1.4.14. DEVELOPMENT OF X-RAY MICROSCOPES OF SUBMICRON RESOLUTION

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Currently, X-Ray radiography is of wide use to study the internal structure of various objects on the micron scale to detect defects in them. The best X-Ray microscopes (TOHKEN, XRADIA) have minimal focal spot of 0.1 – 0.2 microns and provide resolution on the level of 30 – 50 nm [1, 2]. They are mainly designed to inspect the various objects including electronic devices and biological objects and have a large size and high cost.

For laboratory research of the small objects and details of the micron and nanometer size, a small and low-cost X-Ray microscope has been developed on the base of dismountable (open type) tube operating in the range of 5 – 30 kV.

At present, an X-Ray measuring microscope (20 – 30 kV) has been developed and manufactured to inspect fuel elements for GT-MHR reactor [2] being in the form of spherical balls with the carbon containing layers of 30 – 150 um thickness. Enhanced edge contrast (fig. 1) due to the soft X-Ray refraction at the object boundaries gives the possibility to detect them with high accuracy in automatic mode. Relative error of the control is of 3 – 5%. The typical factor of geometric magnification in the microscope is 1,000 and its maximum value is 5000. Dismountable X-Ray tube with a pump assembly, an X-Ray detector and a high-precision coordinate table for the objects alignment are placed inside a shielding chamber, 400 × 500 × 800 mm of size.

The minimum focal spot of less then 0.3 microns (fig. 2) is provided by the electron-optical system, which consists of the tungsten cathode electron gun and two magnetic lenses. When lowering the accelerating voltage down to 10 kV, a focal spot of 0.1 microns can be obtained. The selected operating range of the tube voltage is determined by the characteristics of the used X-Ray detector. Accurate and focusing the electron beam on a target in the entire power range (0.1 – 5 W) and the accelerating voltage is provided by semiconductor detector and scanning system, which, in scanning electron beam on a target allows one to receive the X-Ray image of the target.

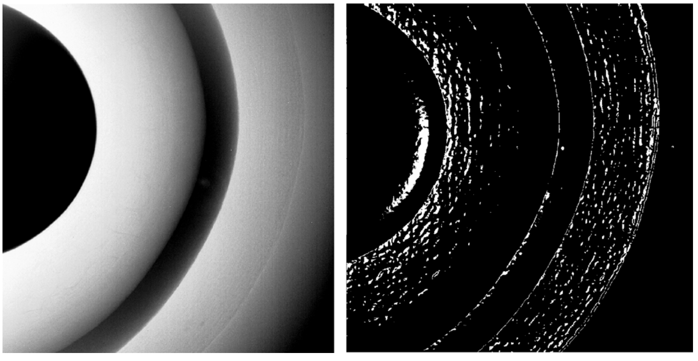

Fig. 1. X-Ray microscopic image of a nuclear fuel element, 500 um in diameter:
Left – Original image, Right – after binarization step in digital image processing

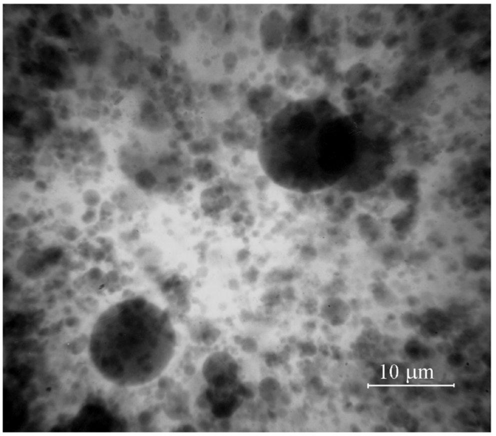

Fig. 2. X-Ray microscopic image of Zn particles embedded in 270 um thickness organic film. The edges of the particles have a refractive contrast which is reverse to the absorption contrast of volume area

In addition, a near focus X-Ray microscope (3 – 30 kV) has been developed and tested with a minimum focal spot 10 – 20 nm, to study biological, polymeric and composite materials with nano-sized particles [3]. This microscope is a hybrid because it can operate in the mode of SEM and TEM. The design allows the microscope to operate with the AFM and X-Ray fluorescence detector.

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