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Effect of microwave treatment on the parameters of Au-TiB$_x$-GaAs(SiC 6H) surface-barrier structures

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Abstract. We studied *I-V* curves of Au-TiB$_x$-*n*-n^+-GaAs and Au-TiB$_x$-*n*-SiC 6H surface-barrier structures. The structures were exposed to microwave treatments (frequency of 2.45 GHZ, irradiance of 1.5 W/cm^2, duration of 0–500 s). For these structures we measured how the Schottky barrier height and ideality factor depended on microwave treatment duration. It was shown that microwave treatments whose duration are up to 20 s do not impair the main structure parameters, while those with duration of 0.5–10 s may even improve these parameters.

Keywords: microwave treatment, surface-barrier structures, gallium arsenide, silicon carbide.

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1. Introduction

Interactions of various radiations with semiconductor materials and device structures are intensely investigated in recent years [1-5]. Of special interest among these studies are those dealing with effect of microwave radiation on parameters of semiconductor devices. Such studies are aimed at either search for new technological procedures [1, 3, 6, 7] or investigation of mechanisms for semiconductor device degradation [8-10].

The effect of microwave action on the Schottky-barrier semiconductor device structures (that are used for development of microwave diodes on their basis) is less well understood. That is why the objective of our work was to study the effect of microwave irradiation (frequency of 2.45 GHz, irradiance of 1.5 W/cm^2, duration of 0–500 s) on parameters of Au-TiB$_x$-GaAs(SiC) surface-barrier structures (SBSs).

2. Experimental details

The Au-TiB$_x$-*n*-n^+-GaAs SBSs studied were made on the basis of *n*-n^+-GaAs epitaxial structures (*n*-layer thickness of about 3÷5 μm, dopant concentration of about 10^{16} cm^{-3}). The n^+-layer was ~ 300 μm thick; the dopant concentration in it was ~2×10^{18} cm^{-3}. The Schottky barrier was formed using magnetron sputtering of TiB$_x$ followed by deposition of Au layer ~100 nm thick. The ohmic contacts to the n^+-region were formed using gold-germanium eutectic.

The Au-TiB$_x$-*n*-SiC 6H SBSs were prepared using also magnetron sputtering of TiB$_x$ (layer thickness of ~ 50 nm) onto a previously chemically cleaned substrate made of single-crystalline *n*-type silicon carbide. (This material, with dopant concentration of ~ 10^{18} cm^{-3}, was made using Lely technique.) After this a gold layer ~ 100 nm thick was sputtered onto the TiB$_x$ layer. The barrier structures (diameter of 200 μm) were formed using photolithography. Ohmic contacts were formed using nickel sputtering and firing at a temperature T = 1000 °C followed with gold plating.

3. Results and discussion

For SBSs of both types we took *I-V* curves, before as well as after microwave irradiation for up to 500 s. Using the theory of semiconductor rectification (see, e.g., [11]), we determined the values of Schottky barrier height φ_B and

Table 1. Barrier height φ_B and ideality factor n of Au-TiB$_x$-n-n^+-GaAs surface-barrier structures as function of duration of microwave annealing (frequency f = 2.45 GHz, irradiance P = 1.5 W/cm^2).

Schottky barrier parameters	Duration of microwave annealing, s						
	0 (initial)	0.5	1	5	10	15	20
φ_B, eV	0.79	0.80	0.82	0.82	0.82	0.82	0.79
n	1.24	1.20	1.15	1.15	1.13	1.15	1.2

ideality factor n from the forward branches of I-V curves. The results of determination of the above values for the Au-TiB$_x$-n-n^+-GaAs SBSs exposed to microwave irradiation are presented in Table 1 (for several rather low exposure times).

One can see from the data presented in Table 1 that no considerable degradation of parameters occurs after microwave treatment with the specified durations. And after microwave irradiation for 0.5–10 s the above SBS parameters become even better.

If the time of exposure to microwave radiation is increased over 20 s, then the SBS parameters begin to degrade: the exponential section of the forward branch of I-V curve becomes shorter, the Schottky barrier height φ_B decreases and ideality factor increases. Shown in Fig. 1 are I-V curves of the Au-TiB$_x$-n-n^+-GaAs SBSs as function of duration of microwave treatment. One can see that some changes appear on both the forward and reverse branches of I-V curves. These changes are due to degradation processes occurring in the semiconductor space charge region. Such a conclusion is supported by (i) an increase of the base resistance calculated from the forward branch of I-V curve and (ii) an increase of reverse current.

The above results agree with the experimental data obtained in [12]. These data evidence that deep-lying centers appear in the epitaxial n-GaAs layer after short-term microwave treatment. The authors of [12] relate appearance of these deep-lying centers to generation of dislocations in GaAs resulting from relaxation of intrinsic stresses in the n-n^+-GaAs structure enhanced by microwave treatment. It should be noted that the changes on I-V curves observed by us were stable; they kept after over-year storage at room temperature.

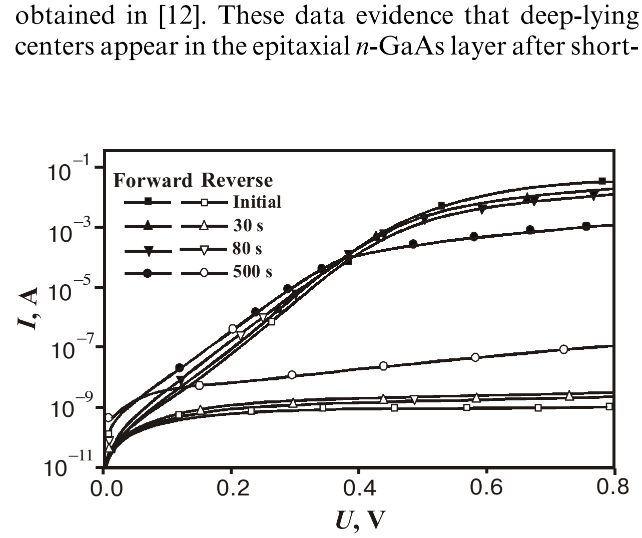

Fig. 1. I-V curves of Au-TiB$_x$-n-n^+-GaAs surface-barrier structures for different durations of microwave annealing.

Similar changes of I-V curves after microwave irradiation were observed for the Au-TiB$_x$-n-SiC 6H SBSs. In some cases we detected parameter improvement for several diode structures exposed to short-term (up to 10 s) microwave treatment. Most of the samples, however, degraded even after microwave irradiation for 2–3 s. It was found that silicon carbide diodes are less tolerant to effect of microwave radiation than gallium arsenide ones. It seems to us, after analyzing a set of experimental data concerning I-V curve changes after microwave treatment for silicon carbide SBSs, that the main reason for degradation of their parameters is a rather high heterogeneity degree of the starting silicon carbide. This factor facilitates nonuniform absorption of microwave power in the SiC near-surface layer, thus resulting in degradation of SBS parameters.

It should be noted that presence in SiC of micropores, another phase inclusions and growth defects of other types remains, up to now, a serious problem. Its solution will determine not only silicon carbide quality but, to a great extent, progress of silicon-carbide electronics as well [13, 14]. It seems that absorption of microwave radiation by the above defects favors both crystal transition into a state of more thermodynamic equilibrium (at short-term microwave irradiation) and generation of new metastable states (at long-term microwave irradiation). Micromechanism for this process is not clear yet, and some additional researches are required to understand it.

4. Concluding remark

When developing GaAs- and SiC-based microwave devices, one should take into account the experimental results concerning the effect of microwave treatment on parameters of Au-TiB$_x$-GaAs(SiC 6H) SBSs obtained by us in this work.

References

1. D.E. Abdurakhimov, F.Sh. Vakhidov, V.L. Vereschagin, V.P. Kalinushkin, M.G. Ploppa, M.D. Raizer, Change of semiconductor material properties due to action of microwave pulses of nano- and microsecond duration // *Mikroelektronika* **20**(1), pp. 21-25 (1991) (in Russian).
2. E.A. Galst'yan, A.A. Ravaev, Thermal effect of pulsed microwave radiation on structurally nonuniform materials // *ZhTF* **62**(1), pp. 42-54 (1992) (in Russian).
3. V.I. Pashkov, V.A. Perevoschikov, V.D. Skupov, Effect of annealing in microwave radiation field on residual strain and impurity composition of near-surface silicon layers // *Pis'ma v ZhTF* **20**(8), pp. 14-17 (1994) (in Russian).
4. T.A. Briantseva, Z.M. Lebedeva, I.A. Markov, T.J. Bullough, D.V. Lioubtchenko, Process-induced modification to the surface of crystalline GaAs measured by photometry // *Appl. Surf. Sci*. **143**, pp. 223-228 (1999).
5. S. Marinel, G. Desgardin, J. Provost, B.A. Raveau, Microwave melt texture growth process of $YBa_2Cu_3O_{7-d}$ // *Materials Sci. and Engineering* **B52**, pp. 47-54 (1998).
6. V.V. Milenin, R.V. Konakova, V.A. Statov, V.E. Sklyarevich, Yu.A. Tkhorik, M.Yu. Filatov, M.V. Shevelev, Physicochemical processes at the Au/Pt/Cr/Pt/GaAs contact interface exposed to microwave annealing // *Pis'ma v ZhTF* **20**(4), pp. 32-35 (1994) (in Russian).
7. A.N. Didenko, On a possibility of application of high-power microwave oscillations for technological purposes // *Doklady RAN* **331**(5), pp. 571-572 (1993) (in Russian).
8. V.I. Chumakov, A model for action of electromagnetic radiation on the element base of electronic facilities // *Radiotekhnika* No 106, pp. 120-123 (1998) (in Russian).
9. S. Kabajashi, V. Kim, R. Mizuno, Control of absorption by microwave irradiation // *Chemistry Lett*. **1**(9), p. 769 (1996).
10. D.A. Usanov, A.V. Skripal', N.V. Ugryumova, Appearance of negative resistance in the *p-n* junction-based structures in microwave field // *Fiz. Tech. Poluprov*. **32**(11), pp. 1399-1402 (1998) (in Russian).
11. H.K. Henisch, *Metal Rectifiers*, Oxford (1949).
12. R.V. Konakova, A.B. Kamalov, P.M. Lytvyn, O.Ya. Olikh, V.A. Statov, Effect of microwave irradiation on the residual intrinsic stress level and parameters of deep-lying levels in GaAs epitaxial structures, in *Proc. III Intern. Conf. "Radiation-thermal Effects and Processes in Inorganic Materials"*, Tomsk, Russia, July 29-August 3 2002, pp. 228-239 (2002) (in Russian).
13. S.F. Avramenko, V.S. Kiselev, M.Ya. Valakh, V.A. Yukhimchuk, Some aspects of sublimation growth of SiC ingots, in *Proc. III Intern. Seminar "Silicon Carbide and Related Materials"*, Novgorod, pp. 22-26 (2000) (in Russian).
14. O.V. Bord, M.S. Ramm, S.Yu. Karpov, A.N. Vorob'ev, Yu.N. Makarov, Redundant phase formation during growth of silicon carbide bulk crystals and epitaxial layers, in *Proc. III Intern. Seminar "Silicon Carbide and Related Materials"*, Novgorod, pp. 53-62 (2000) (in Russian).