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DEGRADATION EFFECTS IN Au–Pt–GaAs SCHOTTKY BARRIER DIODES INDUCED BY THEIR ACTIVE TREATMENT

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The influence of microwave radiation and thermal annealing on the phase-phase interaction at the Pt–GaAs interface and the barrier properties of the junction has been considered. It has been shown that the microwave treatment and the long-term thermal annealing of Au–Pt–n–n^+–GaAs diode structures with a Schottky barrier can stimulate the degradation of the barrier parameters due to the smearing of the Pt–GaAs interface.

1. Introduction

It is known that diodes with a Schottky barrier can be used as ultrahigh-frequency (UHF) generators that operate in circuits exploited in strong enough electromagnetic fields [1]. In so doing, the working region of the semiconductor within the skin-layer depth is subjected to the action of electromagnetic radiation and, depending on an initial state of the diode structure, can substantially change the parameters of the latter.

In this work, the influence of microwave radiation on the phase–phase interaction at the Pt–GaAs interface and the barrier properties of the junction is considered, with an Au–Pt–n–n^+–GaAs diode with a Schottky barrier serving as an example.

2. Objects and Methods of Researches

Au–Pt–n–n^+–GaAs diode structures were fabricated by electron beam sputtering of metals – level by level – onto a chemically cleaned $n-n^+$-GaAs structure. The thicknesses of Pt and Au layers were 0.1 and 1.5 μm, respectively; the concentration of the doping impurity amounted to 10^{16} cm^{-3} in the n-GaAs film and to 10^{18} cm^{-3} in the substrate; the thicknesses of the n- and n^+-layers were 5 and 300 μm, respectively. The diameter of the Schottky barrier was about 500 μm. Ohmic contacts were prepared on the basis of AuGe eutectics. The microwave treatment of specimens was carried out in a magnetron. As a source of UHF radiation, there was used a magnetron with f = 10 GHz and an output power of 800 W. The irradiation time was 10 min. Some specimens were annealed in vacuum at T = 300 °C for 10 h. Before and after the treatment described, the test structures were used to study – with the help of electron Auger spectroscopy – the concentration profiles of component distributions in junctions, and the diode structures were used to measure the forward-bias branches of current-voltage characteristics (CVCs) in the temperature range 77–350 K. The measured forward-bias branches, in their turn, were used to determine the parameters of Schottky barriers, in particular, the barrier height φ_b, the ideality factor n, and the characteristic energy ε.

3. Discussion of the Results Obtained

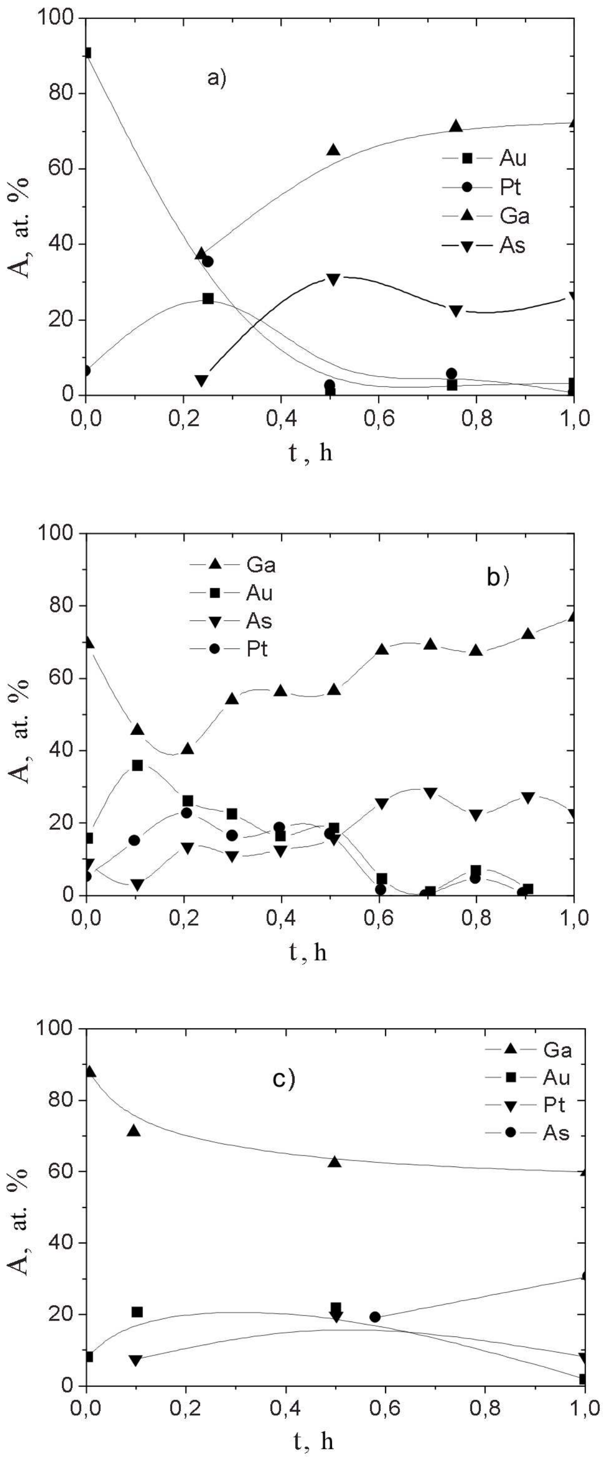
Our measurements showed that the forward-bias branches of the CVCs of initial specimens can be described by an exponential dependence of the current on the voltage in agreement with the thermionic mechanism of charge transfer ($\varphi_b \approx 0.81 \div 0.83$ V and $n \approx 1.18 \div 1.2$).

The parameters of reference diode structures with a Schottky barrier, which are subjected to UHF irradiation and thermal annealing, are listed in the Table.

From the data presented in this table, one can see that the UHF irradiation of diode structures for 10 min results in the degradation of parameters for the forward-bias CVC branch of the Schottky barrier, namely, a reduction of φ_b and an increase of the ideality factor n. Similar variations of the Schottky barrier parameters were observed after the thermal annealing at T = 300 °C for 10 h. The analysis of the temperature dependences of the forward-bias branches of the CVC of Schottky

Parameters of the Schottky barrier Au–Pt–n–n^+–GaAs measured at 300 K before and after treatments

Influence \ Parameter	φ_b, B	n
Reference specimens	0.81–0.83	1.18–1.2
10-min UHF treatment	0.69–0.74	1.3–1.5
10-h thermal annealing in vacuum at T = 300 °C	0.68–0.75	1.3–1.8



Component distributions in Au–Pt–n–n^+–GaAs junctions: reference diode structures with a Schottky barrier (a), diode structures subjected to UHF irradiation (b) and to thermal annealing (c)

diodes subjected to external influences showed that the excess component of the current with a characteristic energy $\varepsilon \approx 60$ meV and the excess current density of about 10^{-4} A/cm^2 prevails in the temperature interval $77 \div 300$ K. A weak dependence of the ε quantity and the excess current density on the temperature evidences for the tunnel character of charge transfer. The concentration ρ of dislocations, which are responsible for the excess tunnel current, was estimated according to the results of work [4] – i.e. taking into account the excess current density $J(0)$, and the values $\varepsilon(0)$ and $\varphi_b(0)$ obtained by the extrapolation to the zero absolute temperature – and making use of the formula

$$\rho = \frac{J(0)}{q\nu_D} \exp\left(\frac{\varphi_b(0)}{\varepsilon(0)}\right),$$

where q is the electron charge and ν_D the Debye frequency. The calculation gives the value $\rho \approx 2 \times 10^7$ cm^{-2}. The ρ-value with such an order of magnitude can arise in A^{3}B^5 compounds as a result of the relaxation of internal mechanical stresses (IMSs), induced by external factors [5]. In this case, for all irradiated and annealed diode structures, the reverse, thermally generated current increases considerably, which can be associated with both a reduction of the lifetime of the minority charge carriers in the base region of diodes (which, in its turn, occurs due to the increase of the concentration of generation-recombination centers such as dislocations) and a reduction of the Schottky barrier height (this fact follows from the analysis of CVCs carried out according to the recommendations of work [2]). The latter circumstance can be explained, if one takes into account a possibility of the phase–phase interaction in junctions stimulated by UHF radiation.

Really, the distributions of components Au–Pt–n–n^+–GaAs junctions exhibited in Figure testify that the specimens subjected to active treatments underwent the essential changes. These changes are related to the mass transfer of junction components (the penetration of Au atoms into GaAs) and, probably, to the formation of platinum arsenides which is a characteristic process running in Pt–GaAs junctions at rather low temperatures according to the Pt–As phase diagram [3].

The latter circumstance points to a certain general mechanism of barrier junction degradation caused by the influence of the temperature on the objects concerned: a local influence confined by the skin-layer depth during the metallization at a microwave treatment, as well as the heating of the whole specimen subjected to the thermal annealing in vacuum.

4. Conclusions

Thus, the reported data testify that the microwave treatment and the long-term thermal annealing at low temperatures of GaAs diode structures with a Schottky barrier, Au–Pt–n–n^+–GaAs, can bring about the degradation of the barrier parameters. The degradation can be caused by two factors: (i) the smearing of the Pt–GaAs interface owing to both the phase–phase interaction stimulated by the microwave irradiation and the mass transfer of Au atoms into GaAs, and (ii) a possible generation of dislocations in GaAs owing to the relaxation of IMSs. Similar processes can be observed after the thermal treatment at $T = 300$ °C for 10 h.

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ДЕГРАДАЦІЙНІ ЯВИЩА
В ДІОДАХ ШОТТКІ Au–Pt–GaAs,
СТИМУЛЬОВАНІ АКТИВНИМИ
ОБРОБКАМИ

А.Б. Камалов, С.Є. Бекбергенов

Р е з ю м е

Розглянуто вплив мікрохвильового випромінювання і термовідпалу на міжфазні взаємодії на межі поділу контактів Pt–GaAs та їх вплив на бар'єрні властивості контакта. Показано, що в результаті мікрохвильової обробки і тривалого термовідпалу діодних структур з бар'єром Шотткі Au–Pt–n–n^+–GaAs можлива деградація параметрів бар'єра, зумовлена розмиттям межі поділу Pt–GaAs.