First productions of large area Silicon Drift Detectors for the eXTP Wide Field Monitor instrument: test results and yield assessment.

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The enhanced X-ray Timing and Polarimetry mission (eXTP website, https://www.isdc.unige.ch/extp/) is a scientific space program that will look at X-rays coming from targets such as neutron stars, magnetars and black holes [1, 2] to study the state of matter under extreme conditions of density, gravity and magnetism. The eXTP satellite will be equipped with state-of-the-art instruments enabling the simultaneous acquisition of spectral, timing and polarimetry information from the photons of the cosmic sources in the energy range from 2 to 30 keV with an unprecedented effective area.

The scientific payload of the mission consists of four main instruments. The Spectroscopic Focusing Array and the Large Area Detector are unprecedented large-area, high-throughput instruments, in soft and hard X-rays respectively. The Polarimetry Focusing Array will be the most sensitive astronomical X-ray polarimeter ever built. The Wide Field Monitor will monitor the X-ray sky with a field of view that far exceeds any previous instrument [3].

The WFM consists of 3 pairs of coded-mask cameras, each made up of 4 Detector Assemblies (DAs), in total 24 sensors, with the SDDs in one camera of the pair oriented at orthogonal direction with respect to the other one. This arrangement allows achieving a FWHM angular resolution better than 4.3 arcmin and an energy resolution better than 300 eV at 6 keV.

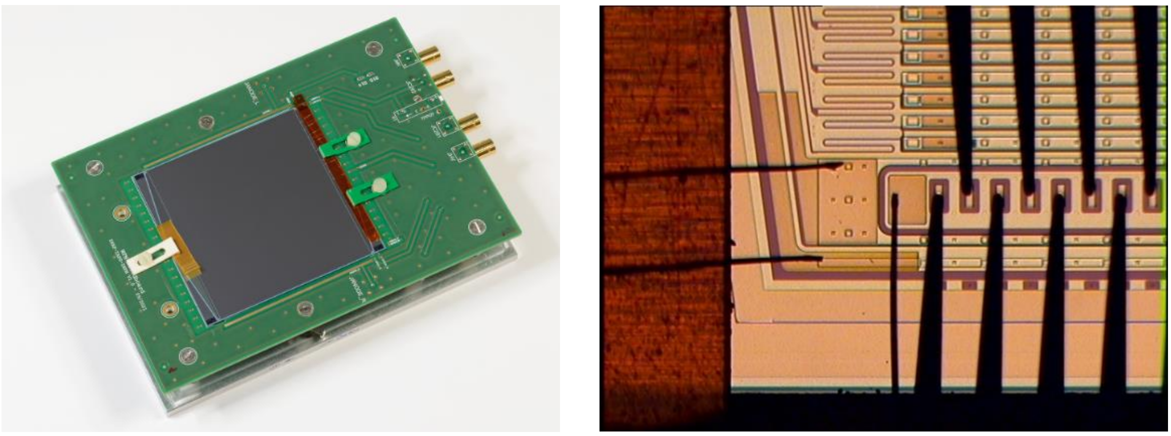

Figure 1. Mounting the SDD on a detector-holder PCB and details of anodes test.

The detector is a 72x77 mm^2, large-area SDD fabricated by FBK on 450 μm thick, 150 mm float-zone n-type Si wafers. It has two symmetrical drift regions, each one defined by 292 p-type cathodes implanted on both sides of the wafer [4]. The cathodes are biased via p-type implanted resistive voltage dividers. A 1.3 kV bias applied to the central cathodes on both sides establishes a linear drift electric field in the sensor sensitive volume. X-rays (2-50 keV) impinging on the SDD generate electron-hole pairs: the nearest cathodes collect holes, whereas signal electrons drift up to n-type readout anodes, organized in two arrays along opposite ends of the detector. Each array contains 384 anodes with a pitch of 169 μm. The centroid of the electric charge collected at the anodes provides one coordinate of the X-ray impact point, while the width of the signal charge projected on the anode axis yields an estimate of the second coordinate.

Upon adoption of the SDD as a WFM sensor for a mission, mass produced SDDs must undergo a characterization procedure to select devices that comply with the spectroscopy requirements. Since the system performance is strictly related to the leakage current at the anodes, the basic acceptance criterium enforces a maximum percentage of anodes whose dark current exceeds a certain critical value at room temperature.

We report on the results of the test and electrical characterization of the two batches of WFM sensors produced in 2021 and 2023. The procedure includes mounting the SDD on a detector-holder PCB, temporarily wire bonding a minimum set of electrodes required to ensure proper double-sided biasing, followed by the leakage current measurements, anode by anode, using a 50 needles probe card in a semi-automatic probe station. (Fig. 1).
Our group has made a significant effort for developing a technology for fabricating SDDs with the lowest anode current, ranging from 1 nA/cm^2 down to 100 pA/cm^2 at room temperature [5].

The analysis of the test results allowed to optimize the production processes to achieve a satisfactory fabrication yield suitable for the eXTP mission.

[1] S. N. Zhang et al., Proc. SPIE, Volume 9905, 99051Q (2016).

[2] S. N. Zhang et al., Sci. China Phys. Mech. Astron., Volume 62, Issue 2, 029502 (2019).

[3] M. Hernanz et al., Proc. SPIE, Volume 10699, 1069948 (2018).

[4] A. Rachevski, et al., Large-area linear Silicon Drift Detector design for X-ray experiments, JINST 9 (2014) P07014, DOI: 10.1088/1748-0221/9/07/P07014

[5] G. Bertuccio et al., X-Ray Silicon Drift Detector-CMOS Front-End System with High Energy Resolution at Room Temperature, IEEE Transactions on Nuclear Science, (2016), Volume: 63, Issue: 1, Pages: 400 - 406, DOI: 10.l109/TNS.2015.2513602