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Investigation of the strength properties of single-crystal InSb depending on crystallographic orientation and growth conditions

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The work is devoted to research of limits of applicability of X-ray analysis, light microscopy and study of microhardness of samples surface within the framework of estimation of complex mechanical characteristics of single crystals which largely determine output of good products (wafers) and form its final cost. Methods of investigation of mechanical properties regulated by GOST often refer to metals and alloys and are not applicable to semiconductor materials. In this regard, a particularly urgent task is to develop a method to evaluate the resistance of semiconductor wafers to brittle fracture, allowing the prospect to optimize the technological regime of growth of single crystals, potentially reducing the final percentage of rejected material.

InSb semiconductor single crystals grown in different crystallographic directions by Czochralski method were used as an object of investigation. It has been shown that the complex of mechanical properties of a material (thick plates also characterize the properties of the ingot as a whole) is directly influenced by the direction of growth. In this case, the lowest resistance to brittle fracture is shown by plates with orientation (100). The influence of plate surface treatment on the complex of mechanical properties is illustrated by X-ray mapping.

It is also shown in the present study that the microhardness of InSb wafers exhibiting different resistance to brittle fracture can have close values ((100)[100] – 183 ± 0.6 HV, (100)[112] – 179 ± 0.7 HV). A possible option for upgrading the microhardness measurement method could be to evaluate the crack resistance of the material by analyzing the geometry of the indentor-formed cracks.

Keywords: semiconductor monocrystals, digital light microscopy, X-ray analysis, dislocation density, indium antimonide.

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REFERENCES

1. Grinchenko L. Ya., Ponomarenko V. P. and Filachev A. M., Applied Physics, № 2, 57–62 (2009) [in Russian].
2. Mil'vidskij M. G. and Osvenskij V. B., Strukturnye defekty v monokristallah poluprovodnikov, Moscow, Metallurgiya, 1984.
3. Gorelik S. S. and Dashevskij M. Ya., Materialovedenie poluprovodnikov i dielektrikov, Moscow, Metallurgiya, 1988 [in Russian].
4. Yugov A. A., Pugachev B. V., Yugova T. G. and Knyazev S. N., Kristallografiya **65** (6), 857–861 (2020) [in Russian].
5. Koh H. J., Choi M. H., Park I. S. and Fukuda T., Crys. Res. Technol. **30**, 397 (1995).
6. Rudolph P., Matsumoto F. and Fukuda T., J. Crystal Growth. **150**, 43 (1996) ; Steinemann A. and Zimmerli U., Solid State Electron. **6**, 597 (1963).
7. Hashio K. and Sawada S., J. Crystal Growth. **173**, 33 (1997).
8. Shtremel' M. A., Prochnost' splavov: v 2-h ch. Deformaciya, Moscow, MISiS, 1999 [in Russian].
9. Komarovskij N. Yu., Yushchuk V. V., Bindyug D. V. and Bogembaev N. R., Mezhdunarodnyj nauchno-issledovatel'skij zhurnal, № 4-1 (106), 26–31 (2021) [in Russian].
10. Fajnshtejn S. M., Obrabotka i zashchita poverhnosti poluprovodnikovyh priborov, Moscow, Energiya, 1970 [in Russian].
11. Husid L. B., Luft B. D., Sverdlin I. A. and Dmitrieva G. A., Travitel' dlya himicheskogo polirovaniya antimonidov indiya i galliya. Patent SU 784635A1, 1982 [in Russian].
12. Gorin S. N., Travlenie poluprovodnikov. Izd. 1., Moscow, MIR, 1965 [in Russian].
13. GOST 9450-76 (ST SEV 1195-78) [in Russian].
14. Orlova G. Yu. and Kalashnikova I. I., Issledovanie morfologii i fazovogo sostava vysokokoncentrirovannyh i smeshannyh kristallov dlya aktivnyh sred lazerov. Proc. XLVI1 Nauchnaya konferenciya «Sovremennye problemy fundamental'nyh i prikladnyh nauk». 26–27 noyabrya 2004. Trudy konferencii. CHast' V. Moscow, Dolgoprudnyj, MFTI, 2004, pp. 65 [in Russian].
15. Samojlov A. M., Belenko S. V., Siradze B. A., Toreev A. S., Doicov A. I. and Filinova I. V., Kondensirovannye sredy i mezhfaznye granitsy Condensed Matter and Interphases **15** (3), 322–331 (2013) [in Russian].
16. Kormilicina S. S., Molodcova E. V., Knyazev S. N., Kozlov R. Yu., Zavrazhin D. A, Zharikova E. V. and Syrov Yu. V., Izvestiya vysshih uchebnyh zavedenij. Materialy elektronnoj tekhniki **24** (1), 48–56 (2021) [in Russian].
17. Mirofyanchenko E. V., Mirofyanchenko A. E. and Popov V. S., Applied Physics, № 2, 47 (2020) [in Russian].
18. Kudrya A. V. and Sokolovskaya E. A., Aktual'nye voprosy prochnosti: Sbornik tezisov LXIV Mezhdunarodnoj konferencii (g. Ekaterinburg, 4 aprelya 2022 g.). 2022, pp. 85–86 [in Russian].
19. Knyazev S. N., Kudrya A. V., Komarovskiy N. Yu., Parkhomenko Yu. N., Molodtsova E. V. and Yushchuk V. V., Methods of dislocation structure characterization in AIIIBV semiconductor single crystals. Modern Electronic Materials **8** (4), 131–140 (2022). https:// doi.org/10.3897/j.moem.8.4.99385
20. Brinkevich D. I., Vabishchevich S. A. and Vabishchevich N. V., Fizika i himiya obrabotki materialov, № 5, 32–35 (2007) [in Russian].