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Research Article

Research into Excited 0.6–6.0 keV Energy Levels in the Cathode Solid Medium of Glow Discharge by X-ray Spectra Emission

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Abstract

The results of X-ray spectra registration are presented. The X-ray spectra were registered in film using a curved mica crystal X-ray spectrometer. The experiments were carried out using a high-current glow discharge device, which consisted of a water-cooling chamber, water-cooling cathode and anode units. X-ray emission was detected through a diagnostic window placed above the cathode. The discharge was performed in H_2, D_2, Ar, Kr and Xe at pressure ranging from 1 to 5 Torr, using cathode samples made of Al, Sc, V, Ti, Ni, Zr, Nb, Mo, Pd, Ta, and W. Current ranged from 50 up to 300 mA and discharge voltage was 1500–4300 V. A pulse-periodical power supply was used to generate the glow discharge. The X-ray spectrum were registered both as bands of the continuum with energies ranging 0.6–10.0 keV and as spots resulting from the emission of series of high-density monoenergetic X-ray beams (with energies of 0.6–10.0 keV) characterized by small angular divergence. The X-ray spectra were repeatedly recorded during the Glow Discharge operation and after the Glow Discharge current switch off (for up to 20 h afterwards). The obtained results were direct experimental evidence of excited long living energy levels with the energy of 0.6–6.0 keV in the solid cathode sample.
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Keywords: Cathode, Glow discharge, X-ray spectra

1. Introduction

Experimental detection of excess heat nuclear reaction products in the high-current glow discharge cathodes prove that there exist certain conditions and mechanisms that lead to the initiation of Low Energy Nuclear Reactions (LENR) in the condensed medium of the solid cathode. Theoretical estimation shows that a nuclear reaction in solid (for 10^{27} atom/m^3) requires of the production of the excited states with the excitation energy of 1–2 keV. Such excited energy levels can be produced by the mechanism of converting the initial energy of the ions plasma flux, which have the energy

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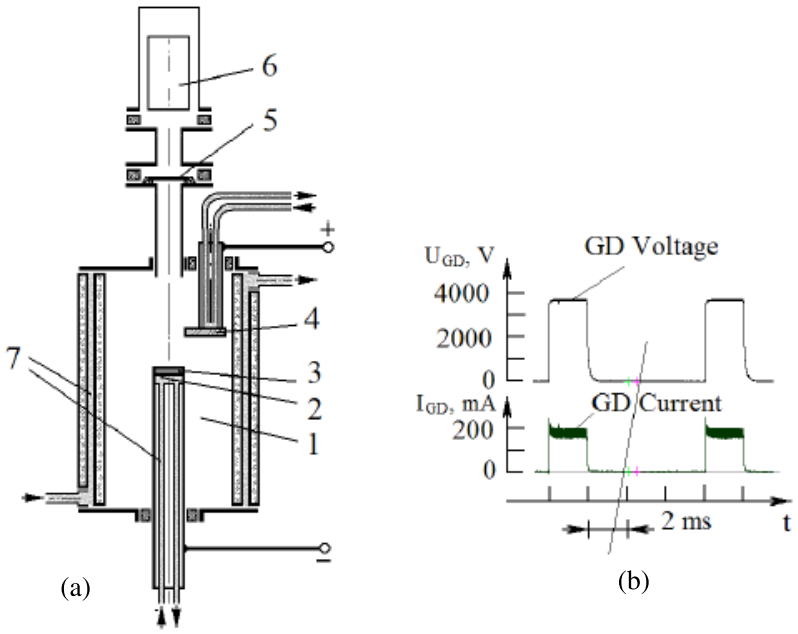

Figure 1. Schematic representation of the experiment. (a) Glow discharge device, 1– discharge chamber, 2– cathode holder, 3– cathode sample, 4– anode, 5– Be foil screens, 6– X-ray detectors different kind (pinhole, TLD detectors, scintillator- photomultiplier, spectrometer), objective, 7 –cooling water; (b) Glow discharge voltage and current oscillograms.

0.5–2.0 keV, into the high energetic (0.6–10.0 keV) excitation of a nuclear-electronic solid state system. This should occur in the solid such as a cathode when it is bombarded by the discharge plasma ions. The deexitation occurs by X-ray emission. An X-ray emission experiment was made to elucidate the LENR triggering process.

2. The X-ray Emission Spectra Detection

2.1. Glow discharge device

The measurements were carried out using the Glow Discharge device [1] consisting of a water-cooled vacuum chamber, the cathode and the anode assemblies (Fig. 1(a)). The cathode design allowed the placement of cathode samples made of various materials on a water-cooled surface. The experiments were carried out using a high-current glow discharge in D_2, H_2, He, Kr and Xe and the cathode samples being made of Al, Sc, V, Ti, Ni, Nb, Zr, Mo, Pd, Ta, and W.

In previous experiments [2,3] X-ray detection was carried out with X-ray pinhole, thermo-luminescent detectors, and scintillation detectors with photomultiplier. The energy spectrum of the X-ray emission was registered with the help of a curved mica crystal spectrometer. The Glow Discharge Device power supply is designed to feed the Glow Discharge with a pulse-periodic direct current and that allows us to generate the desired current forms of various pulse length and pulse period and to obtain the required current voltage and meaning (Fig. 1(b)). In the separate experiments the pulse duration varied from 0.1 up to 1.0 ms, and the period was from 0.3 up to 100 ms. The Glow Discharge conditions were as follows: current (amplitude) was from 30 up to 300 mA, voltage 1000–4300 V, and gas pressure in the discharge chamber was 3– 10 Torr.

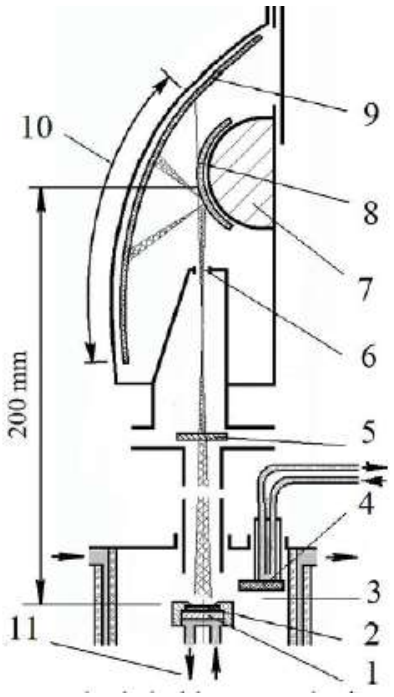

Figure 2. X-ray spectrometer 1–cathode holder, 2–cathode sample, 3–vacuum discharge chamber, 4–anode, 5–15 μm Be screen , 6– input slit of spectrometer, 7– crystals holder, 8–curved mica crystal, 9–X-ray film, 10–area of reflection spectra , 11–input and output cooling water.

2.2. X-ray spectrometer and procedure

The X-ray emission spectra were measured using the curved mica crystal X-ray spectrometer (the mica crystal holder is 50 mm diameter), with the spectrum being registered on X-ray film (Fig. 2). The film includes the refraction spectra, the direct X-ray lighting, and reflection spectra. The reflection spectra were used for data processing. The direct X-ray lighting limits the reflection spectra in the high energy area. The wavelength and the energy of the X-ray were determined according to the expression: $m\lambda = 2d \sin\theta$; $E_{X-ray} = 1.235/\lambda$.

Where m is the spectrum order, λ stands for the X-ray emission wavelength in nm, $2d$ is the constant of the mica crystal lattice ($2d$ = 2.0 nm), and θ represents the reflection angle. The exposure times were 1– 5 h. The X- ray negative films were scanned with resolution 4800 points in color modes. The spectra were repeatedly recorded during the glow discharge operation with the exposure time 1– 5 h and after the glow discharge current switch off (for up to 20 h afterwards). The spectra pattern includes bands, dark and light spots (consisting of multiple tiny dark and light dots) and separate dark and light small spots. The bands and spots were located in spectral areas specific for a given cathode material used. The registered energy of the X-ray emission bands and spots (the energetic position of the bands and spots within the spectrum) was dependent upon the cathode material used. The registered X-ray spectra in experiments were similar to characteristic X-ray spectra. The X-ray monoenergetic beams with small angular divergence were recorded as dark spots and in case of the emission beam high density they turned white solarization spots of the photoemulsion. The "solarization" is produced by a photographic negative in response to high energy density irradiation.

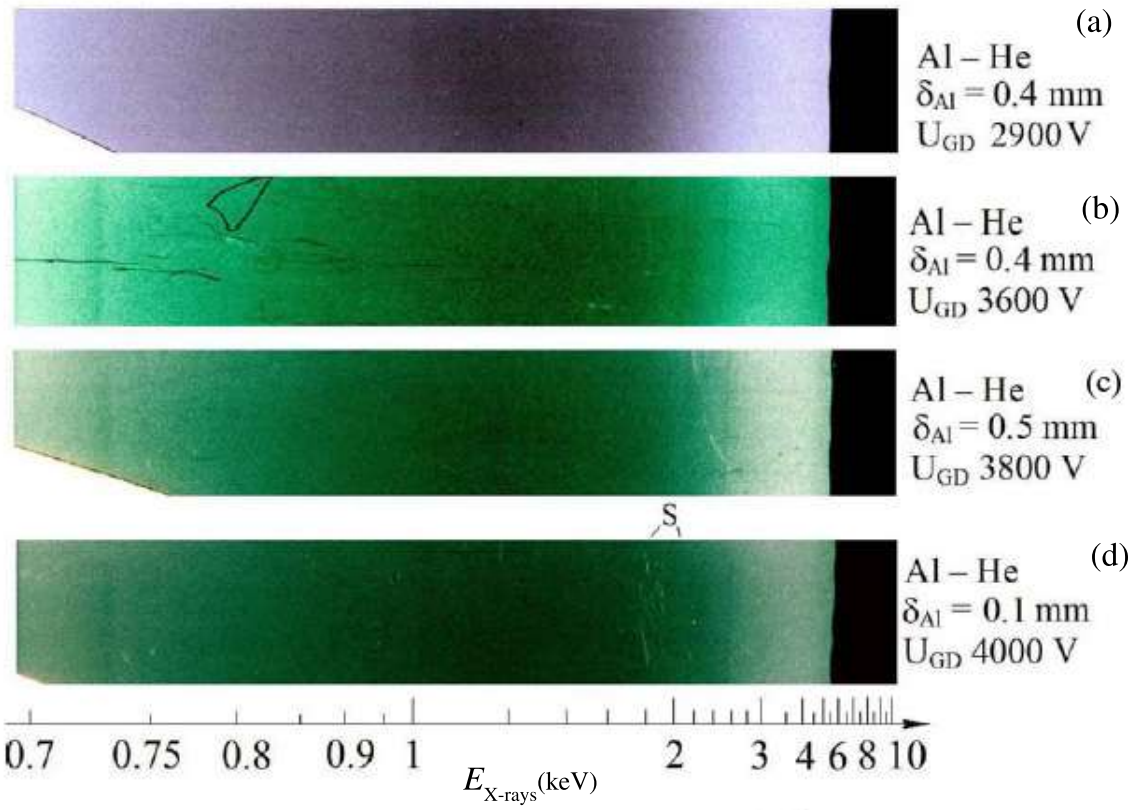

Figure 3. X-ray energy spectra from Al cathode different thickness (δ_{Al}). He discharge. U_{GD} is Glow Discharge voltage. S – white solarization spots of photoemulsion from X-ray monoenergetic beams with small angular divergence.

2.3. X-ray spectra registration in the continuum modes for different cathode materials and gases during the glow discharge operation

An energy area of X– ray spectra in the continuum modes is 0.6– 6.0 keV (may be up to 10 keV). The maximum of specific X-ray emission intensity reside in 1–2 keV energy area for different cathode materials and gases.

2.4. X-ray energy spectra in the spot modes for different cathode materials and gases during the glow discharge operation

The X-ray monoenergetic beams with small angular divergence were recorded as dark spots and in case of the emission beam high density they turned white solarization of the photoemulsion. The beams were recorded as dark spots and in case of the emission beam high density they turned white (solarization of the photoemulsion). The “solarization” is produced by a photographic negative in response to high energy density irradiation.

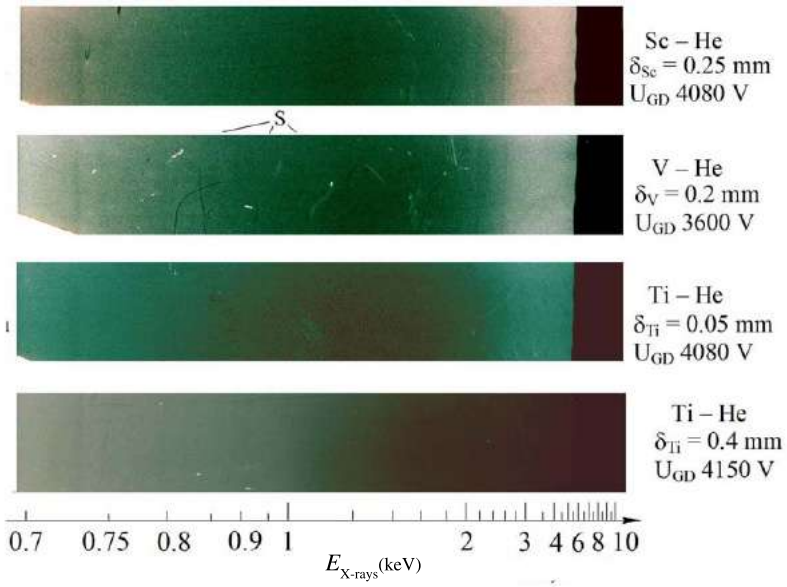

Figure 4. Figure 4. X-ray energy spectra from Sc, V, and Ti cathodes different thickness. He discharge. U_{GD} is Glow Discharge voltage. S – white solarization spots of photoemulsion from from X-ray monoenergetic beams with small angular divergence.

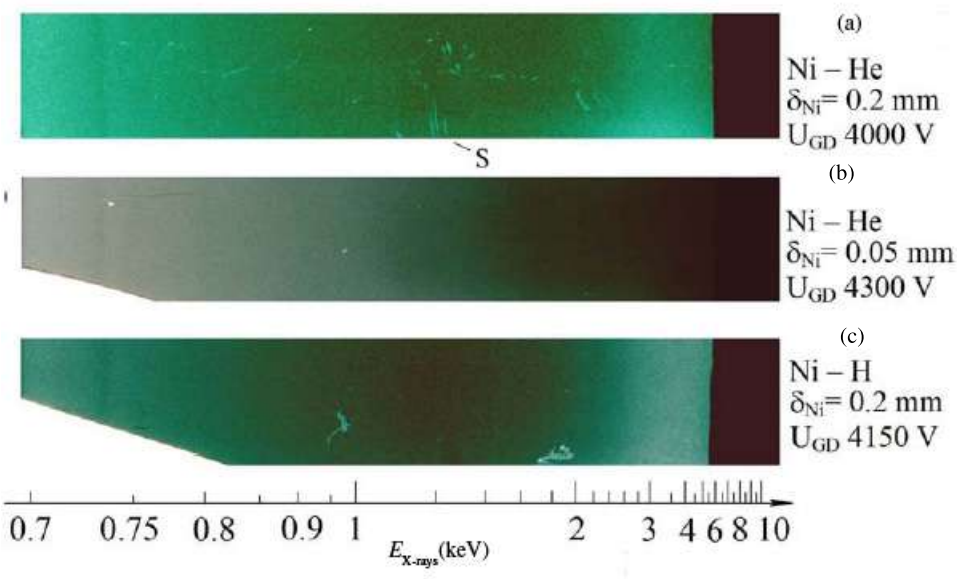

Figure 5. X-ray energy spectra from Ni cathodes different thickness. He and H discharge. U_{GD} is Glow Discharge voltage. S–white solarization spots of photoemulsion from X-ray monoenergetic beams with small angular divergence.

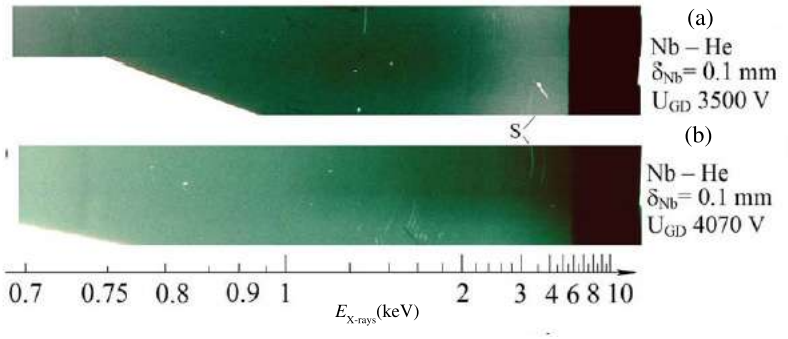

Figure 6. X-ray energy spectra from Nb cathode different thickness. He discharge. U_{GD} is Glow Discharge voltage. S – white solarization spots of photoemulsion from X-ray monoenergetic beams with small angular divergence.

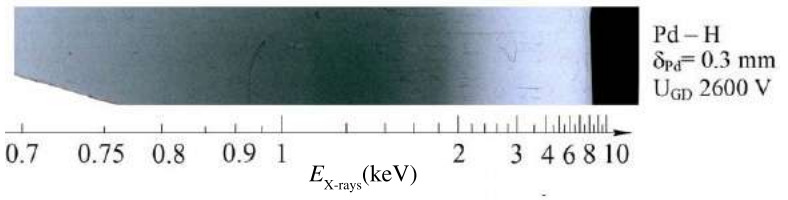

Figure 7. X-ray energy spectra from Pd cathode B H_2 discharge.

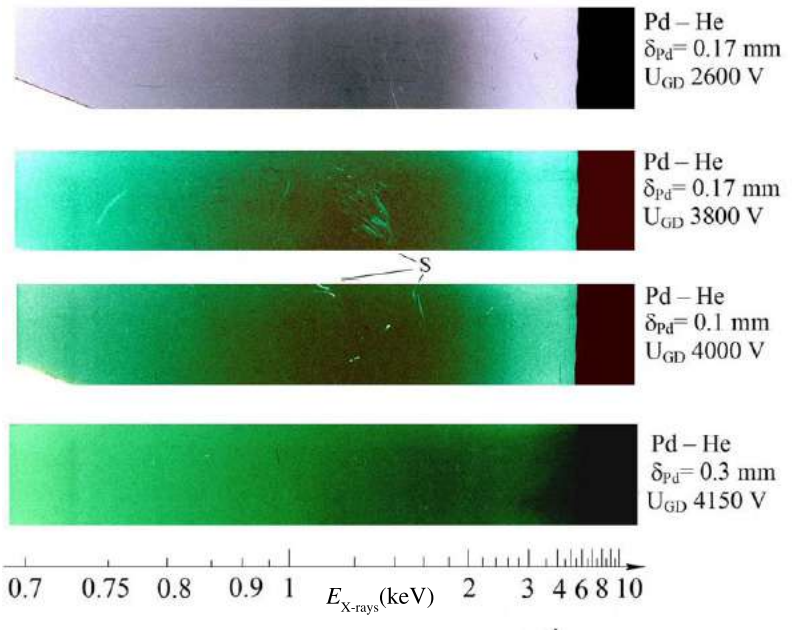

Figure 8. X-ray energy spectra from Pd cathode different thickness δ_{Pd}. He discharge. U_{GD} is Glow Discharge voltage. S – white solarization spots of photoemulsion from X-ray monoenergetic beams with small angular divergence.

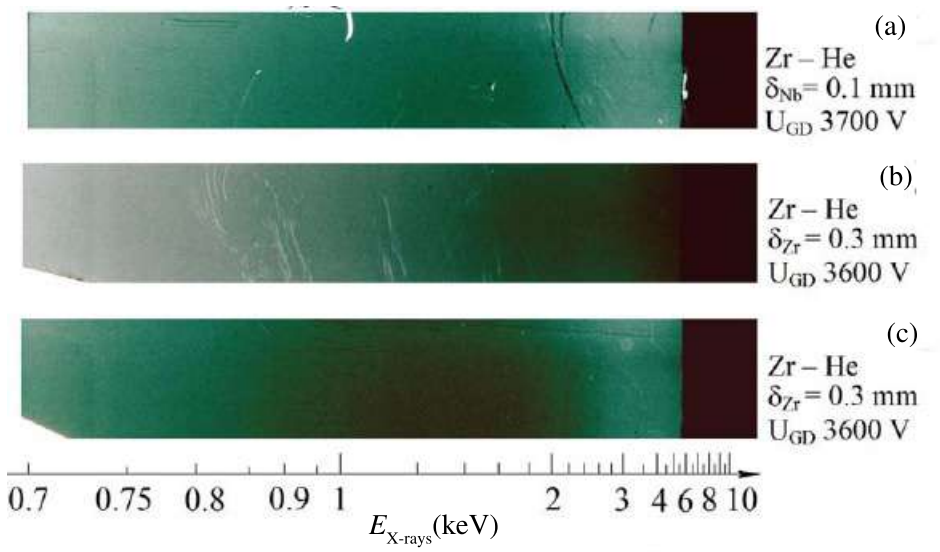

Figure 9. X-ray energy spectra from Zr cathode different thickness δ_{Pd}. He discharge. U_{GD} is Glow Discharge voltage. S–white solarization spots of photoemulsion from X-ray monoenergetic beams with small angular divergence.

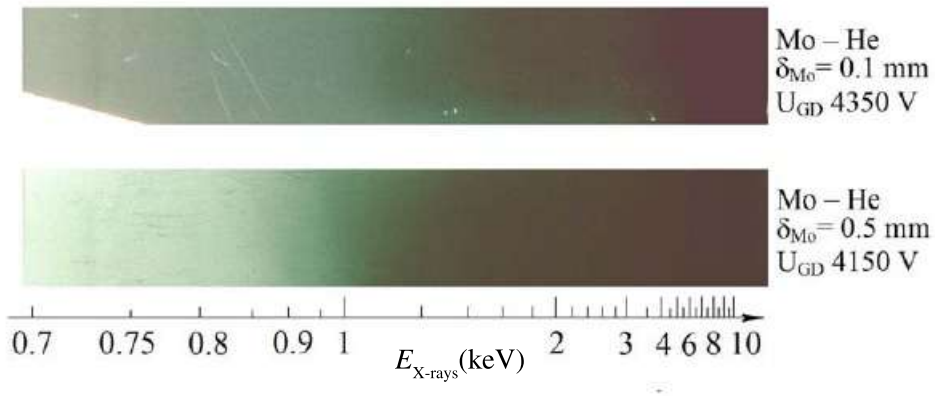

Figure 10. X-ray energy spectra from Mo cathode different thickness δ_{Mo}. He discharge. U_{GD} is Glow Discharge voltage. S – white solarization spots of photoemulsion from X-ray monoenergetic beams with small angular divergence.

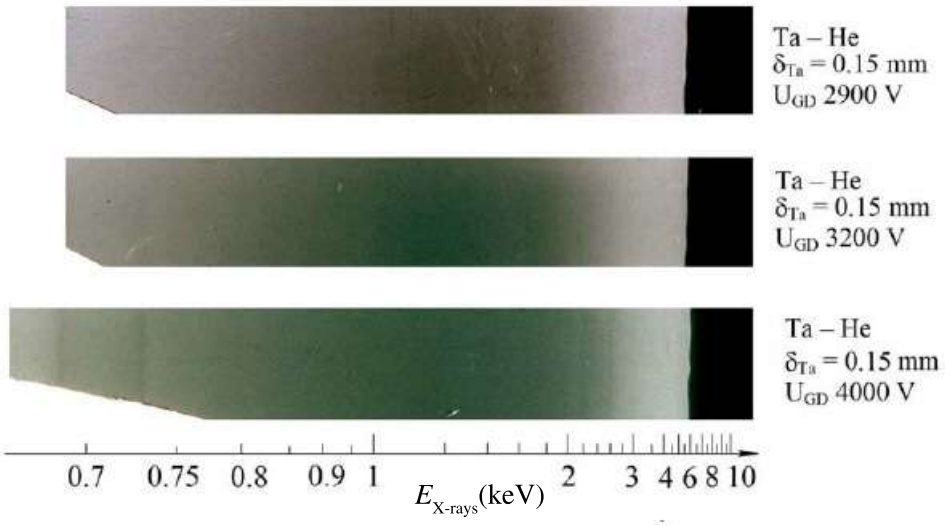

Figure 11. X-ray energy spectra from Ta cathode different thickness δ_{Ta}. He discharge. U_{GD} is Glow Discharge voltage.

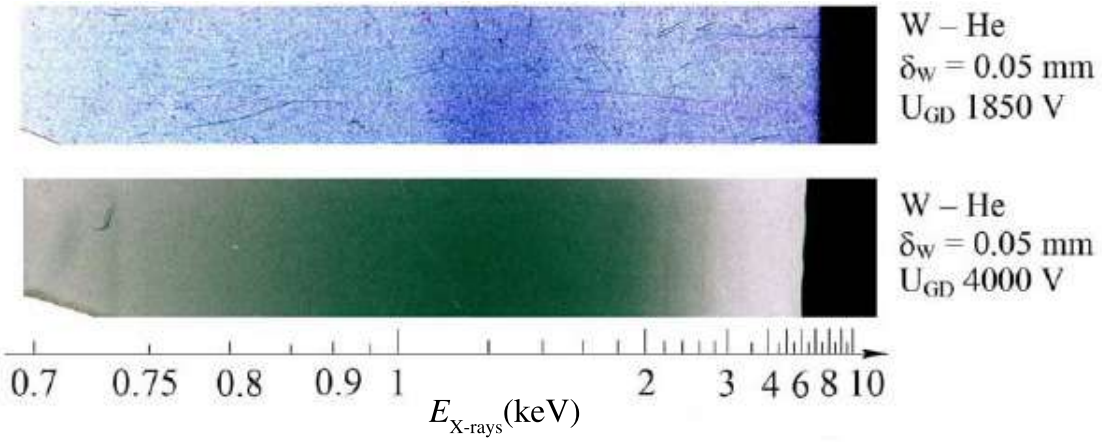

Figure 12. X-ray energy spectra from Mo cathode different thickness δ_{W}. He discharge. U_{GD} is Glow Discharge voltage.

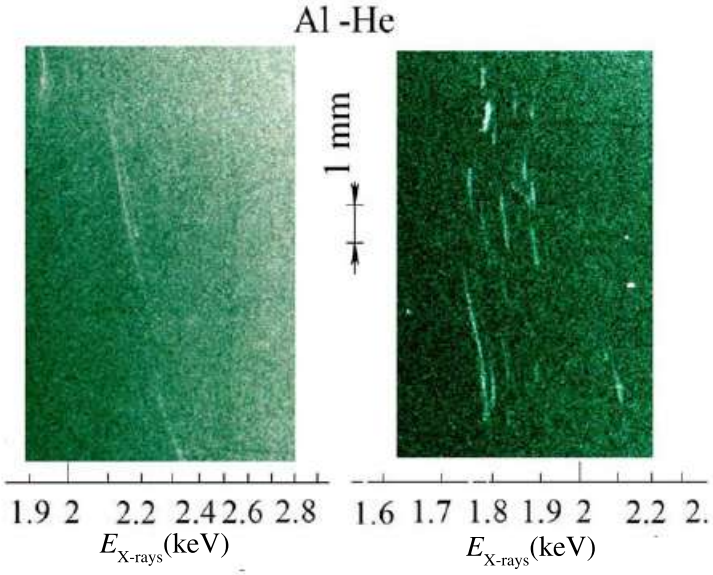

Figure 13. X-ray energy spectra in the spot modes for Al cathode, He discharge.

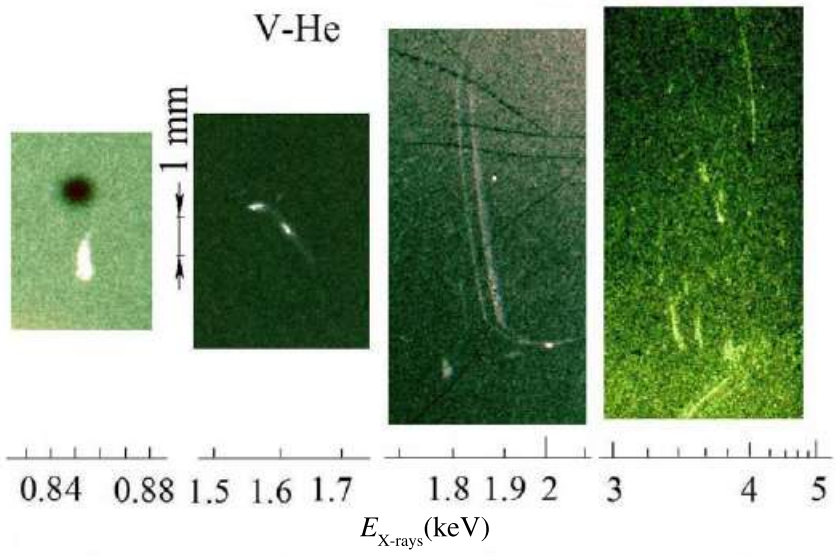

Figure 14. X-ray energy spectra in the spot modes for V cathode, He discharge.

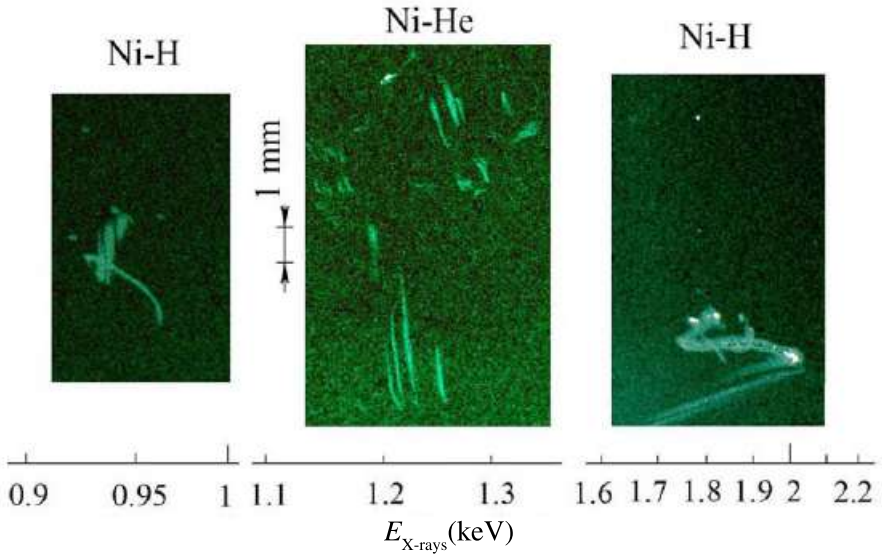

Figure 15. X-ray energy spectra in the spot modes for Ni cathode, H and He discharge.

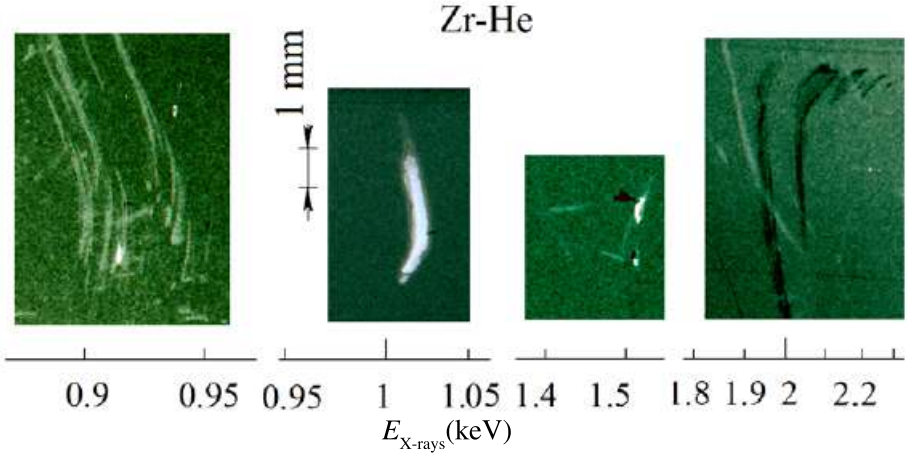

Figure 16. X-ray energy spectra in the spot modes for Zr cathode, He discharge.

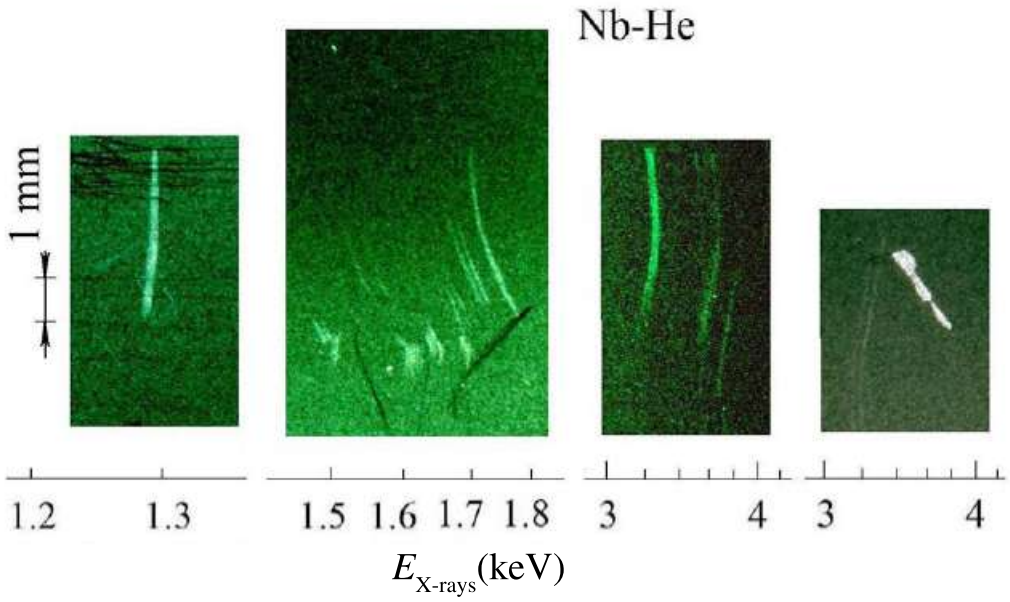

Figure 17. X-ray energy spectra in the spot modes for Nb cathode, He discharge.

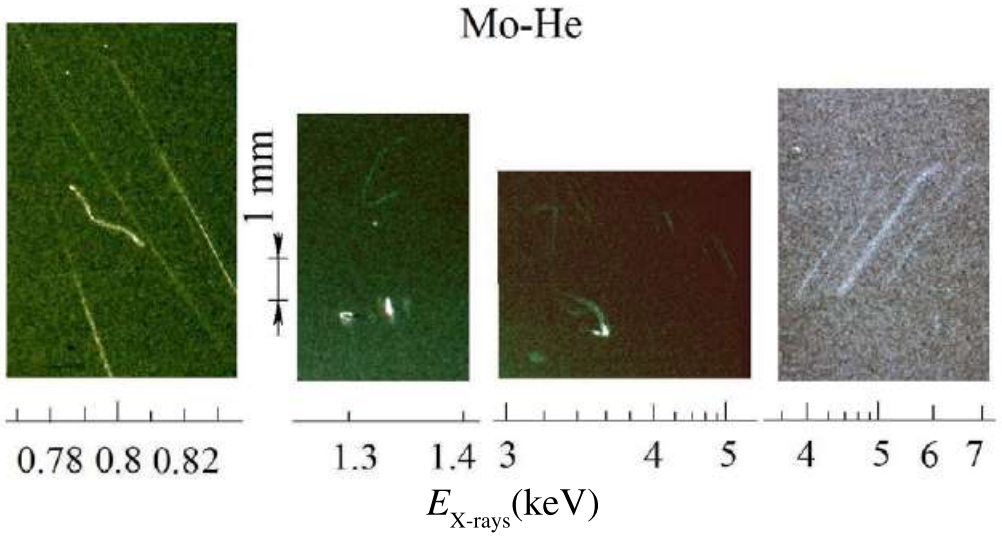

Figure 18. X-ray energy spectra in the spot modes for Mo cathode, He discharge.

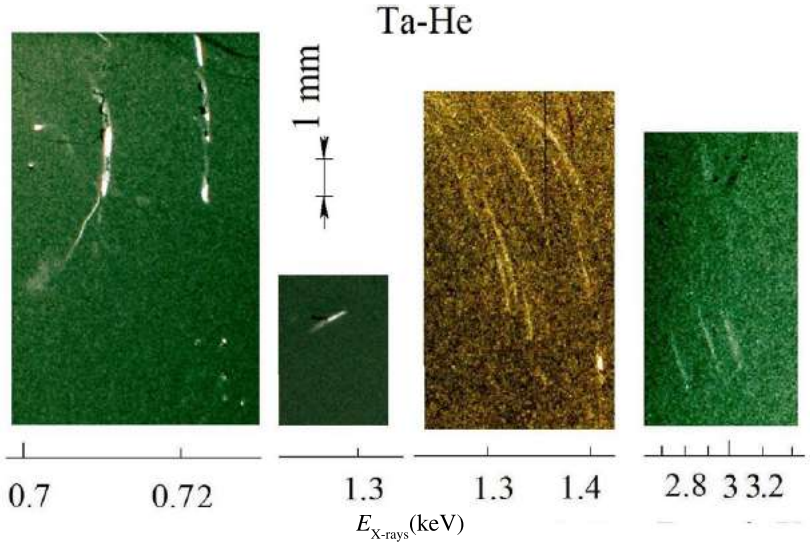

Figure 19. X-ray energy spectra in the spot modes for Ta cathode, He discharge.

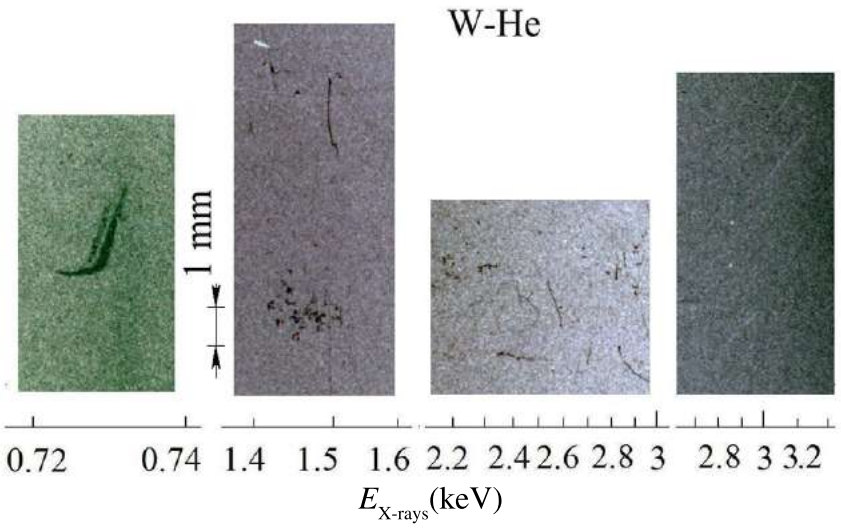

Figure 20. X-ray energy spectra in the spot modes for W cathode, He discharge.

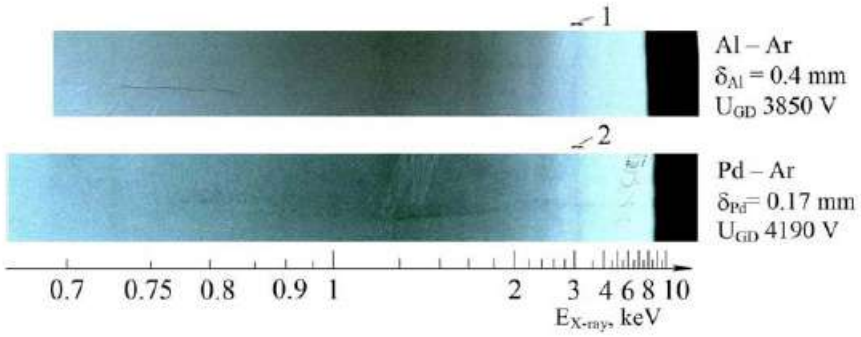

Figure 21. X-ray energy spectra in the band modes. 1,2 – energy is 3.19 keV, K–M_3 transition for Ar.

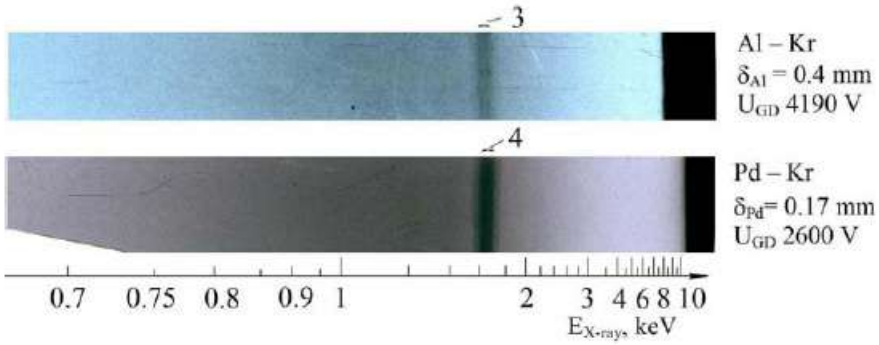

Figure 22. X-ray energy spectra in the band modes. 3,4 – energy is 1.65 keV, L3-M1 transition for Kr.

2.5. X-ray energy spectra in the band modes for different cathode materials and gases during the glow discharge operation

It was assumed that the diffusion component of the X-ray emission was registered on the spectrum as a series of bands. The X-ray emission bands energy correlated with K–L and L–N X-ray transitions. X-ray spectra include bands: K–M_3 X-ray transitions with 3.19 keV energy for Ar (discharge in Ar), L_3– M_1 (1.65 keV) for Kr (discharge in Kr), L_1– N_3 (2.503 keV) for Zr (discharge in He), L_2– M_4 (2.395 keV) and L_2– N_2 (2.623 keV) for Mo (discharge in He). X-rays emit from the solid cathode medium.

2.6. X-ray Energy spectra in the spots and bands modes for different cathode materials after the glow discharge switch off

X-ray energy spectra were registered in the black spots and bands modes. An energy area of X-ray spectra were determined the cathode materials.

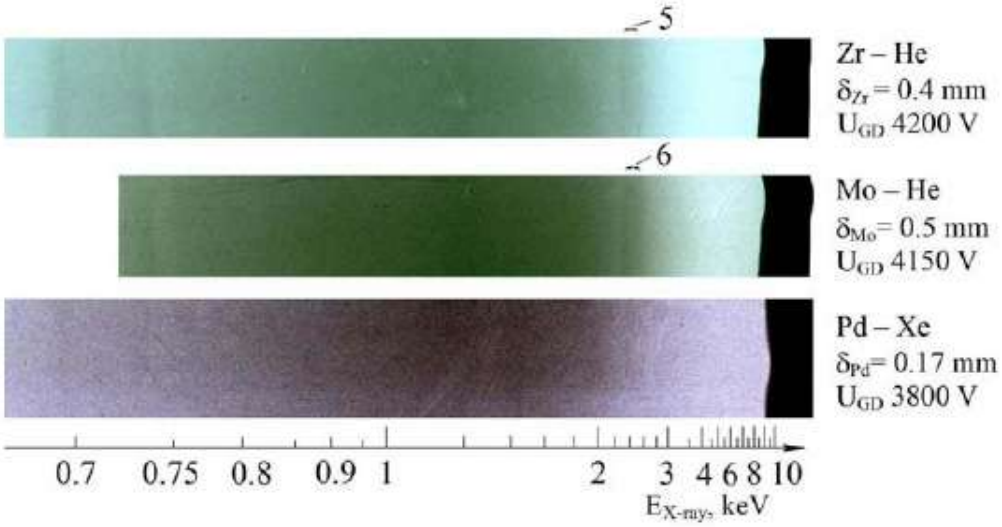

Figure 23. X-ray energy spectra in the band modes. 5 – energy is 2.503 keV, L1-N3 transition for Zr, 6 – energy is 2,395 keV, L2- M4 transition for Mo.

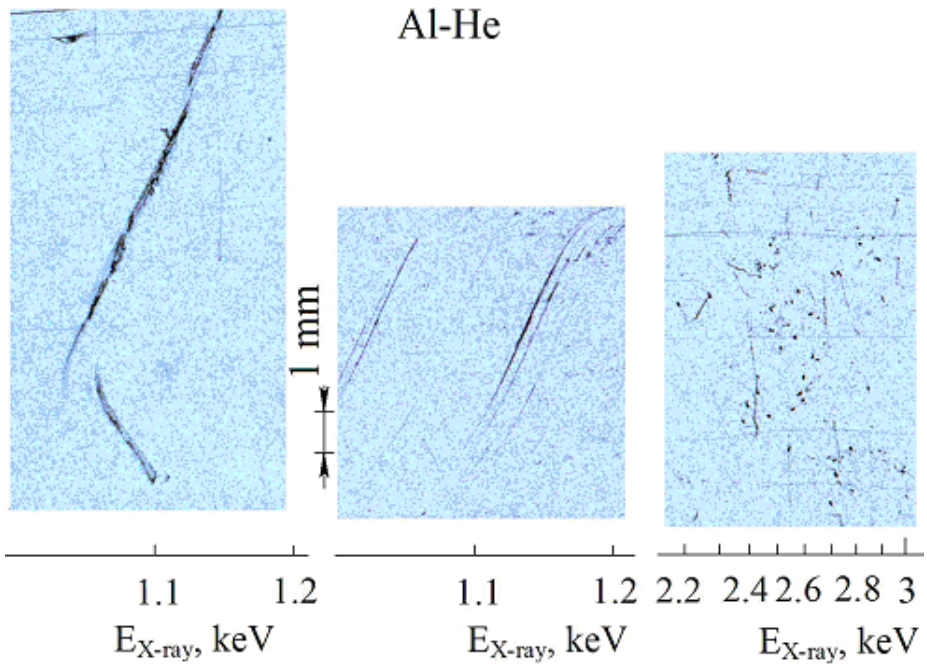

Figure 24. X-ray energy spectra in the spots and bands modes for Al cathode after the He glow discharge switch off. Exposition time is 20 h.

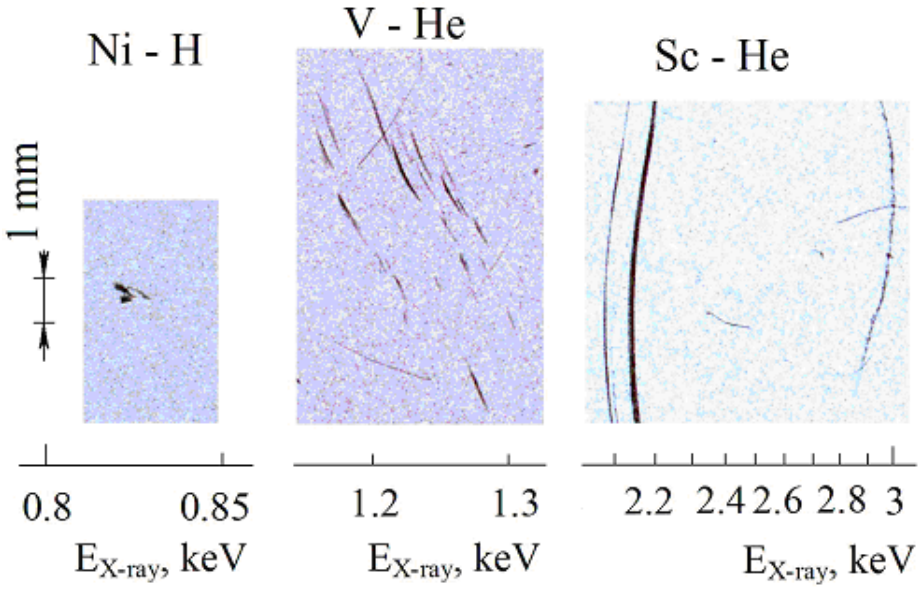

Figure 25. X-ray energy spectra in the spots and bands modes for Ni, V, and Sc cathodes after the He glow discharge switch off. Exposition time is 20 h.

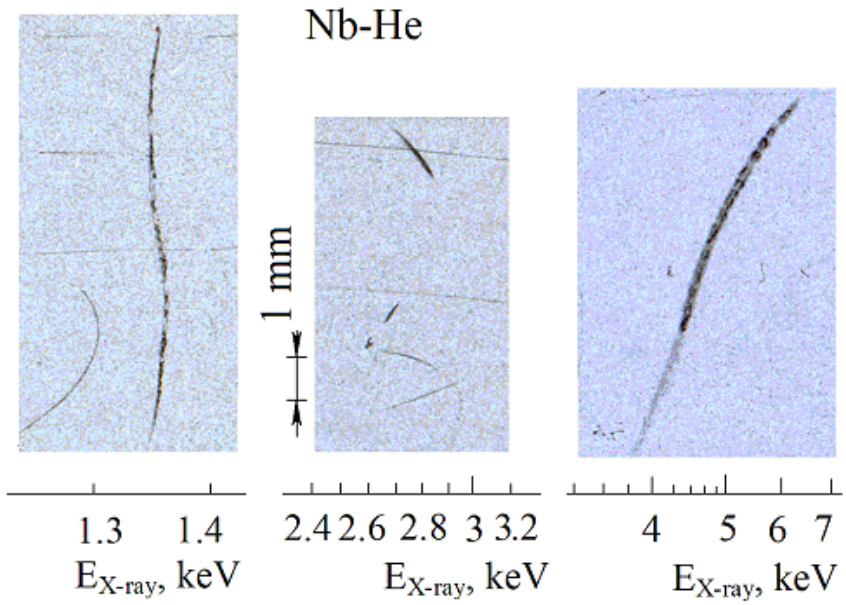

Figure 26. X-ray energy spectra in the spots and bands modes for Nb cathode after the He glow discharge switch off. Exposition time is 20 h.

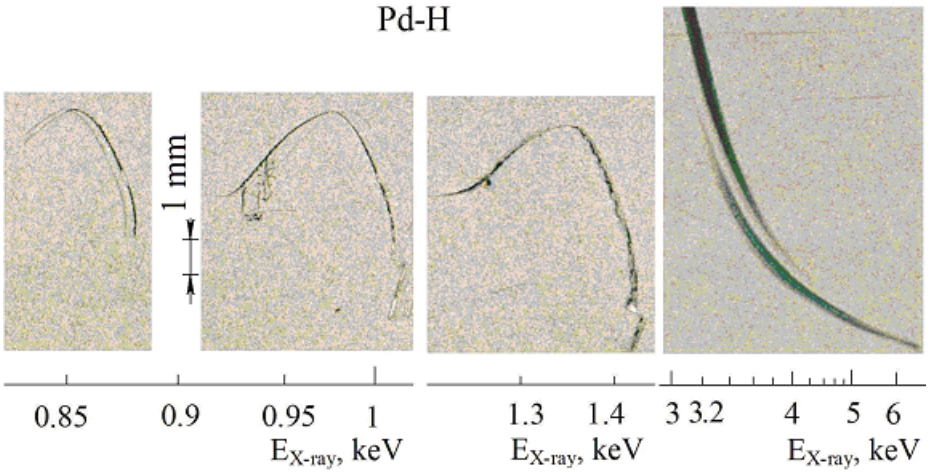

Figure 27. X-ray energy spectra in the spots and bands modes for Pd cathode after the H_2 glow discharge switch off.

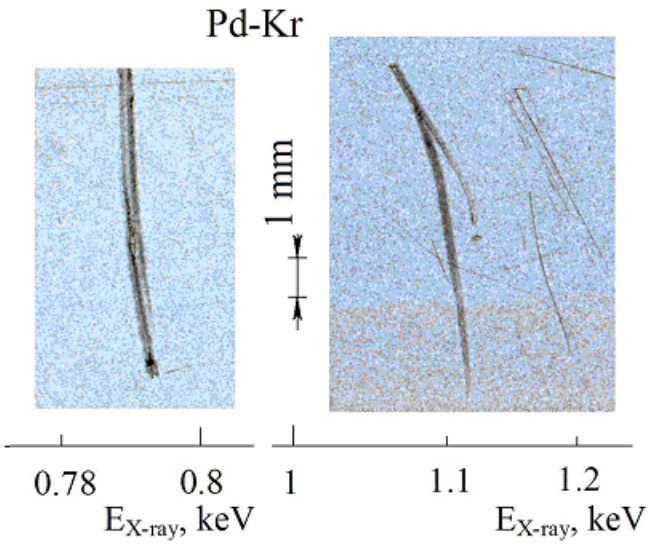

Figure 28. X-ray energy spectra in the spots and bands modes for Pd cathode after the Kr glow discharge switch off. Exposition time is 20 h.

3. Conclusion

The obtained experimental results allow us to consider the possible energy processes in the cathode solid material. The following processes may lead to initiation of LENR reactions. Presumably, some excited energetic levels are formed in the cathode solid when its surface is exposed to bombardment by the ions flux generated in plasma or electrolyte medium. The X-ray emission occurs as a result of de-excitation of these energetic levels.

The obtained results show that creating optically active medium with long-living levels with the energy of 0.6–6.0 keV and more is possible in solid matter.

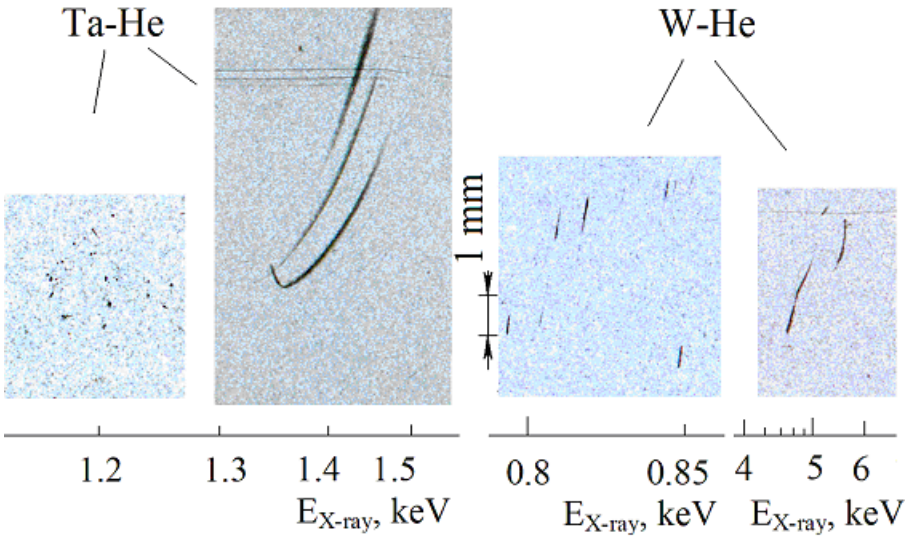

Figure 29. X-ray energy spectra in the spots and bands modes for Ta and W cathodes after the He glow discharge switch off. Exposition time is 20 h.

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