SEMICONDUCTOR X-RAY SENSORS BASED ON CHROMIUM COMPENSATED GALLIUM ARSENIDE*

I. D. CHSHERBAKOV[1], *O. P. TOLBANOV*[1], *A. V. TYAZHEV*[1], *A. N. ZARUBIN*[1], *P. V. KOSMACHEV*[1], *V. A. NOVIKOV*[1], *A. V. SHEMERYANKINA*[1]

[1]*National Research Tomsk State University, Tomsk, Russia*

X-ray sensors have found wide application in modern research centers (colliders) and applied areas (computed tomography, security systems, synchrotron radiation stations). Currently, the main interest is focused on semiconductor materials. Sensors based on them are more sensitive and effective in the field of X-ray radiation. Materials with high atomic number and density are required to absorb high-energy X-ray quanta. Such semiconductors include GaAs, the density of which exceeds the density of Si by more than 2 times. A group of scientists from Tomsk State University has developed a method for modifying the properties of *n*-GaAs by introducing a compensating acceptor-type impurity (Cr). A number of studies have shown that such a material has high resistivity (HR) [1-3]. This provides a high signal-to-noise ratio at room temperature. The conducted studies showed that sensors based on HR-GaAs:Cr can become the basis for the design of detection systems in such areas as medicine and high-energy physics, as well as for non-destructive testing systems [4-10].

This paper presents the main characteristics of sensor structures based on HR-GaAs:Cr. The time resolution of the sensors has been studied and it has been shown that by reducing the thickness of the active region it is possible to achieve a speed of 1 ns. An analysis of charge carrier transport processes was carried out based on measurements of impulse characteristics. It has been shown that carrier drift in HR-GaAs:Cr material is accompanied by the capture of electrons by $EL2^{+}$-centers and holes by chromium (Cr^{-}) impurities.

REFERENCES

[1] D. Budnitsky, V. Novikov, A. Lozinskaya, I. Kolesnikova, A. Zarubin, A. Shemeryankina, T. Mikhailov, M. Skakunov, O. Tolbanov and A. Tyazhev, “Characterization of 4 inch GaAs:Cr wafers”, Journal of Instrumentation, vol.12, no. P. C01063, 2017, doi: 10.1088/1748-0221/12/01/C01063.

[2] I. Kolesnikova, A. Lozinskaya, T. Mihaylov, V. Novikov, A. Shemeryankina, I. Sherbakov, O. Tolbanov, A. Tyazhev and A. Zarubin, “Temperature dependencies of current-voltage characteristics of GaAs:Cr”, Journal of Instrumentation, vol.11, no. P. C03059, 2016, doi: 10.1088/1748-0221/11/03/C03059.

[3] I. Chsherbakov,I. Kolesnikova, A. Lozinskaya, T. Mihaylov, V. Novikov, A. Shemeryankina,O. Tolbanov, A. Tyazhev and A. Zarubin, “Electron mobility-lifetime and resistivity mapping of GaAs:Cr wafers”, Journal of Instrumentation, vol.12, no. C02016, 2017 doi: 10.1088/1748-0221/12/02/C02016.

[4] A. Dragone, C. Kenney A. Lozinskaya, O. Tolbanov, A. Tyazhev, A. Zarubin and Zhehui Wang, “Feasibility study of a 4H X-ray camera based on GaAs:Cr sensor”, Journal of Instrumentation, vol.12, no. C01047, 2015, doi: 10.1088/1748-0221/11/11/C11042.

[5] E Hamann, A Cecilia, A Zwerger, A Fauler, O Tolbanov, A Tyazhev, G Shelkov, H Graafsma, T Baumbach and M Fiederle, “Characterization of photon counting pixel detectors based on semi-insulating GaAs sensor material”, Journal of Physics: Conference Series, vol. 425, no. P. 062015, 2013, doi: 10.1088/1742-6596/425/6/062015.

[6] E. Hamann, T. Koenig, M. Zuber, A. Cecilia, A. Tyazhev, O. Tolbanov, S. Procz, A. Fauler, T. Baumbach and M. Fiederle, “Performance of a Medipix3RX spectroscopic pixel detector with a high resistivity gallium arsenide sensor”, IEEE Trans Med Imaging., vol. 34, no. 3, P. 707, 2015, doi: 10.1109/TMI.2014.2317314.

[7] M.C. Veale, S.J. Bell, D.D. Duarte, M.J. French, M. Hart, A. Schneider, P. Seller, M.D. Wilson, V. Kachkanov, A.D. Lozinskaya, V.A. Novikov, O.P. Tolbanov, A. Tyazhev and A.N. Zarubin, “Investigating the suitability of GaAs:Cr material for high flux X-ray imaging”, Journal of Instrumentation, vol. 9, no. P. C12047, 2014, doi: 10.1088/1748-0221/9/12/C12047

[8] M.C. Veale, S.J. Bell, D.D. Duarte, M.J. French, A. Schneider, P. Seller, M.D. Wilson, A.D. Lozinskaya, V.A. Novikov, O.P. Tolbanov, A. Tyazhev and A.N. Zarubin, “Chromium compensated gallium arsenide detectors for X-ray and γ-ray spectroscopic imaging”, Nuclear Instruments and Methods in Physics Research A., vol. 752, p. 6-14, 2014, doi: 10.1016/j.nima.2014.03.033

[9] Kirsty A. Paton, Matthew C. Veale, Xiaoke Mu, Christopher S. Allen, Dzmitry Maneuski, Christian Kübel, Val O’Shea, Angus I. Kirkland, Damien McGrouther, “Quantifying the Performance of a Hybrid Pixel Detector with GaAs:Cr Sensor for Transmission Electron Microscopy”, Ultramicroscopy, vol. 227, no. P. 113298, 2021, doi: S0304399121000851

[10] C. Ponchut, M. Cotte, A. Lozinskaya, A. Zarubin, O. Tolbanov and A. Tyazhev, “Characterisation of GaAs:Cr pixel sensors coupled to Timepix chips in view of synchrotron applications”, Journal of Instrumentation, vol. 12, no. P. C12023, 2017, doi: 10.1088/1748-0221/12/12/C12023.

* The research of the energy and time resolution of sensors was financially supported by the Ministry of Science and Higher Education of the Russian Federation (Project No. FSWM-2022-0018). The study of the charge carrier transport process in HR-GaAs:Cr sensors was carried out with the support of the Russian Federation Government (Grant No. 075-15-2022-1132), July 1, 2022 in accordance with the Order No. 220, April 9, 2010