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X-ray Fluorescence Two-dimensional Microanalysis at the VEPP-3 Storage Ring: Aplications in Environmental Science

I.P. Dolbnya and K.V. Zolotarev
Budker Institute of Nuclear Physics, 630090 Novosibirsk, Russia

Some experimental capabilities of the experimental station of X-ray transmission subtraction microscopy and microtomography with the using of the synchrotron radiation (SR) from the 2T wiggler-magnet installed at the VEPP-3 storage ring (2 GeV, 100 mA) (Novosibirsk, Russia) (Dolbnya et al. 1992) in com-bination with X-ray fluorescence (XRF) energy-dispersive registration analysis and fluorescence scanning microprobe technique are presented. The X-ray double-crystal sagittally focusing Si(111) monochromator was employed. The using photon energies range from 7 to 25 keV. The scintillation counters were usually in use as X-ray absorption detectors. We have also employed the ionization chamber filled with nitrogen at normal pressure as the monitoring detector. To register X-ray fluorescence quanta solid state Si(Li) (180 eV at the energy of 5.9 keV, 7 μm Be window in thickness) detector was used. Point-by-point scanning of an object across the properly formed pencil monochromatic beam is used for the X-ray imaging. X-ray transmission imaging enable us to visualize two-dimensional not only an absorption mapping but also the elemental distribution by means of XRF analysis.

There is special interest to study the distribution of elements over the single microparticles in biomedical and environmental aerosol samples. X-ray scanning transmission subtraction microscopy in combination with X-ray fluorescence energy-dispersive registration analysis and fluorescence microprobe technique have been expected to be a promising analytical tool for such investigations.

As a test sample to check the capability of the developed investigation technique, the filter fabricated from the material Whatman-41 was taken. The filter was chosen from the lot of similar filters served as a filters of atmospheric aerosols at the environmental monitoring station near the city Novosibirsk (the large industrial center). The filter under investigation had microparticles with typical mean size of ~7 μm ranging up to ~30 μm. Fig. 1a demonstrates the subtraction roentgenograph (80×80 image points, 8 μm scanning step in horizontal X-direction and 4 μm in vertical) of aerosol filter under study which was taken at Fe K-edge. The coordination cross made from two Mo wires was inserted on a sample as absolute coordinate marker over the image field. This Mo cross is also seen in Fig. 1a. The XRF spectra were taken at photon energies of excitation of 10 and 18.4 keV from the region of different microparticles shown in Figure. For estimation of absolute amount of iron in one particle the information about absorption jump of intensity at Fe K-edge was used from results of the X-ray subtraction imaging of this particle on energies just before and after K-edge. In table 1 the results of measurements and calculations are presented. The detection limit in these measurements is about 1 pikogram for iron.

Using insects as a convenient object for environment monitoring seems to be most promising. Due to the fact that their integuments are not smooth and there are a great deal of a pubescence on their bodies, insects accumulate very well various inclusions from the atmosphere. Moreover, due to their durable flights, sometimes remote migrations, the flying insects are able to give us some information on the state of the atmosphere over rather vast territories, which is very difficult to get by means of conventional control techniques. The available data show that in addition to the elements contained in their food and stored in their organisms, the flying insects can also store different kinds of aerosol particles, being a factor of pollution, in the integuments (Heliovaara et al. 1987).

In further detailed investigations, it seems to be

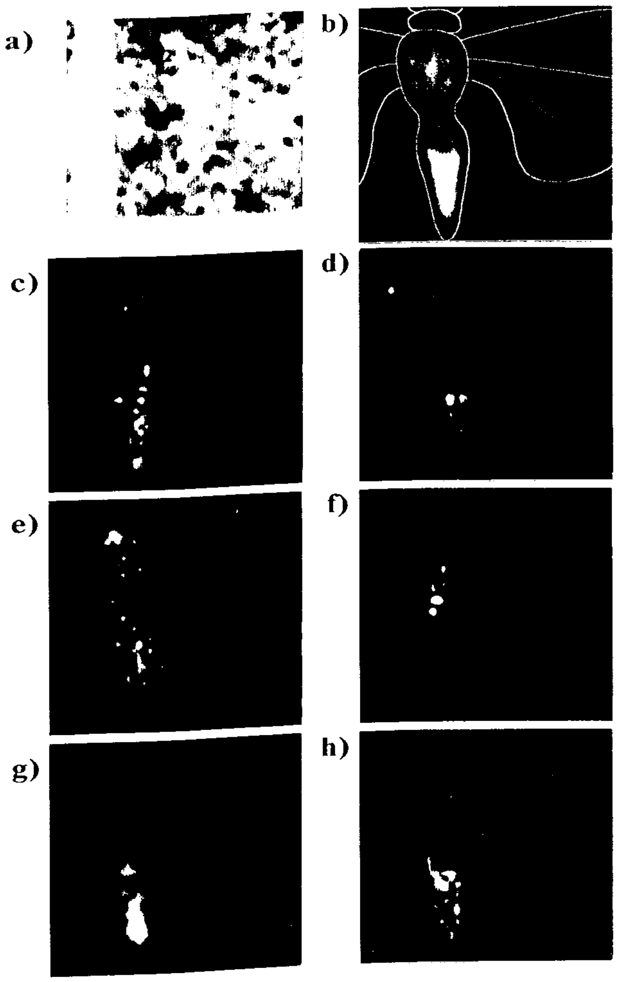

Fig. 1. (a)-subtraction roentgenograph of aerosol filter under study taken at Fe K-edge, 80×80 image points, 8 μm scanning step in horizontal and 4 μm step in vertical; the two-dimensional distribution of different elements under study over the meadow moth, the size of all images is 50 ×46 points, the image pixel is 200×250 μm^2, (b)-general view, the white contours are an art work, (c)-Ca, (d)-Fe, (e)-Ni, (f)-Cu,(g)-Zn,(h)-Br.

important to determine "marking" elements which can be used for reliable biological monitoring. The application of the scanning XRF elemental analysis allows one to determine the distribution of different elements in the body of an individual meadow moth. In this experiment, two moths were examined and the results of the study of one of them are shown in Fig. 1. The images were taken at the photon energy of 14.05 keV corresponding to the position just upper Br K-edge. Analysis of the obtained images has confirmed the hypothesis on the nonuniform distribution of elements in every moth. It is also seen that the major portion of the pollutant elements is concentrated in the body of a moth rather than on its wings. This circumstance permits us to conclude that it is feeding that is mainly responsible for the presence of pollutant elements in moth's bodies. The fraction of pollutant elements which accumulates on the wings from aerosol particles is insignificant.

Table 1. The results of microanalysis of aerosol particles (absolute amounts of elements are in pikograms (10^{-12}g)).

Particle	Ca	Ti	Fe	Cu	Zn
1	20.0	5.41	80.9	0.54	1.12
2	18.9	7.67	82.7	0.69	1.47
3	22.8	1.88	54.1	0.32	0.79
4	43.9	5.79	152.9	0.96	1.23
5	24.9	1.79	45.1	0.42	1.48

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