Nuclear Instruments and Methods in Physics Research B 355 (2015) 293–296

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

X-ray radiation channeling in micro-channel plates: Spectroscopy with a synchrotron radiation beam

M.I. Mazuritskiy [a,*], S.B. Dabagov [b,c,d], A. Marcelli [b,e], K. Dziedzic-Kocurek [f], A.M. Lerer [a]

[a] Physics Department, Southern Federal University, Rostov-on-Don, Russia
[b] INFN Laboratori Nazionali di Frascati, 00044 Frascati, Italy
[c] RAS P.N. Lebedev Physical Institute, Leninsky pr. 53, 119991 Moscow, Russia
[d] National Research Nuclear University MEPhI, Kashirskoe shosse 31, 115409 Moscow, Russia
[e] RICMASS, Rome International Center for Materials Science Superstripes, via dei Sabelli 119A, 00185 Rome, Italy
[f] M. Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland

ARTICLE INFO

Article history:
Received 9 November 2014
Received in revised form 2 February 2015
Accepted 9 February 2015
Available online 5 March 2015

Keywords:
X-ray capillary waveguides
X-ray scattering
X-ray fluorescence channeling
X-ray spectroscopy
X-ray angular distribution

ABSTRACT

We present here the angular distribution of the radiation propagated inside MultiChannel Plates with micro-channels of ~3 μm diameter. The spectra collected at the exit of the channels present a complex distribution with contributions that can be assigned to the fluorescence radiation, originated from the excitation of the micro-channel walls. For radiation above the absorption edge, when the monochromatic energy in the region of the Si L-edge hits the micro-channel walls with a grazing angle $\theta \geqslant 5°$, or at the O K-edge when $\theta \geqslant 2°$ a fluorescence radiation is detected. Additional information associated to the fine structures of the XANES spectra detected at the exit of MCPs are also presented and discussed.

1. Introduction

The propagation of X-rays through a capillary system is a complex phenomenon that depends on the optical layout, the capillary parameters, the radiation properties, etc., whose knowledge is still a matter of debate. Actually, because the technology based on the capillary optical elements may, in principle, deliver a high flux density within a sub-micrometer spot, its understanding is mandatory to develop novel optical systems. Such systems would be capable to increase the radiation density and eventually to shape X-ray beams without the use of the long optical focusing devices. Channeling based devices may indeed guide and shape an X-ray beam in order to control the intensity, the spot size, the divergence and the homogeneity [1]. At present, studies of X-ray transmission through the micro-capillary structures, aimed at the R&D of dedicated optics working in the "water window" spectral region are limited. Being large and effective low weight optics, the micro-channel plates (MCPs) have been already used in case of the low power instruments for different scientific applications and techniques development [2]. Their characteristics make them suitable for many other applications, for example, such as focusing of the excited radiation. Moreover, their broadband characteristics make them applicable for micro beam X-ray fluorescence, for scanning microscopy or as filters [3].

Our previous studies [4–7] were devoted to the characterization of the propagation of radiation hitting the walls inside a hollow channel, when the excited fluorescence radiation can be transported by MCP polycapillary structures. Underneath, we show and discuss X-ray fluorescence synchrotron radiation spectra and the angular distribution of the intensity collected at the exit of MCPs. In particular, we analyze the low energy inelastic scattering experiments in the region of the anomalous dispersion at the Si L-edge and at the O K-edge.

2. Experimental set-up

The experimental layout shown in Fig. 1, describes the optical configuration available at the Polarimeter end-station of the UE52_SGM at the BESSY II synchrotron radiation facility. We used for the experiments ~0.3 mm thick MCPs with a hexagonal shape in the transverse cross-section, made with a lead silicate ($PbSiO_3$) composition, manufactured by the *BASPIK* [8]. Such compact optical devices contain regular holey channels with a diameter of 3.4 μm and with a pitch size of 4.2 μm. As shown in Fig. 1, the top surface of the MCP was illuminated by a monochromatic beam with a divergence <5 mrad. The radiation propagating inside the

* Corresponding author.

http://dx.doi.org/10.1016/j.nimb.2015.02.033
0168-583X/

micro-channels was collected by a single photodiode placed on the other side of the polycapillary structure.

Data have been collected at the Polarimeter with a beam size of 60 μm (hor./vert.) while the diaphragm of the photodiode's window has a diameter of 0.2 mm. The distance between the sample and the window of the photodiode is 145 mm. Looking at the layout of Fig. 1, the angle corresponding to the "zero" position of the polarimeter has been identified, without the MCP, as the direction, for which the primary beam hits the photodiode.

In the transmission geometry, the grazing angle θ between the incident primary beam and MCP microchannel walls was set while rotating the device around the "θ" axis (see Fig. 1). It was assumed that microchannel walls were oriented parallel to the normal of the MCP surface. Inserting the MCP along the radiation path, the "normal" direction to the MCP surface corresponds to the relative "zero" position of the measured angular scans. After setting the grazing angle θ of the polarimeter, scanning the detector position the angular distributions of the radiation behind the MCP were collected.

The angular distribution of the radiation, i.e., the intensity vs. angle at the exit of a MCP, in the total external reflection condition for different grazing angles of the incident beam has been investigated. Performing the angular scan of the photodiode position sets at the exit of the MCP (angles "ϕ" of the photodiode), we can identify the positions where the maximum intensity of emitted radiation occurs. For any fixed value of the θ-angle between the incident monochromatic radiation and MCP microchannel walls, the intensity distribution between two maxima $\phi = \pm\theta$ in the angular range $-\theta \leqslant \phi \leqslant \theta$ has been measured. Finally, the spectra for different θ angles and for different positions of the photodiode: $\phi_1, \phi_2, \phi_3, \ldots, \phi_n$, have been collected.

3. Results and discussion

The angular distributions of the radiation intensity at the exit of a MCP sample, at different θ-angles and different photodiode positions (ϕ-angles) have been collected in the transmission mode. The multiple reflection radiation distributions and corresponding maxima in the spectra shown by dash lines in Fig. 1, are the main characteristics of the measured angular distributions. At the Si L-edge energy the critical angle θ_c is ~8°. In Fig. 2 we compare three angular scans performed at different energies just below and above the energy of the absorption edge. The recorded distributions have shown that the spectra taken at the grazing angle $\theta = 3°$ are almost symmetric with two intense specular maxima due to the reflection contributions of the primary radiation: A ($\phi = -3°$) and A′ ($\phi = 3°$). At the Polarimeter station we had the possibility to set the position of the photodiode independently of the two maxima. In Fig. 3 we compare energy spectra in the region of the Si L-edge collected at the grazing angle of $\theta = 3°$ at the MCP exit for $\phi = -3°$ and $\phi = 3°$. The observed fine structures of both spectra resemble the fine structure of the reflection spectrum of this lead silicate and of MCPs previously measured and published [3]. It should be underlined, that the fine structures of the spectra measured at the output of a MCP sample are basically similar to the characteristics of a simple reflection spectrum.

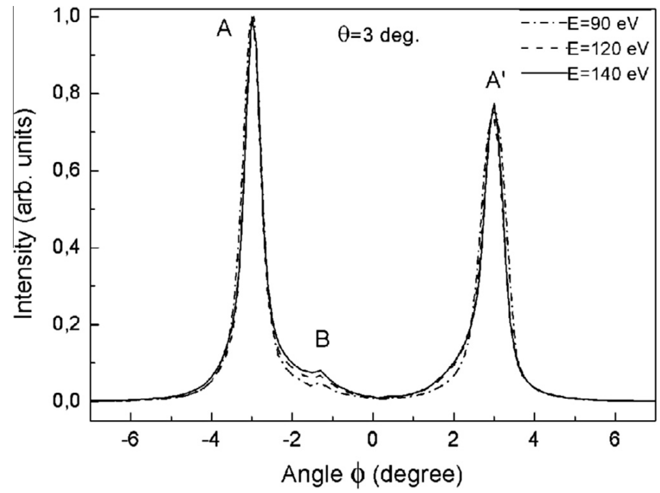

Fig. 2. Angular resolved spectra measured at the grazing angle of $\theta = 3°$ (see layout in Fig. 1) for different values of the incident radiation below and above the Si L-edge.

The spectra shown in Fig. 4 are slightly more complex and asymmetric. They reveal two maxima at the positions A ($\phi = -5°$) and A′ ($\phi = 5°$) corresponding to defined photodiode positions and due to multiple reflections of the incident radiation at the grazing angle of $\theta = 5°$. These maxima have the same nature, i.e., multiple reflected radiation, of the peak observed at the grazing angle of $\theta = 3°$ in Fig. 2. At the same time, Fig. 4 shows other structures observed in both spectra, such as those marked by positions B, C and D. Although being similar, they give different contributions observed in the spectra of Fig. 2.

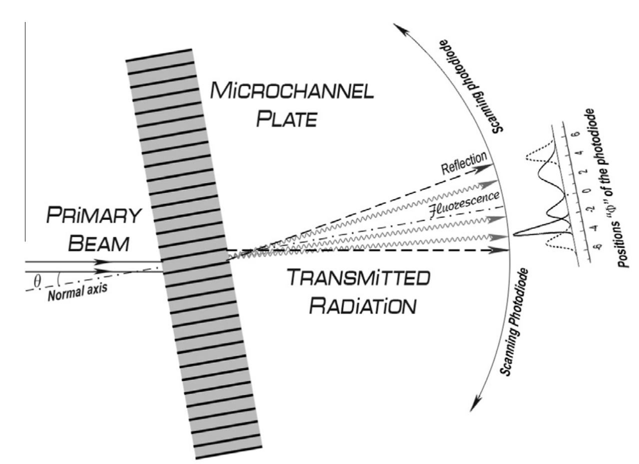

Fig. 1. Layout of the transmission experiments for a MCP installed at the Polarimeter station at BESSY II.

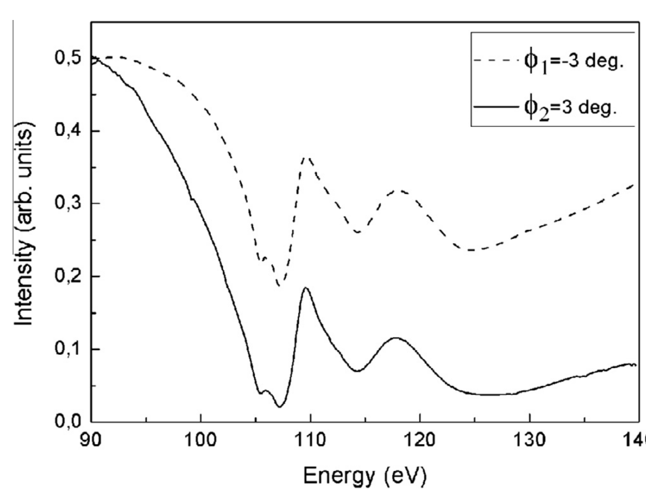

Fig. 3. Reflection spectra vs. energy measured for two symmetric angular positions of the photodiode.