Applied Surface Science 254 (2008) 8041–8045

Contents lists available at ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

New reconstruction-stoichiometry correlation for GaAs(0 0 1) surface treated by atomic hydrogen

K.V. Toropetsky [a], O.E. Tereshchenko [a,b,*], D.A. Petukhov [a], A.S. Terekhov [a,b]

[a] *Institute of Semiconductor Physics, 630090 Novosibirsk, Russia*
[b] *Novosibirsk State University, 630090 Novosibirsk, Russia*

ARTICLE INFO

Article history:
Available online 14 March 2008

PACS:
68.35.Bs
81.65
61.14.Hg

Keywords:
GaAs
Atomic hydrogen
Surface structure
Stoichiometry
Low energy electron diffraction
X-ray photoelectron spectroscopy

ABSTRACT

The structure, stoichiometry and electronic properties of the GaAs(0 0 1)-(2 × 4)/*c*(2 × 8) surface treated by cycles of atomic hydrogen (AH) exposure and subsequent annealing in UHV were studied with the aim of preparing the Ga-rich surface at low temperatures. Low energy electron diffraction showed reproducible structural transformations in each cycle: AH adsorption at the (2 × 4)/*c*(2 × 8) surface led to the (1 × 4) structure at low AH exposure and to a (1 × 1) surface at higher AH exposure with subsequent restoration of the (2 × 4)/*c*(2 × 8) structure under annealing at 450 °C. The cycles of AH treatment preserved the atomic flatness of the GaAs(1 0 0) surface, keeping the mean roughness on to about 0.15 nm. The AH treatment cycles led to the oscillatory behavior of 3dAs/3dGa ratio with a gradual decrease to the value characteristic for the Ga-rich surface. Similar oscillatory variations were observed in the work function. The results are consistent with the loss of As from the surface as a result of the desorption of volatile compounds which are formed after reaction with H. The prepared Ga-rich GaAs(0 0 1) surface showed the stability of the (2 × 4)/*c*(2 × 8) structure up to the annealing temperature of 580 °C.

© 2008 Elsevier B.V. All rights reserved.

1. Introduction

The ability to control the structures of solid surfaces with atomic precision is of technological relevance for surface dry etching, surfactant properties and passivation as well of fundamental interest in the understanding of solid-state physics. For modern nanotechnology it is important to develop techniques such as layer-by-layer removal of a semiconductor with monolayer resolution, keeping an atomically smooth surface morphology [1]. Another important requirement is that surface modification occurs at low temperatures. Recently, it was shown that Cs adsorption on the clean arsenic-rich GaAs(1 0 0)-(2 × 4)/*c*(2 × 8) surface followed by annealing at 450–470 °C induced conversion to the (4 × 2)/*c*(8 × 2) gallium-rich reconstruction [2]. Due to Cs-induced conversion the temperature is lowered by ~100 °C relative to that required to produce the Ga-rich surface by a conventional UHV annealing without preliminary Cs adsorption. It was proposed that the low-temperature conversion is due to Cs-induced weakening of arsenic bonds on the surface, which, in turn, is supposedly caused by electron charge redistribution between Cs adatoms and the GaAs surface atoms.

In contrast to Cs, atomic hydrogen forms chemical bonds with the surface atoms of As and Ga inducing both charge redistribution and formation of volatile compounds. The hydrogen reaction with the As-rich GaAs(1 0 0)-(2 × 4)/*c*(2 × 8) surface was divided into three steps [3]: (i) saturation of an As dangling bond with subsequent breaking of the As dimer by adsorption of the second H; (ii) attachment of a third hydrogen atom at some As atoms results in the formation of volatile AsH_3; (iii) further exposure to higher amount of atomic hydrogen results in surface roughness, with corrugations on the 1–2 nm level. If AH adsorption is stopped at the second stage, the etching of the first arsenic layer and, thus, transition to Ga-rich surface becomes possible. The idea of this work consists in the conversion of the As-rich to Ga-rich surface induced by the adsorption of atomic hydrogen up to the formation of the AsH_3 phase and subsequent annealing at moderate temperature.

We have proved experimentally that cycles of AH adsorption on the As-rich GaAs(1 0 0)-(2 × 4)/*c*(2 × 8) surface followed by annealing at 450 °C, induce conversion to the Ga-rich surface with the same (2 × 4)/*c*(2 × 8) reconstruction, keeping an atomically smooth surface morphology. Thus, the new Ga-rich GaAs(1 0 0)-(2 × 4)/*c*(2 × 8) surface is prepared at temperatures which are about 100 °C lower than those required to produce the Ga-rich surface by a conventional UHV anneal.

* Corresponding author at: Institute of Semiconductor Physics, 630090 Novosibirsk, Russia. Tel.: +7 383 3332771; fax: +7 383 3332771.
E-mail address: teresh@thermo.isp.nsc.ru (O.E. Tereshchenko).

0169-4332/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.apsusc.2008.03.021

2. Experimental

In this work we have used p-type GaAs(0 0 1) samples which were grown by liquid phase epitaxy. The GaAs(0 0 1)-(2 × 4)/*c*(2 × 8) surface was prepared initially by removing the oxides in HCl–isopropanol solution followed by vacuum annealing at 450 °C [4]. After preparation of a clean GaAs(0 0 1) surface, the cycles of atomic hydrogen (AH) adsorption at room temperature and subsequent annealing at T = 450 °C during 10 min were performed. The final annealing was performed at T = 580 °C for 10 min. The treatment cycles were as follows: 20 L(AH) → 450 °C → 40 L(AH) → 450 °C → 100 L(AH) → 500 L(AH) → 450 °C → 1 kL(AH) → 450 ° 450 °C → 10 kL(AH) + 450 °C → 580 °C. The exposures were chosen based on our preliminary experiments in which the surface structure modification was measured as a function of AH exposure.

An atomic hydrogen treatment was performed in a home made UHV chamber which was attached to the preparation chamber of the electron spectrometer ADES-500. An atomic hydrogen source of the capillary type was used in our experiments [5]. The molecular hydrogen was dissociated within a tungsten capillary which was heated by electron bombardment up to a temperature of 1800 °C. It was shown that the degree of dissociation of such a source approached 100% [6]. The hydrogen admitted into the capillary was passed through a palladium filter to remove spurious contaminants. The samples were fixed on a vacuum-annealed Mo sample holder at a distance of about 50 mm from the capillary. The total AH exposure was calculated from ion gauge measurements of the chamber pressure and the exposure time.

The composition and structure of the GaAs(0 0 1) surface were determined by X-ray photoelectron spectroscopy (XPS) and low energy electron diffraction (LEED) in the analytical chamber of an ADES-500 electron spectrometer. The nonmonochromatized Zr Mζ (151.4 eV) line was used for XPS measurements. Electrons emitted normally to the sample surface plane were analyzed with a

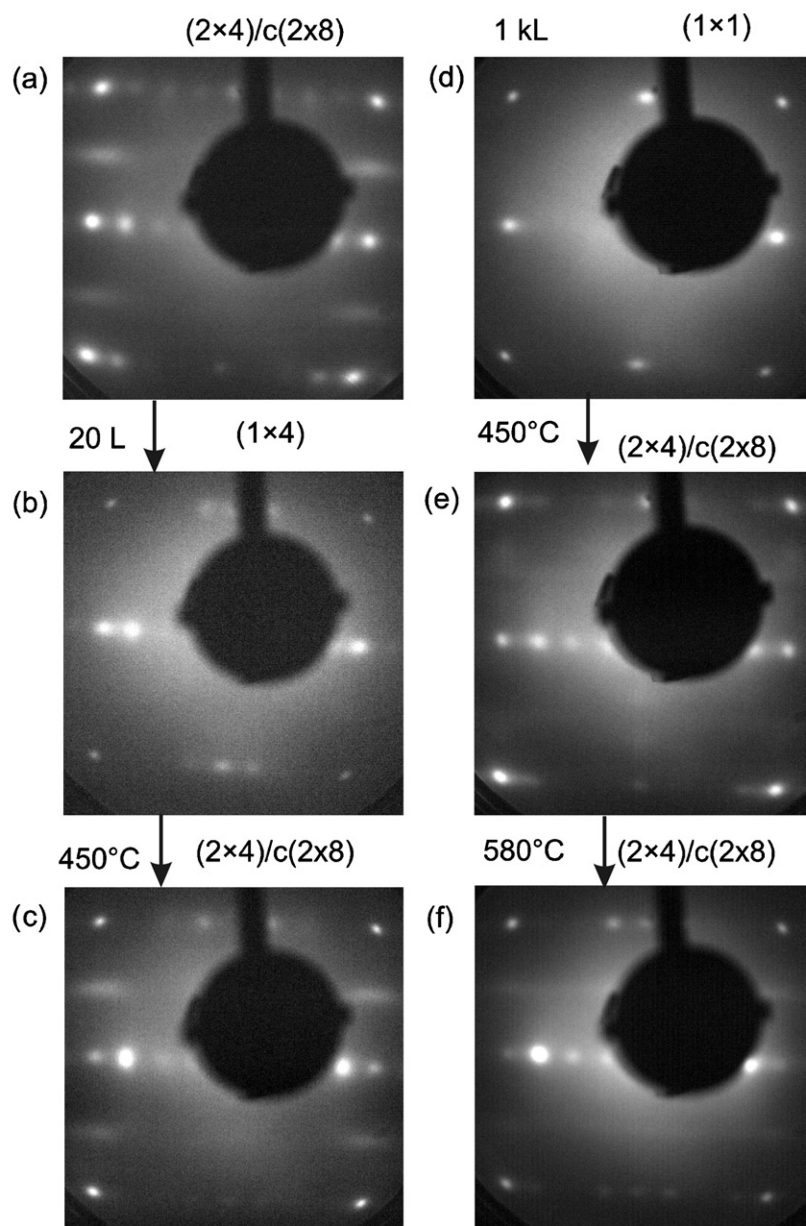

Fig. 1. LEED patterns obtained on GaAs(0 0 1) surface after subsequent AH treatment cycles: (a) clean (2 × 4)/*c*(2 × 8), (b) (1 × 4) after 20 L exposure, (c) (2 × 4)/*c*(2 × 8), T_{ann} = 450 °C, (d) (1 × 1) after 10 kL exposure, (e) (2 × 4)/*c*(2 × 8), T_{ann} = 450 °C, and (f) (2 × 4)/*c*(2 × 8), T_{ann} = 580 °C. The LEED patterns were taken at room temperature at electron energies of 44–55 eV.

Download English Version:

https://daneshyari.com/en/article/5365664

Download Persian Version:

https://daneshyari.com/article/5365664

Daneshyari.com