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Photoemission properties of flat and rough GaAs surfaces with cesium and oxygen layers

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Abstract. The evolution of surface band bending and the probabilities of electron emission in a vacuum are studied under cesium and oxygen deposition on atomically flat and rough As-rich and Ga-rich GaAs (001) surfaces by means of photoreflectance spectroscopy and photoemission quantum-yield spectroscopy. On the rough surface, as compared to the flat one, the suppression of non-monotonic Cs-induced band bending variations is observed, along with the overall band bending increase. Multiple repeated activations of the GaAs (001) surface by cesium and oxygen followed by vacuum anneals led to an increase in the root-mean-square roughness from $R_q \sim 0.1$-0.2 nm up to ~ 3 nm. As a result, the probability of electron escape into vacuum decreased by half.

1. Introduction

The *p*-GaAs surfaces with adsorbed cesium and oxygen layers are widely used to create photocathodes with a negative effective electron affinity (NEA) [1]. The surfaces of semiconductors with a relatively low (0.2 - 0.4 eV) positive affinity, such as *p*-GaAs with adsorbed cesium, have recently attracted attention due to the possibility of increasing the solar energy conversion efficiency using photon-enhanced thermionic emission [2, 3, 4]. The quantum yield and other photoemission parameters are determined by a set of electronic properties of Cs/GaAs and GaAs (Cs,O) interfaces, including band structure, kinetic and transport parameters, such as true and effective electron affinity, the magnitude and width of surface band bending, surface recombination rate, and the probability of electron escape into vacuum. It is reasonable to assume that these electronic properties should depend on the morphology of the initial GaAs surface and of the interfaces with the adsorbates [5], but the available experimental data on these dependences are scarce. One can start photoemission studies from a smooth GaAs surface with atomically flat terraces separated by monatomic steps. However, the chemical treatment and vacuum anneals aimed at preparing an atomically clean surface, cesium and oxygen deposition, and additional anneals in vacuum for the adsorbate layers removal may substantially change the surface morphology in the course of the two-stage activation procedure [1]. In particular, the chemical removal of oxides in the solution of HCl in isopropyl alcohol retains the overall step-terraced morphology of the GaAs (001) surface, but it leads to the appearance of small-scale roughness with a monolayer amplitude on terraces [6, 7]. Vacuum anneals also lead to the GaAs(001) surface roughening [8]. The literature does not offer sufficient data concerning the influence of cesium and oxygen deposition, as well as of subsequent vacuum anneals on the surface