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Influence of preparation parameters for low-energy ion beam nitridation of III–V semiconductor surfaces

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Abstract

The nitridation of InAs, InP, and InSb by low-energy N_2^+ ion bombardment at different preparation parameters was studied by near-edge X-ray absorption fine structure, photoemission spectroscopy (PES), and resonant PES measurements. The investigated surface nitride layers mainly consist of compounds with In–N, V–N bonds and interstitial nitrogen (N_i). The final remaining nitride layer composition strongly depends on the chosen preparation parameters. The nitridation affect composition and annealing temperature offers several opportunities to affect defect curing by ordering and removing oxinitrides, N–O bonds and N_i from nitrided surfaces.

1. Introduction

The nitridation of III–V semiconductor surfaces has attracted much attention due to the importance of epitaxial nitride growth on well-established substrates and of semiconductor surface passivation by nitridation. In addition to thermal [1] and plasma [2–5] nitridation the bombardment with low-energy N_2^+ ions at room temperature is an alternative approach for the surface nitridation, and has been already investigated for InP [6,7] and GaAs [8]. The nitrided surfaces show an extreme smoothness (rms roughness $\leqslant 0.3$ nm as measured by AFM) [9,10] which is attributed to the surface nitridation due to N_2^+ ions. The process of surface nitridation by low-energy N_2^+ ion bombardment of In–V semiconductors and GaAs at room temperature has been investigated in detail using near-edge X-ray absorption fine structure (NEXAFS) and photoemission spectroscopy (PES). In previous works [11,12], it was reported, that beside the formed nitrides there always exist indications for interstitial molecular nitrogen. A model for the nitridation process and the remaining nitride surface layer was given. This report focuses on the influence of the preparation parameters like ion beam energy or annealing and nitridation temperature of In-based III–V compounds. A strong dependence of the nitride layer composition on the preparation conditions is found, which points to the possibility of defect curing. Additionally, new evidence by resonant PES for the implantation of interstitial molecular nitrogen will be given.

2. Experimental

The samples used in this work were commercially available, nominally undoped Czochralski-grown (1 0 0) InAs, InP and InSb substrates, taken into process as received without pre-cleaning. The framework of the sample preparation, the NEXAFS and PES measurements, and the data analysis is described elsewhere [11,12]. Additional resonant PES spectra were recorded using an OMICRON EA-125 electron energy analyzer at the BESSY II U49/2-PGM2 beamline in an angle-integrating mode. The energy resolution was better than 0.2 eV at 400 eV. The energy scale was calibrated using gaseous N_2 and metallic Ag.

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