NEW MANUFACTURING TECHNOLOGY FOR InP EPITAXIAL LAYERS AND PROPERTIES OF SCHOTTKY DIODES MADE ON THEIR BASIS

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Abstract

A new technological approach to production of structurally perfect epitaxial films LPE-grown on "soft" porous n^+-InP substrates is considered. We studied surface morphology, boundary between phases in TiB_x–*n*-InP contact and *I–V* curves of Au–TiB_x–*n*-InP Schottky diodes made on "soft" and "rigid" (standard) n^+-InP substrates. The advantages of epitaxial layers grown on porous n^+-InP substrates and barrier structures on their basis are demonstrated

1. Introduction

The development of microwave (mm wavelength range) devices imposed severe requirements on semiconductor epitaxial structures that served as a basis for device manufacturing. As a rule, such epitaxial structures are thin (2–3 epitaxial layers of total thickness below 1 μm) and are characterized by a high level of intrinsic stresses. In this case the active areas of microwave devices (especially of those with Schottky barriers) are located in a thin near-surface layer immediately adjacent to a metal–semiconductor contact and are sensitive to structure changes in this layer due to both technological (during device manufacturing) and operational factors. Therefore the intrinsic stresses in these structures must be reduced to such an extent as to practically exclude stress relaxation induced by external actions.

So one of the basic problems is the development of new methods for production of epitaxial structures with low (or even zero) level of stresses [1, 2]. Fulfillment of the main requirement – obtaining structurally perfect epitaxial layers in the film–substrate structures without stresses – still meets difficulties. One of the ways to solve this problem (being developed at Ioffe Physico-Technical Institute) is formation of epitaxial layers on "soft" (porous) semiconductor substrates [3].

In this work we studied the epitaxial layers and Schottky barriers on the basis of *n*-type indium phosphide grown on porous n^+-InP (100) substrates.

2. Sample preparation and experimental procedure

Three-layer *n*-InP films were LPE-grown (see our earlier work [4]) on specially prepared InP (100) substrates doped with tin ($2\cdot10^{18}$ cm^{-3}). Porous material interlayers (9−12 µm thick) were obtained using electrochemical etching in chloride and bromide water solutions. Epitaxy was performed from an InP−In solution-melt; crystallization began at a temperature of 655 °C. To suppress primary underetching and liquid phase penetration into pores, the initially saturated melt was overcooled by 10 °C before contacting with the substrate [5]. For the sake of comparison, epitaxial layers on the standard "rigid" substrates were grown also in the same process.

The Schottky barriers were formed using magnetron sputtering of TiB_x from a target of stoichiometric composition followed by gilding. Ohmic contacts were prepared with Au−Ge eutectics. The diode structures with diameters of 20…200 µm (at 20 µm intervals) were made with photolithography.

We studied the component concentration depth profiles in TiB_x−InP barrier layers for structures of both types with Auger electron spectroscopy; surface morphology of epitaxial layers was studied with atomic force microscopy. Besides, we took *I*−*V* curves of the diode structures.

3. Results of measurements

An analysis of surface morphology of epitaxial layers grown on substrates of both types showed that these surfaces do not differ greatly from each other. They are characterized by Gauss distribution of irregularity heights and presence of grains, their boundaries being not clearly pronounced. The distinctions were in size and boundary depth (Table 1).

Table 1. Surface characteristics of epitaxial layers grown on "soft" and "rigid" InP substrates.

Characteristics	"Soft" substrate	"Rigid" substrate
surface grain size, ±2 nm	33	52
surface fragment (5×5 μm^2) height, nm	6.877	47.042
surface irregularity size, nm	0.2	0.9

A dramatic increase of surface irregularity size and height on a "rigid" substrate indicates its considerable surface nonuniformity as compared with that for a "soft" substrate.

The component concentration depth profiles in TiB_x−InP barrier structures (Fig. 1) evidence that mass transfer in the TiB_x−InP contacts formed on "soft" InP substrates is proceeding slower than in similar contacts formed on "rigid" substrates. These results agree with those of x-ray diffractometry [6] that characterize a device structure on a "soft" substrate as having intrinsic stress 40% below that on a "rigid" substrate.

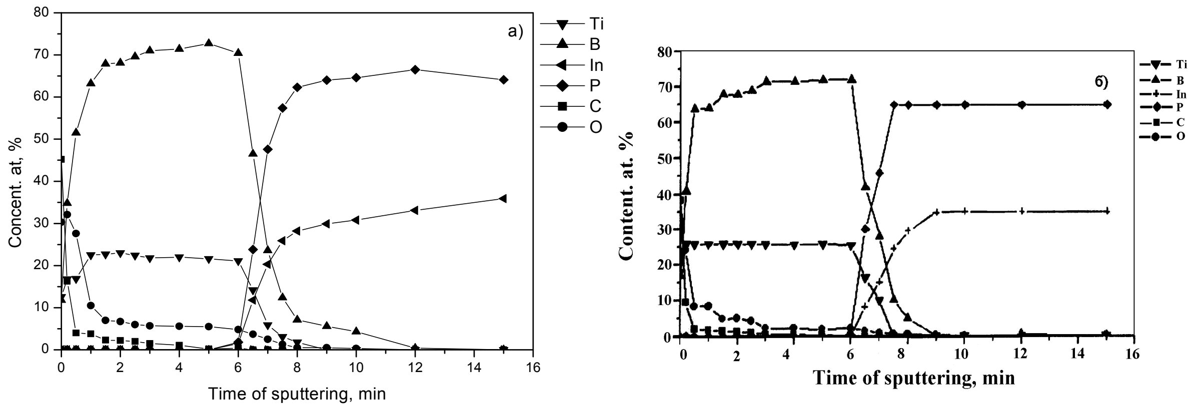

Fig. 1. Component concentration depth profiles in TiB_x–InP barrier structures formed on "rigid" (a) and "soft" (b) InP substrates.

The results of our measurements of *I–V* curves in the diode structures of both types and calculations of Schottky barrier heights φ_b and ideality factors *n* are presented in Table 2. They are in agreement with the data on structure obtained when studying surface morphology of epitaxial layers and component concentration depth profiles in the contacts.

Table 2. φ_b and n as function of diameter D of Schottky diodes made on "soft" and "rigid" InP substrates.

D, µm	"soft" substrate									
	20	40	60	80	100	120	140	160	180	200
φ_b, V	0.54	0.54	0.54	0.53	0.54	0.54	0.52	0.52	0.52	0.52
N	1.08	1.08	1.05	1.09	1.09	1.09	1.1	1.1	1.1	1.1
"rigid" substrate										
φ_b, V	0.54	0.54	0.5	0.5	0.49	0.49	0.49	0.47	0.48	0.47
n	1.09	1.09	1.18	1.18	1.20	1.21	1.22	1.25	1.24	1.27

4. Conclusions

From the results obtained one can see that InP epitaxial layers grown on porous "soft" InP substrates are more perfect and uniform than those grown on "rigid" InP substrates. This is confirmed by the values of parameters of Schottky diodes made on the basis of these structures. Both Schottky barrier height φ_B and ideality factor *n* of diodes formed on "soft" substrates depend on the barrier structure diameter but slightly and are close to the corresponding calculated values. The above facts indicate that such diodes are promising for application in microwave electronics.

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