwell capacity per pixel provides flexibility in convergence and collection angle setup to optimize the diffractive imaging result for different applications.

Easy workflow of operation from simple control of the beam current via an additional measurement unit to optimization of the result via "live view" during recording to storage of calibrated images and diffraction patterns for quantitative data analysis.

One-stop solution for assured performance. Optimum integration on Titan/Themis TEM platforms without loss of performance on dedicated mounting port.

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Figure 1. Images of sensor and control computer with current measurement unit.

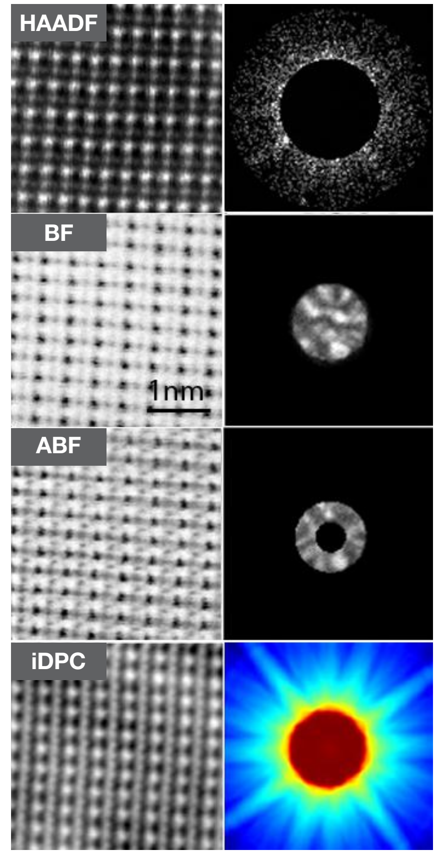

Figure 2. Reconstructed STEM images of $SrTiO_3$ in [110] projection using one data set acquired with a pixelated STEM detector. Post processing of the data allows for extraction of various images with complementary information in one acquisition.

High-tension, flexible, robust design

The EMPAD Detector is radiation hard up to 300 keV and can be operated as low as 30 kV. The included current measurement unit enables the electron dose conditions on the sensor to be verified and enables easy optimization of the beam currents for the experiment at hand.

Integration with Thermo Scientific TEM platforms

The EMPAD Detector works with guaranteed performance on Thermo Scientific TEM platforms. The EMPAD Detector is an additional component that is compatible with all other available cameras on the Titan and Themis TEM platforms.

Figure 3. Screenshot of graphical user interface.

EMPAD Detector Specifications

Sensor dimensions	Active area Pixels Pixel size Active thickness	19.2x19.2 mm 128x128 150 µm x150 µm 500 µm
Performance	DQE(0): Dynamic range Well capacity SNR Minimum integration time High-tension range	0.96@60 keV, 0.95@80 keV and 0.94@300 keV 10^6:1 @200 keV 2 pA/pixel @ 200 keV 140 @200 keV 30 µs 30-300 keV
Maximum speed	1100 fps (128x128 pixel)	
Radiation hardness	@300 kV > 10^{12} e/pixel	
System hardware	• Retractable lead-shielded camera head • Scan generator • Temperature control (water + Peltier cooling) • Software-controlled power supplies and detector insertion/retraction mechanism • Current measurement unit (Keithley model Nr 2400) • Data acquisition cabinet with PC within 10 meters from the detector (possible control extension to 100 m for a remote control room)	
Control and imaging software	• Scan control for field of view and dwell time • Live synthesized STEM image via online data processing of user-defined masks for ABF, BF, DF, HAADF and DPCx, DPCy • Live single (or series) diffraction patterns • Supportive live view annotations to set up and reproduce experiments quickly • Advanced data management to keep track of experimental metadata • Save raw data and live analysis of results • Offline analysis of projects on your laptop	
System requirements	Titan/Themis TEM high- and low-base platforms running Windows® 7 operating system and Thermo Scientific™ TEM Software version 6.7 and later	
Retrofit	Yes, without compromising existing detector configurations.*	

*Please contact Thermo Fisher Scientific for additional information.

References

The EMPAD Detector is based on detector technology described in the publication *High dynamic range pixel array detector for scanning transmission electron microscopy*; authored by Mark W. Tate, Prafull Purohit, Darol Chamberlain, Kayla X. Nguyen, Robert Hovden, Celesta S. Chang, Pratiti Deb, Emrah Turgut, John T. Heron, Darrell G. Schlom, Daniel C. Ralph, Gregory D. Fuchs, Katherine S. Shanks, Hugh T. Philipp, David A. Muller and Sol M. Gruner; in *Microscopy and Microanalysis 22, 237-249.* DOI: http://dx.doi.org/10.1017/S1431927615015664.

Sub-nanometre channels embedded in two-dimensional materials; Yimo Han, Ming-Yang Li, Gang-Seob Jung, Mark A. Marsalis, Zhao Qin, Markus J. Buehler, Lain-Jong Li & David A. Muller; *Nature Materials volume 17, pages 129–133 (2018)*; doi:10.1038/nmat5038.

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Notes

Find out more at **Thermofisher.com/EM-Sales**

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