Realization of InAsP compliant substrates for the fabrication of lattice-mismatched InP-based devices

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Abstract

Previously we have reported on the fabrication of lattice-mismatched InGaAs detectors for detection up to 2.5 μm [1]. State of the art results were obtained, but linear detector arrays were lacking uniformity, most likely due to non-uniform dislocation distribution. Recently GaAs based compliant substrates were successfully introduced which result into a significant reduction of the dislocation density of different materials [2]. These compliant substrates consist of a thin (In)GaAs template which is twist-bonded to a host substrate, e.g. GaAs. We are now investigating the realization of compliant substrates using InAsP twist-bonded template layers, which are bonded to an InP or Ge host substrate. These substrates can then subsequently be used for the realization of low-defect density lattice-mismatched classically InP-based devices.

Introduction

Although (In)GaAs twist bonded compliant substrates have been used for the mismatched MOVPE (MetalOrganic Vapor Phase Epitaxy) of InGaAs layers with lattice-constant larger than InP [3], regrowth of (lattice-mismatched) InGaAs onto an InGaAs template layer was found to be difficult [4] and generally leads to 3D growth mode. Therefore alternatively $InAs_{0.25}P$ template layers were proposed and free-standing compliant substrates were prepared [4]. However, only up to 300x300 μm free-standing $InAs_{0.25}P$ layers can be prepared with this technique, limiting the practical use of this kind of substrates for devices. We are now reporting on the preparation of large-scale, twist bonded $InAs_{0.25}P$ compliant substrates, overcoming the latter problem.

Results

The preparation of twist-bonded compliant substrates is shown in Fig. 1: (a) a wafer containing an thin $InAs_{0.25}P$ layer and an $In_{0.53}GaAs$ etch stop layer, deposited by MOVPE, are twist-bonded to a host substrate (InP, Ge); (b) bonding is established by applying pressure at higher temperature; (c) the sacrificial InP substrate and the $In_{0.53}GaAs$ etch stop layer are removed, respectively using a $HCl:H_3PO_4$ (1:1) and a $FeCl_3:H_2O$ (1:2) solution. The lattice mismatched $InAs_{0.25}P$ layer (to the $InP/In_{0.53}GaAs$) thickness is grown below critical thickness in order to avoid relaxation. Bonding temperatures between 320-500°C and 350-650°C for respectively InP and Ge host substrates were used. Although bonding was realized over these temperature ranges, differential thermal expansion causes the host substrate to bend, especially for Ge host substrates. However, after removal of the sacrificial InP substrate, the bending is removed almost completely. Fig. 2 shows the morphology of the InGaAs etch stop layer after removal of the sacrificial substrate, for both InP and Ge host substrate. Finally, XRD analysis (Fig. 3) before and after bonding shows that there is no degradation of the InAsP layer for Ge bonded substrates, whereas substantial degradation of the InAsP layer bonded at 500°C is found for InP substrates, although lower bonding temperatures were applied. Because generally lower bonding temperatures are found using InP host substrates, decomposition and diffusion of the $InAs_{0.25}P$ layer is suspected.

References

[1] M. D'Hondt, I.Moerman, P. Demeester, *Proc. IPRM 98*, pp 489-492, 1998.

[2] F.E. Ejeckam, M.L. Seaford, Y.H. Lo, H.Q. Hou, and B.E. Hammons, *Appl. Phys. Lett.* 71, pp. 776-778, 1997.
[3] K. Vanhollebeke, I. Moerman, P. Van Daele and P. Demeester, *Proc. SPIE* Vol. 4169, in print, 2000.
[4] J.F. Damlencourt, J.-L. Leclercq, M. Gendry, M. Garrigues, N. Aberkane and G. Hollinger, *Jpn. J. Appl. Phys.* 38, pp. L996-L999, 1999.

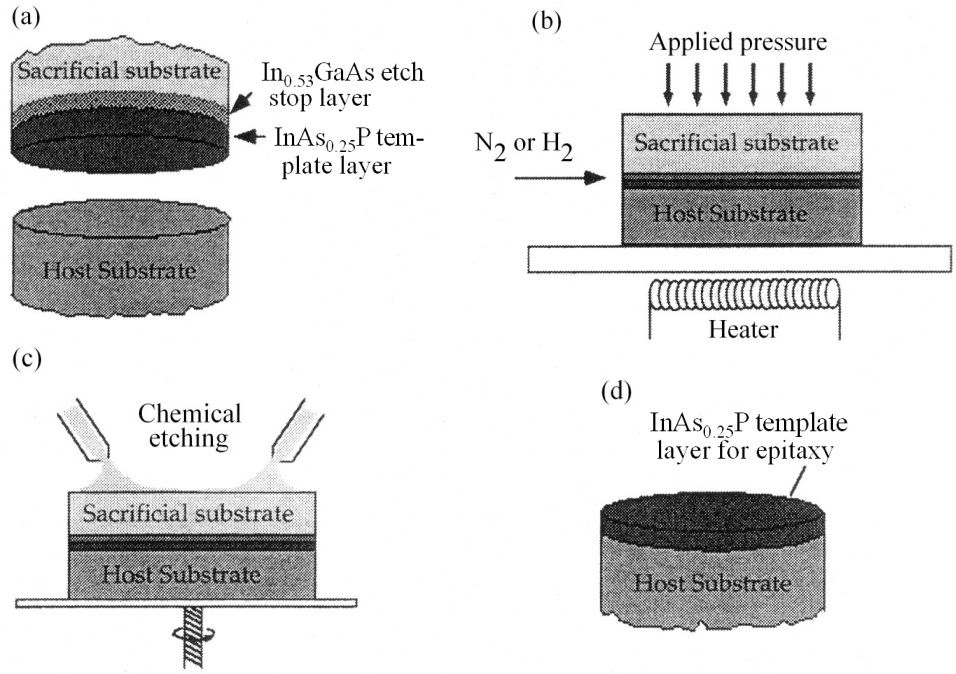

Fig. 1: Fabrication of $InAs_{0.25}P$ twist-bonded compliant substrates, using an InP or Ge host substrate.

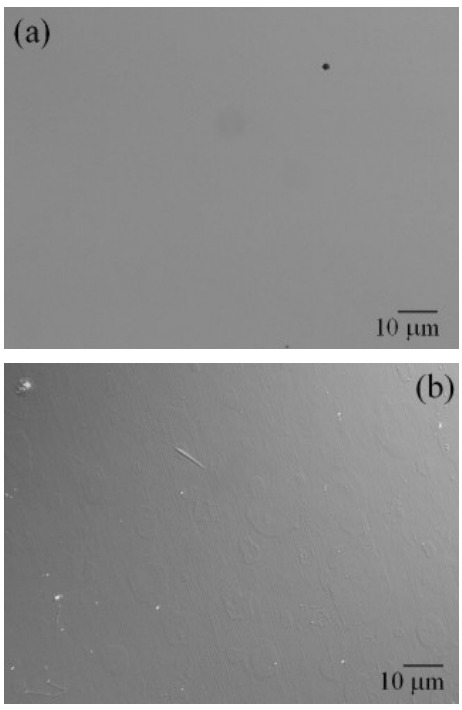

Fig. 2: Normarski microscope images of twist-bonded $InAs_{0.25}P$ layers (with InGaAs etch stop layer) bonded onto (a) InP and (b) Ge.

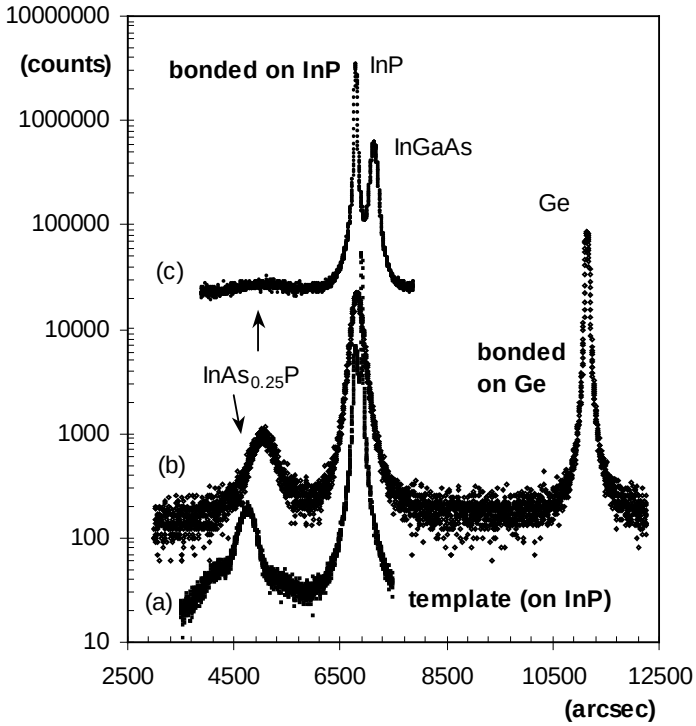

Fig. 3: XRD rocking curves of (a) the as grown template (on InP) and the $InAs_{0.25}P$ template bonded onto Ge (b) and InP (c) after removal of the InP sacrificial substrate.