ISSN 0020-4412, Instruments and Experimental Techniques, 2017, Vol. 60, No. 4, pp. 605–607. © Pleiades Publishing, Ltd., 2017.
Original Russian Text © Yo.K. Toshmurodov, 2017, published in Pribory i Tekhnika Eksperimenta, 2017, No. 4, pp. 147–149.

Position-Sensitive Detectors of Nuclear Radiation and a Study of their Current–Voltage Characteristic

Yo. K. Toshmurodov

Physical Technical Institute, Physics–Sun Scientific and Production Association, Academy of Sciences of the Republic of Uzbekistan, Tashkent, 100084 Uzbekistan

e-mail: detector@uzsci.net

Received May 4, 2016; in final form, December 14, 2016

Abstract—The production technology of silicon semiconductor position-sensitive detectors of nuclear radiation with a sensitive area of 24 × 24 × 1.5 mm and eighth current-collecting strips is described. Their current–voltage characteristics are investigated.

DOI: 10.1134/S0020441217040108

Semiconductor position-sensitive detectors (SPSDs) based on *p*–*i*–*n* structures are among the key tools for studying various particles and radiations [1, 2]. Nevertheless, their development and manufacture give rise to a number of technological problems, which result, in particular, from the satisfaction of requirements for the leakage current (1–10 μA) if a high-resistance silicon is used, the production of a defect-free structure on large areas (1–60 cm^2) at a thickness of 0.5–2.5 mm, and the limitations imposed by the technological equipment.

The front *p*–*n* junction must be sharp and be located close to the surface layer in detector structures in order to provide a thin entrance window, i.e., a thin dead layer. The base *i*-region must possess a very high specific resistance in order to provide its full depletion when a bias voltage is applied to the *p*–*i*–*n* structure. New technologies for forming *p*–*i*–*n* structures on large-diameter single-crystal silicon samples were developed in [3]. The thickness of a gold current-collecting contact must be uniform over the entire detector area [4].

The SPSD described in this paper was produced from industrial *p*-type silicon (resistivity $\rho = 3–8$ kΩ, carrier lifetime $\tau \geq 300$ μs, and oxygen concentration $N_{O_2} \sim 10^{16}$ cm^3) in the form of a plate with a diameter of approximately 50 mm and a thickness of 2.0–2.5 mm. Lithium diffusion proceeded from one side of the plate in a vacuum of the order of 10^{-6} Torr at temperature $T_{dif} = 450°C$ to a depth of 120–150 μm over approximately 0.5 min [2].

The n^+–p structure in the plate acquires a T shape upon chemical technological operations; afterward, drift of lithium ions in an electric field ($U \sim 300$ V) is activated in this structure.

We proposed the operating conditions and carried out investigations of the effect that the pulsed electric field exerted on the compensating drift of lithium ions.

The compensating drift of ions in an electric field makes it possible to eliminate the negative aftermath of the ion drift in traditional regimes (at high values of the temperature and electric field strength). This promotes production of high-performance Si(Li) *p*–*i*–*n* detectors with a large working area.

After termination of the lithium ion drift, the plate was subjected to mechanical treatment using M14–M5 micropowders, which consisted in sequentially applying finer and finer powders and polishing both sides to a depth of 100 μm. After the polishing, the silicon plates were washed in suds and in running distilled water using ultrasonic mixing.

Chemical etching is the next stage in the detector-production technology. The silicon plates were polished by etching agents using nitric, hydrofluoric, and acetic acids for 8–10 min. The plates were then rinsed in distilled water for 7 min.

Based on the above, we developed the operation-routing sequence for manufacturing large SPSDs (Fig. 1).

After the chemical etching, contacts were deposited on the plates by evaporation. A continuous rectangle-shaped germanium contact 500 Å thick was deposited on one side of a plate, and an aluminum contact 1000 Å in thickness was deposited after placement into a paper-based laminate shell. To obtain low-ohmic contacts 200 Å thick, gold was deposited on the front plate side through a special mask with holes shaped as thin strips.

The current–voltage characteristics of the Si(Li) SPSD were investigated using techniques developed in accordance with the GOST 26222-86 Russian State

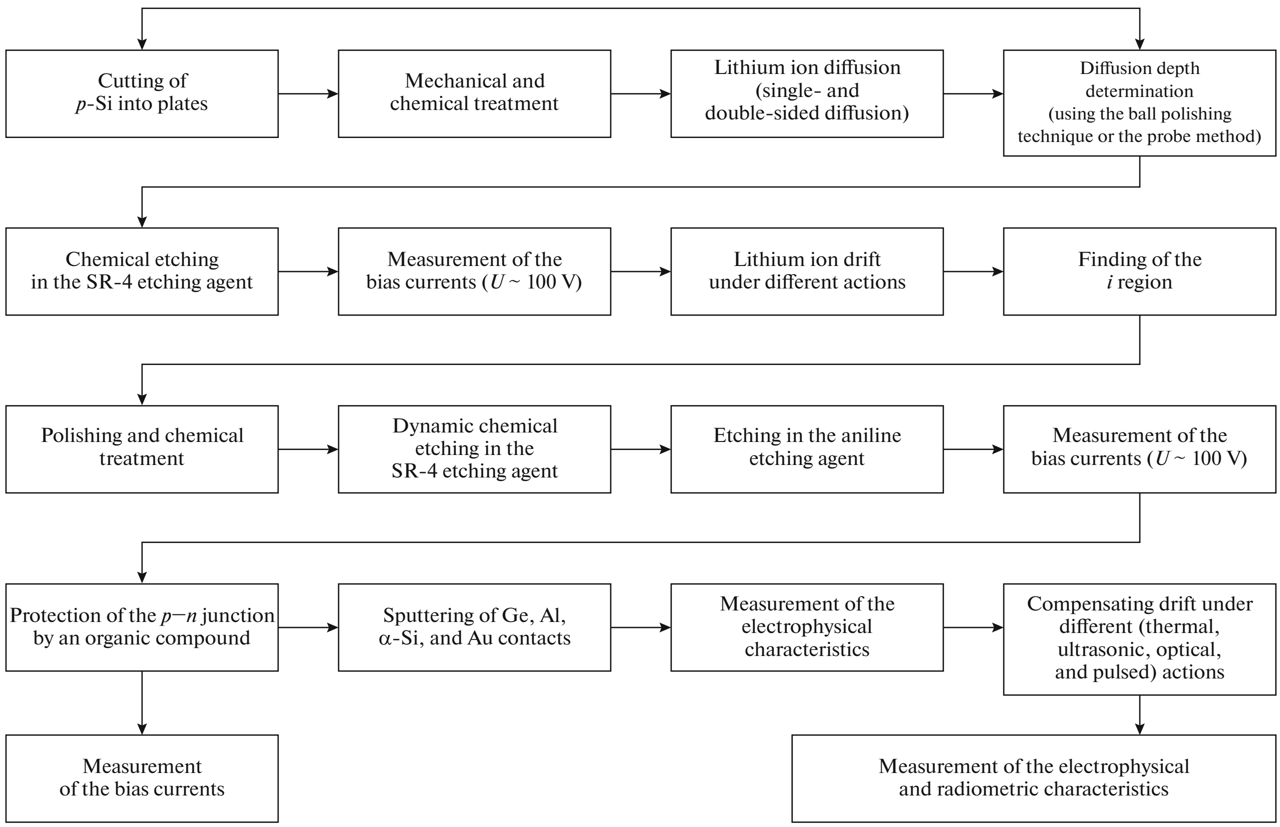

Fig. 1. The operation-routing sequence for manufacturing Si(Li) detectors.

Standard. The overall view of the SPSD is shown in Fig. 2. This figure also presents the current–voltage characteristics, i.e., the dependences of leakage current I_{leak} on voltage U of the 8-strip detector with a T-like cross section. The area of one strip is 24 × 1.5 mm^2. The current–voltage characteristics are presented for all eight strips.

According to Fig. 2, the values of the leakage current at a voltage of 140 V are in the range of 0.5–3.0 μA for all strips. This means that uniform compensation of the silicon volume with lithium ions has been attained in large samples (50 mm in diameter and 4 mm in thickness). These data are considered to be the best result for semiconductor detectors.

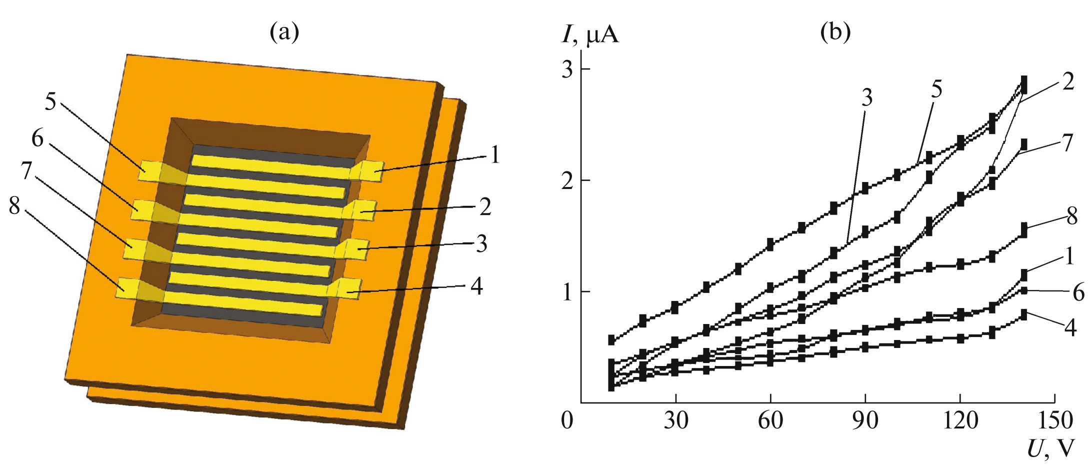

Fig. 2. (a) The overall form of the 8-strip SPSD: (1–8) strip numbers; and (b) the voltage dependences the leakage currents in the 8-strip discrete SPSD for each of the eight strips (the strips are designated by numbers).

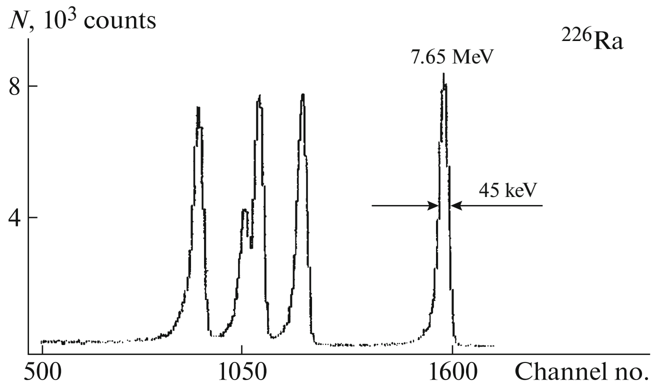

Fig. 3. The energy spectra of α particles from a ^{226}Ra source (E_α = 7.65 MeV) that were measured by the Si(Li) *p–i–n* detector.

Thus, the production technology for large SPSDs based on Si(Li) *p–i–n* structures was developed and optimized. The operating practices were optimized, the operating conditions were determined for diffusion and drift of lithium ions, and the electrophysical characteristics of the produced SPSDs were investigated at room temperature. The 8-strip large (24 × 24 × 1.5 mm) SPSDs that were developed and produced have enhanced electrophysical characteristics.

The typical energy spectra measured by strips of a Si(Li) *p–i–n* SPSD are presented in Fig. 3. According to Fig. 3, the energy spectra of the strips differ only slightly and correlate with the respective radiometric characteristics.

REFERENCES

1. Perevertailo, V.L., *Yader. Fiz. Energ.* 2008, no. 1, p. 88.
2. Akimov, Yu.K., *Instrum. Exp. Tech.,* 2007, vol. 507, no. 1, p. 1. doi 10.1134/S0020441207010010
3. Saimbekov, A.K. and Toshmurodov, Yo.K., *Nauchn. Vestnik Kremenchug. Univ. Ekonom., Imform. Tekhnol., Upravl. Novye Tekhnol.,* 2012, no. 1, p. 31.
4. Muminov, R.A., Radzhapov, S.A., Toshmurodov, Yo.K., and Bekbaev, S., *Uzbek J. Physics*, 2013, nos. 3–4, p. 179.
5. Muminov, R.A., Radzhapov, S.A., Toshmuradov, Yo.K., Risalieva, S., Bekbaev, S., and Kurmantaev, A., *Instrum. Exp. Tech.*, 2014, vol. 57, no. 5, p. 564. doi 10.1134/S0020441214040083

Translated by N. Goryacheva