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STATISTICS OF SECONDARY ELECTRON EMISSION OF THIN FOILS

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The authors describe a method and apparatus for study of the statistics of secondary electron emission from both sides of thin foils under bombardment by atomic particles of kiloelectron-volt energies. Specially developed assemblies of microchannel plates are used as electron detectors; the measurements are automated by a CAMAC system controlled by a DVK-2 computer. The possibilities of the apparatus are illustrated by data obtained in bombardment of a thin carbon foil by helium atoms with an energy of 3 keV.

Processes of energy loss and transfer in solids are conveniently studied by the secondary electron emission of thin (50-500 Å) foils (TFSE) caused by beams of energetic atomic particles (atoms, ions, and electrons) and hard photons. Electron emission can be used as an effective probe of atomic processes in solids. Important applications of TFSE can be found in energy and mass analyzers of energetic atomic particles [1, 2].

Until recently, chiefly integrating methods of current measurement were used to study TFSE [3, 4], i.e., the average number of emitted electrons was measured. Differential measurements — that is, determination of the probabilities of emission of 0, 1, 2, … electrons, the statistics of TFSE — are of considerable interest for understanding of processes of particle interaction with materials. Interest in such measurements is also stimulated by practical requirements: in the cosmic instruments that are being developed today, information on the number of emitted electrons is to be used for particle identification by mass [5, 6].

In earlier studies of emission statistics, the electrons were, as a rule, registered by means of scintillators (along with photomultipliers) or semiconductor detectors [7-9]. This requires acceleration of the electrons to energies of tens of kiloelectron volts, which creates considerable practical difficulties. The alternative possibility of selection of multielectron events involves the use of detectors based on microchannel plates (MCP), which have narrow amplitude distributions [10, 11].

We shall describe apparatus for the study of TFSE statistics. The apparatus contains a sensor unit and a measuring system for data acquisition, processing, and storage.

Sensor Unit. The sensor unit (Fig. 1) consists of a thin foil target 1, two electrostatic mirrors 2 for electron transport, electron detectors D_1 and D_2, and a primary-particle detector D_3.

The thin foil (of carbon with a thickness of 100 Å) is deposited on a fine-mesh screen that is spot-welded beforehand to a holder ring. The ring has an inside diameter of 27 mm. Rings with foil specimens can be interchanged.

The electrostatic mirrors provide acceleration and isochronous transport of the electrons emitted by reflection and shooting through to detectors D_1 and D_2, respectively. This ensures spatial separation and independent registration of primary particles (energetic atoms) and second particles (electrons). With electron transport, the electrostatic mirror retains information from the point of emission. Thus, the sensor unit can be used not only for time-of-flight measurements but also for determination of the coordinates of particle passage through the foil, if MCP-based coordinate-sensitive detectors are used as D_1 and D_2 [5, 6, 12-14]. The latter would make it possible to reconstruct, for example, the track of a heavy energetic particle that entered the sensor unit. The grids of the electrostatic mirrors are one-dimensional and have high (95%) transparency.

The described device employs three detectors: one for registration of primary particles (D_3) and two for registration of secondary electrons (D_1 and D_2). Detector D_3 is a standard VÉU-7-1 MCP-based secondary multiplier. Detectors D_1 and D_2, which select emission events according to the number of electrons emitted, use specially developed [15] herringbone assemblies

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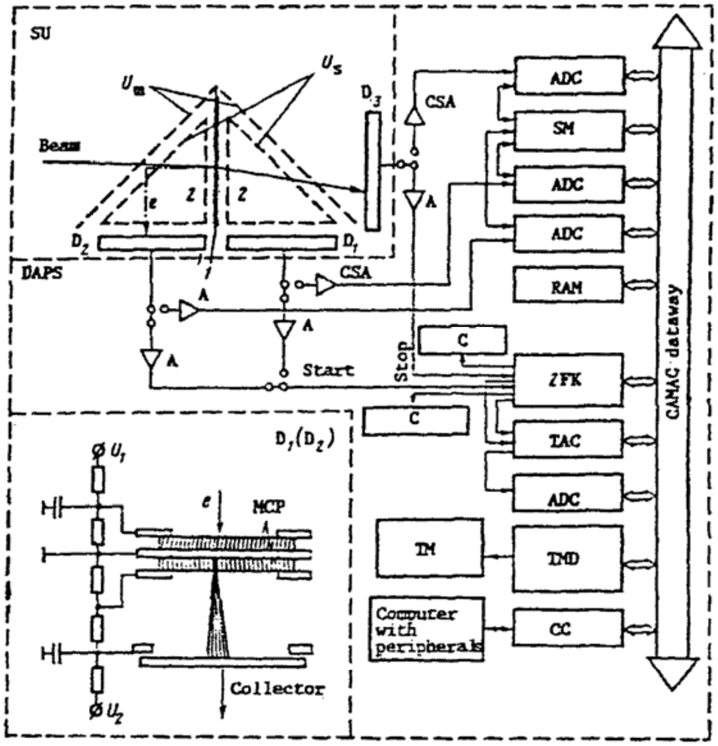

Fig. 1. Measuring system for study of secondary electron emission consisting of sensor unit SU and data acquisition and processing system DAPS: ADC) analog–digital converter; TAC) time-to-amplitude converter; CSA) charge-sensitive amplifier; A) high-speed amplifier; SM) synchronization module; RAM) random-access memory; C) counter; TM) television monitor; TMD) television-monitor driver; CC) crate controller.

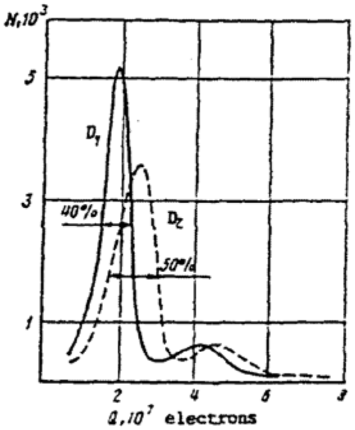

Fig. 2. Amplitude distributions of detectors D_1 and D_2 obtained in registration of secondary electrons emitted from foil when He atoms with an energy of 3 keV passed through it. N is the number of counts and Q is the charge of an electron avalanche.

of MCPs with micrometer gaps between the plates (Fig. 1). A detector for study of TFSE statistics must satisfy the following requirements: 1) the width of the single-electron amplitude distribution must be minimal; and 2) registered electrons that are separated on the sensitive surface of the detector by a distance greater than 50 μm must be multiplied independently, i.e., the charge avalanches generated by the electrons of a single multielectron event must not overlap in the second (output) MCP.

Just as earlier [15], the detectors were based on standard MKP-34-10 plates (an MCP diameter of 34 mm, a channel diameter of 10 μm, and a ratio of channel length to diameter of 40). The obtained amplification factors of (3-4)10^7 and amplitude resolutions of 0.35 for D_1 and 0.40 for D_2 (Fig. 2) and also the smallness of the gap ($\sim$10 μm) between plates in an assembly permit reliable selection of multielectron (up to four or five) events.

Events are registered by coincidence of the signals from detectors D_1 (D_2) and D_3, and, as has been shown [16, 17], the absolute intensity of the bombarding beam I_0 can be determined from the ratio $I_0 = f_{1(2)}f_3/f_{1(2),3}$, where $f_{1(2)}$ is the count rate of detector D_1 (D_2), f_3 is the count rate of detector D_3, and $f_{1(2),3}$ is the count rate of coincidences of signals of detectors D_1 (D_2) and D_3.

When the primary-beam intensity I_0 is known, the amplitude distributions permit, with allowance of instrumental effects (imperfections of mirrors and detectors), determination of the probability P_n of emission of n ($n \geq 0$) electrons for each side of the foil under study. The quantity P_n characterizes the statistics of the secondary emission caused by passage of energetic particles through the foil.

Data Acquisition and Processing System. A block diagram of the data acquisition system, which contains a multichannel time—amplitude analyzer (MCA), is shown in Fig. 1. The system is based on standard CAMAC modules, which operate under the control of a DVK-2 microcomputer. The MCA employs the following modules: Polon-712 10-bit analog—digital pulse converters, Polon-1501 high-speed amplifiers, 2FK discriminators with compensation for the effect of input-signal amplitude on time drift, Polon-1506 nanosecond-delay modules, and a Polon-1701 time-to-amplitude converter. A set of "Dinamo—Tsvet" modules is used for display on a color television monitor, and a 2TsAP10 two-channel digital—analog converter is used for data output to a plotter. The nonstandard modules of the measuring system are the charge-sensitive amplifiers, which are similar to those described elsewhere [18], and the synchronization module for the analog—digital converters.

The measuring system performs the following operations: accumulation of amplitude spectra from detectors D_1 and D_2; accumulation of time-of-flight spectra (*Start* signal from D_1 or D_2 and *Stop* signal from D_3); accumulation of amplitude spectra from D_1 and D_2 in the presence of coincidences of D_1 and D_3, D_2 and D_3, and D_1 and D_2; and output of the accumulated data to a graphics monitor, printer, and plotter.

The described sensor unit was tested in a vacuum chamber (at a pressure of (2-3)10^{-6} torr) with a collimated ($\sim$1 mm) monoenergetic beam of He atoms with energies of 1.5 and 3 keV. Typical measured amplitude spectra obtained with foil bombardment by He atoms with an energy of 3 keV are shown in Fig. 2. It can be seen that one- and two-electron events are clearly distinguished. An experimental spectrum is processed as follows. First, a model single-electron pulse-amplitude distribution is selected according to the shape of the peak that corresponds to single-electron events. The average amplitude A_i and dispersion D_i of the i-tuple peaks are related to the average amplitude A_1 and dispersion D_1 of the single-electron peak as $A_i = A_1 i$ and $D_i = D_1 i$. The total amplitude distribution is approximated by the expression $P(A) = P_1 f_1(A) + P_2 f_2(A) + \ldots$, where P_i and $f_i(A)$ are the probability of registration of i electrons and the corresponding amplitude distribution. The relationship of function f_i is especially simple if a normal distribution is used as $f_i(A)$. Then, the values of P_i, the absolute partial fractions of registered electrons, are determined by varying the values of P_i and A_1 and D_1 and seeking the best match with the measured distribution. Transition from the distribution of registered electrons to the distribution of emitted electrons does not involve fundamental complexities but requires knowledge of the transparency of the grids and the efficiency of electron registration.

In addition to independent registration of acts of electron emission, it is possible to find the presence of correlated events, i.e., correlations between the numbers of electrons emitted from both sides of the foil in a single event. Detailed information on the statistics of emission, including correlations, will provide deeper understanding of the phenomenon of secondary electron emission, which is of important practical value and independent physical interest. The possibilities of the described apparatus for measurement simultaneously with electron emission of the velocity and coordinates of heavy primary particles provide a comprehensive approach to the study of particle—foil interaction: simultaneous determination of the energy loss, scattering, and electron emission for each passage of a particle. The described apparatus makes it possible to study the statistics of electron emission from the surface of a solid of any thickness (using only the channel for registration by "reflection").

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LITERATURE CITED

1. Yu. V. Gott, Interaction of Slow Particles with Material and Plasma Diagnosis [in Russian], Atomizdat, Moscow (1978).
2. V. Kh. Likhtenshtein, Plasma Diagnosis [in Russian], Issue 4(1), Énergoizdat, Moscow (1981), p. 225.
3. W. Meckbach, G. Braunstein, and N. Arista, J. Phys. B, 8, No. 14, L344 (1975).
4. H. J. Frischkorn, P. Koschar, R. Latz, et al., IEEE Trans., NS-30, No. 2, 931 (1983).
5. M. A. Gruntman and V. B. Leonas, Preprint IKI Akad. Nauk SSSR, No. 1181, Moscow (1986).
6. M. A. Gruntman and V. B. Leonas, Proceedings of International Workshop on Problems of Physics of Neutral Particles in Solid Systems, Zakopane, Poland (1985), p. 151.
7. I. M. Bronshtein and B. S. Fraiman, Secondary Electron Emission [in Russian], Nauka, Moscow (1969).
8. L. A. Dietz and J. C. Sheffield, Rev. Scient. Instrum., 44, 183 (1973).
9. Y. Yamazaki and K. Kuroki, Nucl. Instrum. Methods, A262, 118 (1987).
10. M. Auder, J. C. Delmotte, and J. P. Boutot, Rev. Phys. Appl., 13, 188 (1978).
11. O. M. Sorokin, Prib. Tekh. Éksp., No. 2, 146 (1982).
12. M. A. Gruntman, Prib. Tekh. Éksp., No. 1, 14 (1984).
13. M. R. Ainbund, L. S. Gorn, M. A. Gruntman, et al., Prib. Tekh. Éksp., No. 1, 70 (1984).
14. M. A. Gruntman and V. B. Leonas, Prib. Tekh. Éksp., No. 1, 257 (1985).
15. A. A. Kozochkina, Prib. Tekh. Éksp., No. 5, 149 (1986).
16. M. A. Gruntman and V. A. Morozov, Preprint IKI Akad. Nauk SSSR, No. 667, Moscow (1981).
17. M. A. Gruntman and V. A. Morozov, J. Phys. E, 15, No. 12, 1356 (1982).
18. M. R. Ainbund, L. S. Gorn, M. A. Gruntman, et al., Preprint IKI Akad. Nauk SSSR, No. 787, Moscow (1983).

AUTOMATED SPECTROGRAPH FOR THE VISIBLE AND NEAR-INFRARED REGIONS

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The authors describe an automated instrument that employs a television camera to capture the spectrum and measure the wavelength of continuous and pulsed radiation in the region of 0.4-1.2 μm. The spectrograph has a resolution of 0.05 cm^{-1} and energy sensitivities of ~10-100 μJ for pulsed illumination and ~1 mW for continuous.

Measurement of the wavelength and recording of the spectrum envelope of optical radiation are traditional problems in automated spectrometric experiments. The use of television techniques for this purpose is becoming more and more popular. We shall describe an automated spectrograph with a television recording system.

The spectrograph has an autocollimation scheme (Fig. 1) using an echelette with a period of 75 lines/mm that operates at 20-40 diffraction orders (depending on the wavelength). The spectrum shape is captured by a KPT-67 television camera, which is a part of the PTU-42 television apparatus. The video signal from the camera enters a CAMAC-compatible high-speed eight bit analog—digital converter. The light-intensity distribution on the vidicon cathode along one television line is stored in its buffer memory, which has a capacity of 1K.

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