Effect of technology parameters on the quality of nZnSe(X)/Ni Schottky diodes

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Effect of technology parameters on the quality of nZnSe(X)/Ni Schottky's surface barrier structure used as components of UV photosensitive detectors are studied. Both the spectrum and the total sensitivity of photodiodes depend substantially on the nickel film thickness. Estimation of the film thickness showed that optimal nickel layer thickness is ~ 20 nm. The shape of spectral sensitivity curve does not depend on activator impurity in the ZnSe crystal which the diode is formed from.

Изучено влияние технологических параметров, влияющих на основные выходные параметры поверхностно-барьерной структуры Шоттки nZnSe(X)/Ni, которая является основным компонентом при создании детекторов УФ излучения. Установлено, что как спектр, так и интегральная чувствительность фотодиодов существенно зависят от толщины пленки никеля, причем оптимальной можно считать толщину порядка 20 нм. Форма кривой спектральной чувствительности не зависит от активирующей добавки в кристалле ZnSe, из которого формируется диод.

ZnSe(X) doped crystals where X = Te, O may be effectively applied as components for ZnSe(X)/Ni "n-type semiconductor-metal" UV photo-sensitive structures with Schottky barriers [1–3]. Such crystals contain free electron concentration ($n_0 = 10^{15}$–10^{18} cm^{-3}) necessary to form the Schottky barriers, and semi-transparent nickel barrier contacts provide a good transmission in UV range. Such type Schottky barrier height is defined by difference between photoelectric work function Φ_m and semiconductor electron affinity χ, and is estimated as ~1.0–1.1 eV [4–5]. The sensitivity spectrum of such diodes is in the range 200–480 nm and includes UVA, UVB, and UVC areas of biologically active UV radiation. The current sensitivity of such photo-receivers basing on such structures can reach S_λ = 0.1–0.15 A/W for λ = 420–440 nm and 0.02 A/W for λ = 310–360 nm [4, 6].

The technological scheme for production of such diodes includes the crystal preparation, mechanical and chemical treatment of its surface, fusion of indium contacts, vacuum deposition of semi-transparent nickel layer as rectifying contact onto the photosensitive area, manufacturing of electrical interconnection wiring and boxing. However, as a rule, real structures have a broad scatter in output parameters. Irreproducibility of characteristics may be observed even between diodes made under the same technological conditions. That is why an actual task is to search the causes influencing onto the basic output parameters, and to develop UV detectors based on such type of diodes with optimal characteristics.

Three series (B, S, P) of ZnSe(O,Te)/Ni Schottky diodes produced using the described above technology scheme were stud-

Table. Total sensitivity of Schottky diodes of various series (without light filters, and with light filters separating UVA and UVB ranges)

Series and number of photodiode	Output signal, mV				
	Total, S	With separation of UVA range		With separation of UVB range	
		S_A	S_A/S	S_B	S_B/S
B1	860	674	0.78	560	0.65
B2	1098	945	0.86	886	0.80
B3	1132	973	0.86	829	0.73
B5	995	850	0.85	778	0.78
B7	912	730	0.80	627	0.68
B8	1005	923	0.91	880	0.87
B9	883	728	0.82	677	0.76
S25	613	571	0.93	521	0.85
S13	602	557	0.92	505	0.84
S47	704	661	0.93	615	0.87
P29	651	524	0.8	478	0.73
P19	759	697	0.91	639	0.84
P20	743	699	0.93	654	0.87
P28	683	612	0.89	566	0.82

ied. To determine the spectral composition of the diode sensitivity, an MDR-23 monochromator was applied and a DDS-30 deuterium lamp was used as the irradiation source. As a receiver, the diode under study was used. The output signal was measured under wavelength scanning. The dependence obtained was corrected taking into account the spectral composition of the irradiation source and the monochromator dispersion. To that end, calibrated radiation receiver (FEU-100) with known sensitivity spectral distribution was used.

When studying individual Schottky diodes of one series (S), differences were observed in optoelectronic parameters (volt-ampere characteristics (VAC), total sensitivity vs irradiance, input signal decay time after irradiation switching-off, temperature dependence of sensitivity, noise level over room temperatures) [4]. This indicates complexity of physical and chemical processes during such barrier formation. These differences may be connected with different carrier concentrations in semiconductor substrates, various defect levels on their surfaces, and other factors causing different mechanisms of dark current flowing through the barrier. As well, a possible cause may be existence of an additional dielectric layer between the crystal and the metal film which is formed at preparation of such structures. A scatter in parameters

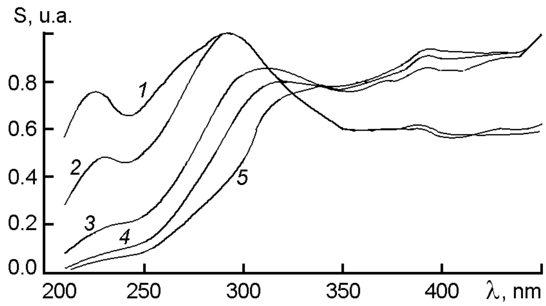

Fig. 1. Spectral dependences for photodiodes: B1 (*1*); B2 (*2*); S47 (*3*); S13 (*4*); S25 (*5*).

is observed when comparing the results obtained for diodes of different series. In the Table, the data on output signal characterizing total sensitivity of Schottky diodes are presented. Measurements were carried out under the same conditions, both without additional light filters, and with light filters separating UVA and UVB ranges. Besides a substantial scatter of output signal values, a non-proportionality between sensitivity data obtained without light filters and with light filters is observed for different samples, thus indicating differences in the sensitivity spectral dependences.

In Fig. 1, the normalized spectral sensitivity dependences for diodes of B and S series are shown. It is seen that the samples of B series are more sensitive in the short-wavelength range as compared to S ones.

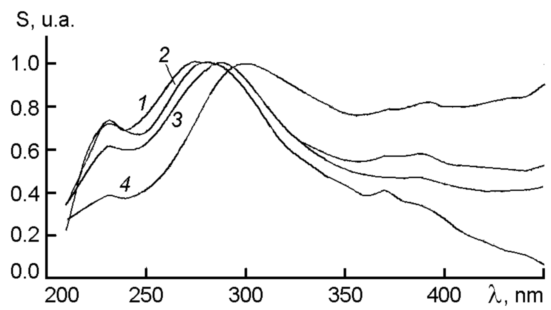

Fig. 2. Sensitivity spectral dependence for diodes of P series: *1*, P29 (ZnSe(O)), *2*, P20 (ZnSe(O)), *3*, P28 (ZnSe(Te)), *4*, P19 (ZnSe(Te)). The crystal composition in parentheses.

Several possible factors able to affect the spectral sensitivity composition were considered, namely, the dopant induced into the ZnSe crystal substrate; the Ni film thickness; the crystal surface preparation. To determine the influence of crystal substrate dopant onto the sensitivity spectrum, the P series diodes with known crystal composition were studied (Fig. 2). It has been established that the photosensitivity spectrum is independent of the activator impurity type in the ZnSe crystal. This is supported by experiments studying the effect of the crystal composition on the photo-sensitivity spectra of S and B-series diodes. The crystal composition was identified by the rentgeno luminescence spectra basing on the fact that the ZnSe(Te) has the X-ray luminescence maximum at 635 nm, while ZnSe(O), at 600 nm [2]. It follows from Figs. 2 and 3 that there is no correlation between sensitivity spectrum and crystal composition.

To determine the effect of nickel film thickness on the Schottky diode sensitivity spectra, the transmission spectra were measured for three films of different thickness on quartz substrates (Fig. 4). The chosen thickness of 1 and 2 films were as used in production of B series diodes, while the film 3 was about one order thicker. It is seen in Fig. 4 that the absorption of nickel films in the UV region is inhomogeneous manifesting itself in increased absorption of "hard" UV (200 to 300 nm) and being most pronounced at increased thickness. That feature of nickel may result in the sensitivity spectrum variations depending on the film thickness. Moreover, the integral diode sensitivity must decrease as the film thickness rises. In fact, both those phenomena are observed in practice. Estimation of the film thickness using photo-electron spectroscopy with XPS-800 spectrometer has shown that the nickel layer thickness was ~20 nm for B series diodes, and 200–300 nm for S series ones.

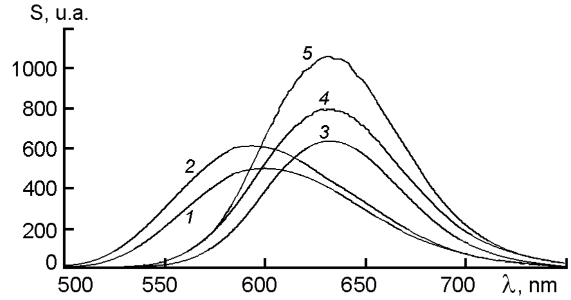

Fig. 3. X-ray luminescence spectra of ZnSe based crystals used for photodiodes: B4 (*1*), P29 (*2*), P28 (*3*), P19 (*4*), S47 (*5*).

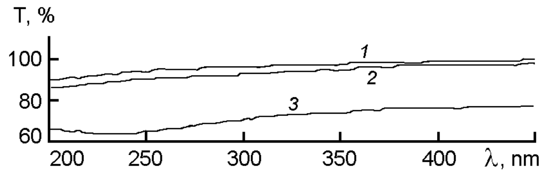

Fig. 4. Transmission spectra of Ni films with different thickness on quartz substrates.

It can be concluded that the shape of the spectral photosensitivity dependence for the Schottky diodes of ZnSe(X)/Ni type within the 200 to 480 nm range depends considerably on the Ni film thickness. As the thickness is reduced down to 15–20 nm, the sensitivity in the 250±30 nm (UVC region) increases considerably as compared to that in the UVB (310±20 nm) and UVA (350±20 nm) ranges. The effect established makes it possible to control intentionally the selective sensitivity of ZnSe-based Schottky diodes within the whole biologically active region of solar UV radiation. At the same time, the sensitivity spectrum of ZnSe(X)/Ni Schottky diodes is independent of the isovalent dopant X type (where X is oxygen or tellurium).

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Вплив технологічних параметрів на якість діодів Шоткі *n*ZnSe(X)/Ni

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Вивчено вплив технологічних параметрів, а також проведено пошук причин, що впливають на основні вихідні параметри поверхнево-бар'єрної структури Шоткі ZnSe(X)/Ni, яка є основним компонентом при створенні детекторів УФ-випромінювання. Встановлено, що як спектр, так і інтегральна чутливість фотодіодів суттєво залежать від товщини плівки нікелю, причому оптимальною можна вважати товщину близько 20 нм. Форма спектральної чутливості не залежить від активуючої домішки у кристалі ZnSe, з якого формується діод.