TXRF spectrometer on base of the waveguide-resonator with specific design

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Abstract. This work presents original scheme of the X-ray total reflection spectrometer with the planar X-ray waveguide-resonator (PXWR) with arranged specimen inside of the flux of the waveguide-resonator. Experiment show this X-ray optical scheme gives more effective using the planar waveguide-resonator for purpose of TXRF.

X-ray fluorescence analysis in conditions of the exciting flux external total reflection (TXRF) is one of the effective methods for the material element diagnostics today [1].

The critical parameter of TXRF spectrometry is the radiation density of X-ray exciting beam owing to the beam influence is limited by the total reflection conditions. The enhancing of this parameter can be achieved by increasing of the radiation source power or by raising efficiency of exciting beam formers. Investigations show that the planar X-ray waveguide-resonator (PXWR) is the best device for X-ray beam formation with enhancing radiation density.

Figures 1 and 2 present schemes of the interference fields of X-ray standing waves in extended planar slit clearances with great and nanosize width, accordingly [2].

The total external reflection phenomenon of quasimonochromatic X-ray beam featured by $\lambda_0$ wavelength, $\Delta\lambda$ monochromatic degree and $L = \lambda_0^2/\Delta\lambda$ coherence length on the material interface is characterized by the interference field of X-ray standing wave appearance. In conditions of two reflectors placing on same distance of them and forming the planar extended slit clearance it is possible two different situations, in principle. In case of wide slit clearance X-Ray flux will propagate in corresponding with mechanism of the multiple total reflections (figure 1).

![Figure 1. The mechanism of multiple total reflections.](image)

When width of slit clearance will be smaller as half of coherence length local interference areas reach mutual superposition and arise the uniform interference field of X-ray standing wave. This case is corresponding to the mechanism of X-ray flux waveguide-resonance propagation through slit clearance almost without attenuation (figure 2).
Figure 2. The mechanism of X-ray flux waveguide-resonance propagation through slit clearance almost without attenuation.

PXWR forms X-ray beam with small angular divergence and great radiation density enhancing this parameters for beams formed by any others devices on three orders. At the same time, in our TXRF spectrometer we apply the waveguide-resonator with specific design.

Its construction allows to introduce studied into waveguide-resonance flux propagating in PXWR slit clearance. Such geometry of the sample positioning presents possibility of maximum fluorescence excitation achievement.

Figure 3 demonstrates X-ray optical schemes of TXRF spectrometer built on base of the conventional design (a) and cell of our TXRF spectrometer fabricated on base of PXWR with specific construction provided a studied sample introduction into its waveguide-resonance slit clearance (b).

Figure 3. Comparison of X-ray optic scheme of conventional TXRF (a) and with PXWR (b).

X-ray fluorescence excitation in conditions of PXWR specific design application has same advantages in comparison with conventional approach to the excitation:

1. The excitation takes place in the waveguide-resonance flux which provides maximum of the secondary fluorescence yield;
2. There is opportunity for studied target transportation in the flux cross-section;
3. The excitation conditions do not depend from the studied sample aggregate state (solid, liquid, powdery states);
4. PXWR construction allows to change experimental conditions in the measurement process.

The experimental advantages of our TXRF spectrometer (TXRF-PXWR) were confirmed by investigation of dry liquid residues, thin films and coatings, filter object, solid materials, powder-like samples, tissues, blood samples, foodstuffs, mineralogical thin sections and so on.

The analytical characteristics of new investigating setup were studied in conditions of application two X-ray sources BSW27 (Ag) and BSW27 (Mo) in regime $U = 40$ kV, $J = 4$ mA. The measurements were executed using standard specimens prepared on base of dry liquid residues of the elements of middle group [3]. Experiments show that our TXRF-PXWR spectrometer is characterized by pollutions detection limits corresponding to analytical interval $(1–5)10^{-13}$ g. At the same time it is known the conventional TXRF spectrometer are limited by the detection limits near $(1–3)10^{-12}$ g [1].

Advantages of TXRF study of object inside of the waveguide-resonance flux can be demonstrated on base of results obtained for the Ta coating ($t = 10$ nm) on glassceramic substrate. Figures 4 shows
TXRF spectra collected in conditions of pure surface geometry (a) and in geometry of the sample introduction into the waveguide-resonance channel on depth $l = 20$ nm (b).

![TXRF spectra diagram]

**Figure 4.** TXRF spectra collected in conditions of pure surface geometry (a) and in geometry of the sample introduction into the waveguide-resonance channel (b).

In the first case (Figure 4(a)) TXRF spectrum contains lines of the coating only. Other spectrum (Figure 4(b)) consist of Ta lines and lines of atoms reflected the substrate composition. Intensity yield of Ta lines are equivalent on the both spectra.

Appearing of lines correlated to substrate atoms presents opportunities to study element composition of layers which is characterized by deep bedding. The aggregate possibilities and set of advantages appearing at using of PXWR with specific construction for practice TXRF measurements application allow to announce about creation of new experimental procedure in frame of TXRF material study.

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**References**

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