SPECTRAL QUANTUM YIELD OF METALLIC AND NONMETALLIC PHOTO CATHODES IN THE 95-20 nm REGION

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The spectral dependence of the relative quantum yield of certain metals (Cu, Ag, Au, Al, In, Sn, Ti, Fe, Ni, Zr, Nb, Mo, Ta, W, Pt) and nonmetals (ThO₂, ZrO₂, HfO₂, Sc₂O₃, Nb₂O₅, LiF, MgF₂, SrF₂, CsI, ZnS, SbS, BeO) has been investigated in the 95-20 nm region of the spectrum.

The efficiency of spectral equipment with photoelectric registration of radiation in the vacuum-ultraviolet region of the spectrum is determined to a considerable extent by the spectral sensitivity of the cathode in the photoelectric radiation detector, when detectors using the surface photoelectric effect are employed. The literature contains little on the extreme ultraviolet spectral photosensitivity of materials suitable for cathodes. Much of the work published on the photosensitivity of various materials relates to the Schumann region [1-6]; some papers include the region from 100 to 50-40 nm [7-11], while it appears that no data from the 40-10 nm region are available.

In constructing an open-type detector, similar to that described in [12], for photoelectric registration of the radiation in the 100-400 nm region we had to select a cathode with very high shortwave spectral sensitivity. We therefore measured the spectral dependence of the relative quantum yield of a number of massive metallic and nonmetallic photocathodes and of thin films of the same materials deposited on an aluminum base.

The spectral characteristics of the surface photoelectric effect were investigated in the 20-95 nm region for the following materials: copper, silver, gold, aluminum, indium, tin, titanium, iron, nickel, zirconium, niobium, molybdenum, tantalum, tungsten, platinum; films of thorium oxide, zirconium oxide, hafnium oxide, scandium oxide, aluminum oxide, niobium oxide; films of lithium fluoride, magnesium fluoride, strontium fluoride, cesium iodide; and films of zinc sulfide, antimony sulfide, and activated beryllium bronze.

The measurements were performed with a vacuum monochromator at grazing incidence; the optics of the system were schematically described in [13]. A special chamber was mounted behind the monochromator slit; a front-end FEU-36 photomultiplier was hermetically sealed to the chamber's exit aperture. Figure 1 shows the chamber schematically. The cathode under investigation, 1, dimensions 2.5 x 16 mm, was mounted on a plastic plate 2, inside the chamber near the front end of the FEU-bulb; the plastic provided suitable electrical insulation from the metal parts of the chamber. Over the openings of the movable carriage, 3, a cathodoluminophor, 4, and a semitransparent sodium salicylate screen, 5, were fixed. Each of these could be brought into operating position from the outside without destroying the vacuum. A cathodoluminophor consisting of a dense layer of FS-IV phosphor was deposited on a metal plate with a rectangular opening through which light fell on the test cathode. The semitransparent layer of sodium salicylate was deposited on a quartz plate. A high voltage (1-2 kV) was applied between the cathode 1 and the cathodoluminophor 4.

A focusing cylinder 6 served to direct the photoelectrons from the cathode on to the cathodoluminophor. On changing cathodes the chamber was disconnected from the monochromator. The cathodes investigated were made small to reduce light absorption to a minimum.

A pulsed discharge in a quartz capillary served as light source; the discharge was operated by a thyatron control with a pulse repetition frequency of 50 cps and took place in a helium stream [4]. A time-selector registration circuit [5] was used to measure the photocurrent from the photomultiplier; an EPP-09 recorder was connected to the output.
The process of measuring the relative quantum yield consisted in successively determining the photocurrent ratio of the multiplier for each wavelength. First, a measurement was made of the multiplier photocurrent due to emission of the cathodoluminophor 4 stimulated by photoelectrons from the photocathode under investigation, 1; then the carriage 3 was shifted and the fluorescence intensity of the sodium salicylate screen was measured. The ratio of the photocurrents served as a measure of the quantum yield at a certain wavelength. The relative quantum yield of sodium salicylate fluorescence has been determined in several papers [10, 16, 17]; from these it follows that the relative quantum yield is a constant over the entire ultraviolet region of the spectrum down to 40 nm. Unfortunately, no experimental data exist for shorter wavelengths. In all the measurements special attention was paid to maintaining a constant voltage between the cathode and the anode-luminophor since the intensity of cathodoluminescence depends upon the accelerating voltage.

In the region 95-30 nm, the photocurrent ratio was measured from the most intense and stable lines of the light source spectrum. In the region below 30 nm, where a marked increase of light scattering sets in, the ratio was determined from the readings on the recorder tape. In our case (glass diffraction grating, angle of incidence 82°), the working region of the spectrum was bounded by a wavelength of 23 nm; with a thin-film polystyrene filter it can be extended to 19.2. The results listed below for the quantum yield of various materials represent the average of three measurements. The accuracy of the measurements is approximately 10%.

![Graphs showing relative quantum yield for various materials](image)

Fig. 2. Relative quantum yield of: 1) copper; 2) gold; 3) silver; 4) nickel; 5) iron; 6) platinum (the broken-line curves for gold (2a) and for platinum (6a) were constructed from the data of [10, 11, 1]); 7) zirconium; 8) titanium; 9) tin; 10) aluminum; 11) indium; 12) tantalum; 13) niobium; 14) molybdenum; 15) tungsten.