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LARGE-FORMAT WEDGE-AND-STRIP COLLECTOR FOR COORDINATE-SENSITIVE PARTICLE DETECTOR

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UDC 539.1.074+621.384.8

The authors describe the design and fabrication method for a large-format wedge-and-strip collector for a coordinate-sensitive detector based on microchannel plates. The working surface has a diameter of 68 mm, the structure spacing is 1.6 mm, and the width of the gap that isolates the collector elements is 16 μm.

The problem of registration of ultraweak images formed by spatially distributed fluxes of particles (electrons, ions, and neutral particles) and photons, which is often encountered in physics research, is solved with the aid of coordinate-sensitive detectors (CSD). These detectors determine in real time the coordinates (in digital form) of impact of a registered particle (photon) on the sensitive surface of the detector and accumulate an image in computer memory. Among CSDs, those based on microchannel plates (MCP) have gained the widest use. First developed at the end of the 1960s, CSDs combine a high space resolution with excellent time characteristics [1-4]. One of the key elements of a CSD is its collector, which converts the coordinates of the center of gravity of the electron avalanche formed by the MCP unit to charge signals, from which the coordinates of particle impact on the sensitive surface are reconstructed. Among the various types of collectors used in CSDs, collectors of the wedge-and-strip type (WS collectors), which were proposed by Anger in 1960 [5, 6], are finding increasing use. The first use of such a collector in a CSD was described by Martin et al. [7]. At the present time, they are widely employed in various photon and particle detectors in laboratory and space research. Wedge-and-strip collectors were first created in our country in 1982 [8, 9]. Today, WS collectors are used not only in MCP-based CSDs but also in CSDs that are based on proportional counters [10] and Penning counters [11]. WS collectors differ greatly in their fabrication method, materials, collector-structure shape, and substrate type [7, 12, 13]. The effect of design characteristics have been examined in detail [14].

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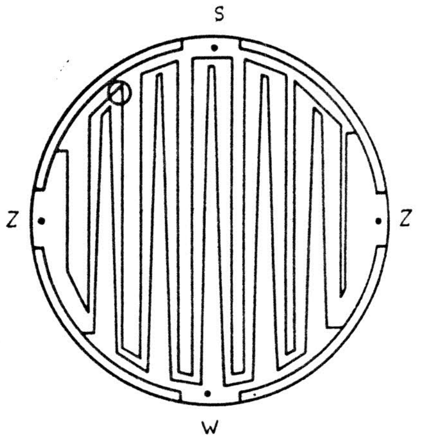

Fig. 1. Simplified diagram of wedge-and-strip collector. The collector (conductive) elements (shown in white): W) set of wedges; S) set of strips; Z) zigzag electrode. The black lines are the nonconductive gaps between the collector elements. The dots indicate the locations of the output pins. The circle in the upper left part shows the approximate location of the collector region an enlarged photograph of which is provided in Fig. 2.

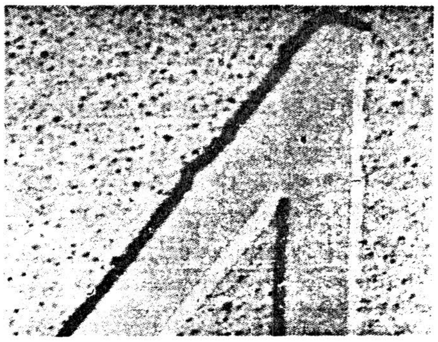

Fig. 2. Photograph of collector region (obtained with electron microscope). The location of the region on the collector is indicated by a circle in Fig. 1. The smooth part forming an acute angle is the nonconductive (etched) gap between collector elements. The gap width is 16 μm. The surfaces with visible irregularities are the metal collector elements.

Various methods for the creation of WS collectors are possible, but the fabrication method realized is frequently determined by the availabilities of the technologies and materials. We created a large-format collector with a useful area with a diameter of ~70 mm for a high-performance CSD [15, 16].

The WS collector consists of three conductive (metal) elements deposited on a nonconductive substrate and isolated from one another. The collector elements are inscribed in a circle and have the following configurations: a set of evenly spaced and interconnected identical wedges (W); a set of interconnected strips whose width varies linearly along one of the coordinates (S); and a zigzag electrode (Z) between the W and S electrodes. A simplified diagram of the collector is provided in Fig. 1. Each edge forms with one adjacent side of a strip the so-called period of the collector structure. The number of structure periods varies from 20 to 50 in real collectors. The operating principle, which is based on division of the charge of an electron avalanche among the collector elements, has been examined in detail [5-7] and will not be discussed here. The main requirements on the collector are: high electrode conductivity and the absence of a nonconductive (oxide) film on the electrodes; minimal capacitance between the collector elements; the possibility of prolonged heating, which is necessary when the collectors are used in sealed coordinate-sensitive photodetectors; and convenience of installation and signal pickup. We selected microphotolithography for fabrication of the collector, which required three steps: design of the collector structure; mask preparation; and preparation of the collector proper.

Collector-structure design was performed by means of the ANGER program, in which the parameters are the desired number of structure periods, the structure spacing (period length), the width of the isolating gaps between the collector elements, the diameter of the useful surface, etc. The program first designs a rectangular collector and then inscribes it in a circle of corresponding size. A sensitive area with shape of a circle is thus formed. The calculation results specify a set of coordinates of points whose connection by straight lines determines the boundaries between the collector elements. The accuracy of coordinate calculation was 0.1 μm.

Mask Preparation. The calculation results are used to prepare a mask with the aid of an ÉM-559 optical image generator. The error of positioning of the elements of the collector structure on the mask was not more than 0.5 μm and the reproducibility of the linear dimensions was ± 1 μm. The inclined regions were approximated in steps of 6′. The masks were made from standard rectangular blanks of quartz glass with a coating of chromium or Fe_2O_3, which gave the image an optical density of 2. Direct exposure of the collector substrate could be used to produce images of higher quality.

Collector Preparation. The substrates were standard (for the electronics industry) disks 76 mm in diameter of sapphire (0.5 mm thick) or silicon (0.38 mm thick). Preliminary chemical treatment was performed in Caro's acid (H_2SO_4:H_2O_2) at a solution temperature of 130°C for 10 min with subsequent washing in deionized water and drying of the plates in a centrifuge. Vacuum deposition of the metal was performed in a UVN-75 apparatus. Two types of collectors, which had different conductive-element materials, were prepared. The conductive elements of the first and second types were an aluminum film 1.5 μm thick and a copper layer 1.5 μm thick with an underlying chromium layer 300 Å thick. The pattern was formed by photolithography using RN-7 photoresist. A mixture of nitric, orthophosphoric, and acetic acids with water was used to etch the aluminum; a solution of hydrochloric acid, hydrogen peroxide, and water was used for the copper.

Four pins were pressed into the substrates for signal pickup on the opposite side of the collector: one for the wedges, one for the strips, and two (at opposite ends) for the Z electrode (Fig. 1). The latter two pins make it easy to measure the electrical resistance of the Z electrode, which is necessary for collector quality control. The contacts are attached by means of INCh conductive cement. A layer of nickel 0.1 μm thick was also deposited on the plates with the copper electrodes to prevent oxidation. Part of the collectors was gold-plated for the same purpose. Short circuits between the electrodes were burned away by means of an ÉM-551A laser retoucher. This operation is very important, since the total length of the isolating gap between the collector elements reaches several meters, and the formation of shorts is practically unavoidable.

The collectors created had the following specifications: a substrate diameter of 76 mm; a working-area diameter of 68 mm; an isolating-gap width of 16 μm between collector elements; a structure spacing of 1.6 mm; 42 periods; a Z-electrode resistance of 200-500 Ω (depending on the specimen); a capacitance between collector elements of 300 pF; and the ability to withstand prolonged heating at 300°C.

The photograph of a nonconductive gap with a width of 16 μm between collector elements in Fig. 2 demonstrates the quality of the collectors (the location of the region on the collector is shown in Fig. 1).

Tests of the collectors in a CSD prototype [15, 16] confirmed their performance and the correctness of the design methods. The collectors provide a space resolution of greater than 1000 × 1000 pixels in the large-format CSD.

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MULTICHANNEL APPARATUS FOR STUDY OF CORRELATED EMISSION PROCESSES IN ION BOMBARDMENT OF SURFACES*

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The authors describe a multichannel apparatus with coincidence circuit that is designed for the study of correlated emission processes in ion bombardment of solids. The apparatus makes it possible to obtain from one bombardment zone the differential and integral energy and escape-angle characteristics of primary and secondary particles and to detect with nanosecond resolution two- or three-particle elementary acts of interaction that result in the emission of ions, electrons, and photons.

So far, vast amounts of experimental data have been accumulated on the sputtering, scattering, and emission of secondary particles (atoms, ions, electrons, and photons) produces as a result of ion bombardment of solid surfaces [1]. All of these results were obtained in single-channel apparatus, which in a number of cases (for example, in studies of the mechanisms of secondary-particle production) does not provide sufficient information for definite conclusions to be drawn. This makes it necessary to seek experimental data that are more profound in their physical meaning, that could serve as a basis for further development of hypotheses concerning the mechanisms of secondary-particle production in the ion bombardment of surfaces [2, 3].

A multichannel method for the study of particle emission in ion bombardment was developed and a corresponding experimental apparatus was created to solve this problem. Important differences in the method, as compared with conventional (single-channel) methods, are: 1) it permits differential and integral energy and escape-angle characteristics of primary and secondary particles to be obtained simultaneously from one bombardment zone; and 2) the use of coincidence techniques makes it possible to distinguish in space and in time two- or three-particle elementary acts of interaction that result in the emission of ions, electrons, and photons in the ion bombardment of surfaces [4].

A diagram of the apparatus for registration of secondary emission is shown in Fig. 1. It consists of the following main units: an ion source 1 with a system for primary-beam focusing, the specimen 2, two identical spherical electrostatic energy analyzers 3 and 4, one of which (4) is combined with a mass separator, an interference light filter 5, and a photomultiplier 6 for the radiation detector.

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