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Power Au–TiB_x–n–n^+–GaAs Schottky Barrier Diodes

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Abstract

A technology is developed for obtaining power Au–TiB_x–n–n^+–GaAs Schottky diodes of planar and mesa structures and with integrated heat sink. The effect of thermal annealing (at T = 500 °C in hydrogen for 1 h) on the contact barrier properties is investigated. The possibility is demonstrated to make thermally stable (up to 500 °C) power Au–TiB_x–n–n^+–GaAs Schottky diodes with the avalanche breakdown voltage of ~200 V.

INTRODUCTION

Power Schottky barrier diodes based on n–n^+–GaAs epitaxial structures have been long attracting the attention of the developers of small-size power devices. Fast operation and high thermal and radiation stability characteristics of gallium arsenide provide substantial advantages for power Schottky barrier diodes in comparison with similar devices with p–n transitions or silicon power Schottky diodes. The realization of these advantages is slowed down by absence of reliable barrier contacts that would be stable firstly to thermal overloading. Schottky barriers in gallium arsenide formed by metals are, as a rule, prone to degradation even at relatively low temperatures. Due to interactions between phases, the interface becomes diffuse (the thickness of the transition layer increases). This provides an increase of the ideality factor and substantial change of the Schottky barrier height [1]. As we have demonstrated in [2], this process may be overcome by using an interstitial phase (nitrides and borides of refractory metals, in particular TiB_x) as barrier-forming material.

The present investigation deals with the effect of thermal treatment at 500 °C and annealing time of 1 h in the hydrogen atmosphere on the parameters of power Au–TiB_x–n–n^+–GaAs Schottky diodes.

MATERIALS AND METHODS OF INVESTIGATION

A diode structure with Schottky barrier based on epitaxial n-GaAs films grown on (100) substrates heavily doped with tellurium was used as the basic one. The diode working area was up to 100 mm^2, the epilayer thickness was 15 μm. The dopant concentration in the n-layer was ~2 10^{15} cm^{-3}, while that in the n^+-substrate was ~2 10^{18} cm^{-3}. The breakdown voltage was ~200 V.

The Schottky barrier was formed using TiB_x magnetron sputtering from a powder target followed by metallization with a layer of gold ~0.3 μm thick. The ohmic contact to the n^+ region was formed by gold-germanium eutectic.

The parameters of the inverse branch of the current-voltage characteristics (CVCs) were stabilized by using a MIS structure grown along the perimeter of the Schottky barrier. SiO_2 layers ~0.2 μm thick were used as an insulator. Such a structure of the diode allows formation of homogeneous avalanche breakdown without premature microplasms [3]. The diode chips were mounted in metal-ceramic packages.

The structure of the power Schottky diodes with similar barrier and ohmic contacts made as inverse mesas with the working areas of 9 and 25 mm^2 were also investigated. The mesa height was (25 ± 2) μm. The diode structures had the integrated heat sinks made of electrochemically grown copper ~80 μm thick, with subsequent gold-plating.

Before and after annealing in hydrogen at T = 500 °C for 1 h, static CVCs of the power Schottky diodes were measured. The major parameters determined from these CVCs were: the Schottky barrier height φ_B, ideality factor n and reverse current I_R at the reverse voltage of 50 V.

The interactions between phases in contacts were studied with Auger electron spectroscopy. Before and after thermal annealing, the concentration depth profiles of the components were measured within the region of the TiB_x–GaAs interface.

RESULTS AND DISCUSSION

Table 1 shows the parameters of the power Schottky diodes before and after thermal treatment. One can see that some Schottky barrier parameters, namely, the ideality factor and reverse current, changed insignificant-

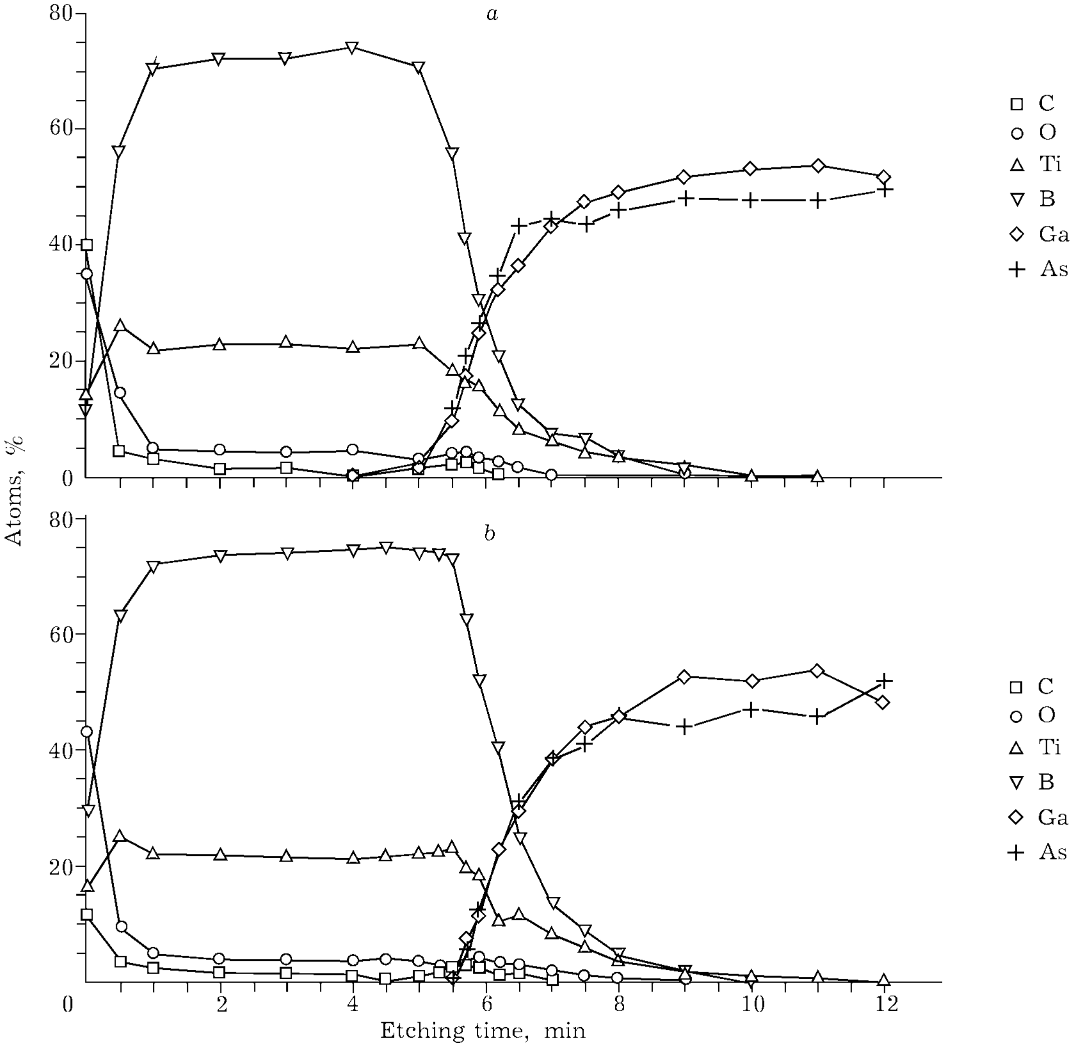

Fig. 1. The concentretion depth profiles of the TiB_x–GaAs contact components near the interface with the semiconductor: *a* – initial sample; *b* – after annealing at T = 500 °C for 1 h in hydrogen.

TABLE 1

The parameters of power Au–TiB$_x$–n–n^+–GaAs Schottky diodes before and after thermal treatment

Parameters	Treatment conditions	
	Initial	Annealing at T = 500 °C, 1 h
Barrier height φ_b	0.78–0.79	0.78–0.79
Ideality factor n	1.15–1.20	1.18–1.20
Reverse current I_R at U_R= 50 V	$2–3 \cdot 10^{-9}$	$3–4 \cdot 10^{-9}$

ly, while the barrier height remained unchanged. These results are in good agreement with the data of the Auger analysis shown in Fig. 1. After thermal annealing, the concentration depth profiles of the contact components remained practically the same. This fact evidences high thermal stability of the TiB$_x$–GaAs interface.

The properties of the Schottky barrier in the power Au–TiB$_x$–n–n^+–GaAs Schottky diodes fabricated according to the planar and mesa technologies were identical before and after thermal treatment. The avalanche breakdown voltages in the diodes of both types, independent of the working area, were (200 ± 10) V in the major part of diodes, thus corresponding to the calculated value.

CONCLUSIONS

1. A technology for obtaining thermally stable power diodes with the Au–TiB$_x$–n–n^+–GaAs Schottky barrier and the avalanche breakdown voltage of ~ 200 V is developed.
2. Thermal annealing of TiB$_x$-based contacts at T = 500 °C for 1 h in hydrogen has practically no effect on their electrical properties.

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