Recent Developments in Silicon Drift Detector Technology: Atomic to mm Scale

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Silicon drift detectors (SDDs) have become popular in energy dispersive X-ray spectroscopy (EDS) for scanning and transmission electron microscopes. Consequently, improvements in detector designs and systems are important.

One topic is the light element performance of SDDs. Fig. 1a shows the energy resolution of SDD-EDS detectors, which are based on the FET on chip technology of PN-Sensor [1] and Bruker's SDD-adapted signal processing electronics. The theoretical resolution curve strictly increases with energy. This means that energy resolution towards lower energies must continuously improve. Many EDS detectors suffer from effects such as incomplete charge collection, leading to deterioration of the lower energy resolution, especially below 1 keV. The detectors measured here follow the theory right down to the light element range. The quality of SDD systems can be clearly distinguished by this type of measurement. Another topic is geometry. Due to the required front-end electronics, SDDs have a slightly larger diameter than LN_2 cooled detectors. This leads to constraints, when optimising the solid angle for X-ray collection in the pole piece region. A smaller detector area and thus detector finger diameter, can achieve a better or a similar solid angle compared to a large detector, while delivering a much better take off angle at the same time. The ideal geometric solution has to be optimised for each case. If space is available, multiple small chip detectors can generally deliver a better solution than a single larger detector area [2]. Additionally, this issue has to be seen in connection to detector efficiency, defined here as throughput (output over input count rate), and the cooling effort. Smaller detector areas allow higher throughput, require a lower cooling effort and deliver better energy resolution, as shown in Fig. 1b for a 4x10 mm² arrangement on SEM. Higher throughput can compensate for a smaller solid angle and is of advantage when high speed analysis of large sample areas at high count rates is required. The aim is to get as many counts as possible at the best possible energy resolution into the spectrum. Various multi- and single chip solutions have already been realised. As with the FEI Osiris for example, four 30 mm² SDD were integrated into the pole piece by the TEM manufacturer in collaboration with the SD-chip and EDS manufacturer [3].

In the future, aberration correction and high brightness electron sources, will provide higher beam currents and lead to improved statistics in the spectra of existing SDD-EDS systems. Fig. 2 demonstrates that quick chemical analysis on the nm-scale is also possible using a single 30 mm² area SDD in a conventional STEM. Employed in STEM/TEM, EDS it is a valuable complement to the well established electron energy loss spectroscopy (EELS). EDS is particularly valuable, if many elements have to be analysed at once, e.g. in life science (Fig.3), and if ambiguities in EELS occur. Furthermore, EDS delivers a better signal to background for deep inner shell excitations at energies above 2keV, where the electron energy loss detection is difficult. Recently atom column EDS at 1.47 Angstrom column distance has been shown for III-V semiconductors [4]. A condition for chemical analysis at high spatial resolution is, that the EDS-detector covers a high enough solid angle and does not disturb the performance of the aberration corrected atomic resolution instrument.

[1] Strüder L., et al., *Microsc. Microanal.* 4 (1999) 622-631.

[2] N. J. Zaluzec, *Microsc. Microanal.* 15 (2009) 93-98.
[3] S. von Harrach et al., *Microscopy and Microanalysis* 15 (Suppl2): (2009) 208.
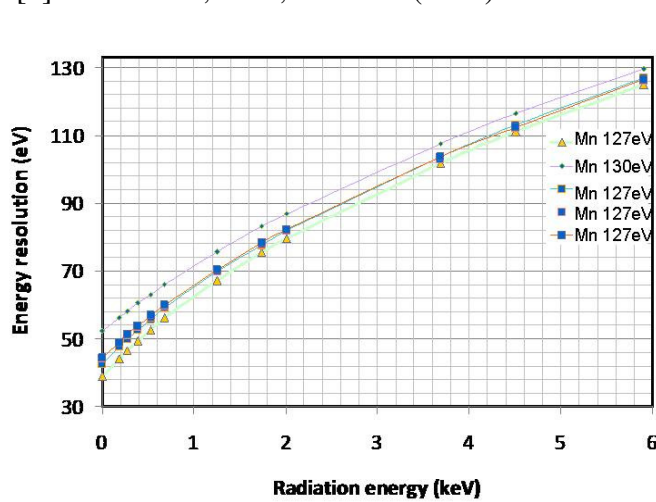[4] M.-W. Chu, et al., *PRL* 104 (2010) 196101.

FIG. 1a Typical energy resolution vs. radiation energy for 30mm² detectors of two different resolution types. Note the monotonous shape of the curve.
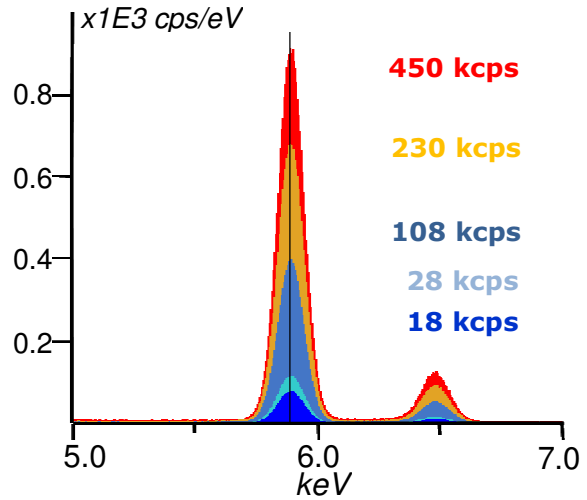
FIG. 1b Spectra showing manganese Kα at low to high input count rates with the same energy resolution (123eV) for a four channel 40mm² SDD.
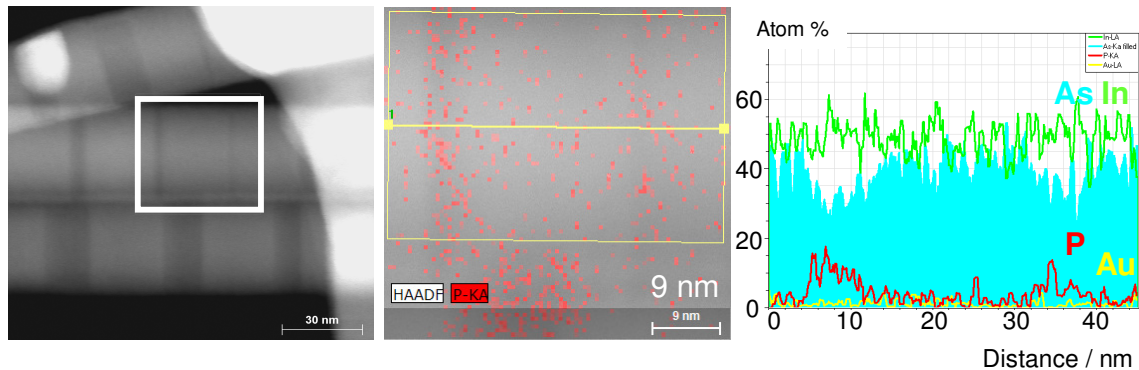

FIG. 2 Quantitative EDS map of an InAs/InP nanowire heterostructure and extracted quantitative line scans in nm resolution. Sample courtesy: D. Ercolani, L. Sorba, NEST, Pisa, Italy; Mapping parameters: 4 min at 400pA, 1nm spot size, 0.12 sr solid angle, 22° take off angle, Jeol 2200FS.
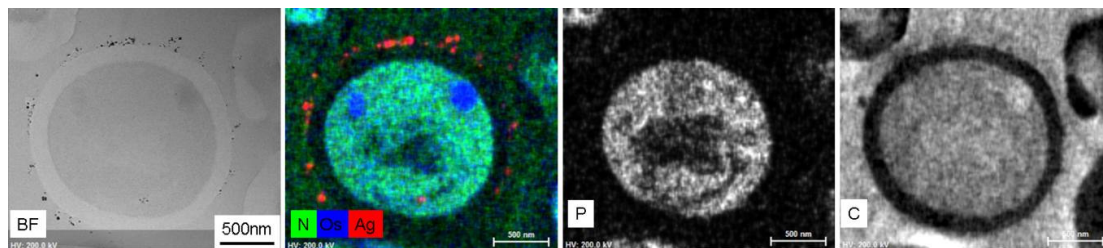

Fig. 3 Yeast cell, Os stained and Ag labelled. Net counts for C and P after deconvolution, Data courtesy: P. Lasson, Synergie 4, France.