Confocal multi-channel arrays as collimators for X-ray Fluorescence micro-Analysis and Radionuclide diagnostics

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Microscopic XRF (μ-XRF) is a branch of XRF that has been developed since 1990 [1,2] mainly thanks to the use and increasing availability of synchrotron radiation (SR) as well as various devices for efficient focusing of X-rays [1,3]. It can provide information on the local elemental composition of inhomogeneous samples. At synchrotron facilities, a variety of micro- and nanofocus optics, based on refraction [4], diffraction [5], or total external reflection [6] of X-rays, is currently in use to create small beams with energies in the 1–100 keV range and diameters of about 0.1–1 μm. In laboratory μ-XRF instruments mostly polycapillary lenses are employed for focusing [7–8], providing focused X-ray beams that usually are 10–30μm in diameter [9]

A specific sub-type of micro-XRF investigations, aimed to get 3D elemental distribution of the samples, are those employing confocal excitation-detection geometry [10-12]. In this case, the recorded XRF signals stem from a small 'confocal' volume that is defined as the intersection of focal spots of two X-ray optical elements: the first positioned between X-ray source and sample (focusing optic) and the second between sample and X-ray detector (confocal collimator) [11, 12].

Most (or almost all) of confocal micro-XRF (CMXRF) experiments [1, 12-13] reported to date have used polycapillary lens (or half lens) as confocal collimators [13, 14]. But its employing limits the scope of CMXRF due to its limited and energy dependent resolution. So the highest resolution offered by a polycapillary was ~8 μm at ~ 17.5 keV with a working distance of ~2 mm [14]. An improvement in resolution may result in shorter and possibly impractical working distances (because defining the resolution focal spot size of polycapillary lense $D_{f.s.} \approx d_c + 2F\Theta_c$ linearly depends on focal distance F, total external reflection (TER) angle Θ_c and glass capillary diameter d_c [13-16]). Moreover using polycapillary optics for high energies (for example, for heavy elements detecting) possesses additional issues: with fluorescent photons energy increase the part of directly (not due to TER) passed radiation increases, as well as Θ_c decreases limiting collimator capture angle and, hence, efficiency.

To overcome these limitation imposed by a polycapillary optics collimating device of novel type [14-20] should be considered. This apparatus consists of an array of straight elongated channels directed to a focal point, so main part of collected radiation passes through them directly, without reflections. To date the realizations of such multi-channel devices were performed via standard lithographic techniques and deep reactive ion etching (DRIE) from Si [17-18] and Ge [19]. Herewith its lateral focal spot size (governing the resolution) was defined mainly by channel width and for Si apparatus [18] nearly energy-independent value of ~1.7 μm was achieved for the energy range 4.5-10 keV. Based on the same working principle and arranged the similar way, multi-channel confocal collimator (but with wider channels of 1-2 mm) can be employed in radionuclide diagnostics [20], possessing all abovementioned advantages. The report will discuss the features of functioning for these multichannel collimators of a new type, the advantages of their use and possible methods of creation.

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