The role of stress anisotropy in Quantum Wire and Quantum Dot formation

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Stress relaxation during growth of lattice-mismatched III-V compounds can induce the formation of nanostructures. For interfaces where group-V changes, the formation of either quantum wires or quantum dots has been associated with group-V element exchange process [1]. We demonstrate the importance of the stress anisotropy of the surface structure for the formation of quantum dots or wires.

We have studied the nanostructure formation in two systems with a change in the group-V element, InAs/InP and GaSb/GaAs. We have monitored both stress evolution and surface reconstruction in [110] and [1-10] directions during growth of both systems. A higher stress in [110] direction is observed which promotes an anisotropic relaxation resulting in InAs/InP(001) quantum wire formation while maintaining a (2x4) RHEED pattern (figure 1). This strong stress anisotropy is related with the As-In bond distortion in [110] direction compared with the As-As dimer along [1-10] direction [2]. This particular surface configuration, arsenic stabilized, is the standard condition for MBE growth. The growth in other surface conditions as (4x2) surface [1] or according to our results [3] on short range disordered surfaces can avoid this surface stress anisotropy, favouring the formation of quantum dot structures.

However during growth of the GaSb/GaAs(001) system unexpected quantum dots are obtained. We have measured the stress evolution in [110] and [1-10] directions during the Sb-As exchange process and the ulterior quantum dot formation. The initial GaAs (2x4) surface evolutes under Sb flux to a GaSb (2x8) surface, which involves two layers of Sb [4]. The formation of this surface structure produces a similar increase in the stress in both directions (figure 2). When GaSb is supplied, surface reconstruction remains (2x8) and the accumulated stress increases isotropically. In this case, relaxation appears simultaneously in both directions leading to the quantum dot formation (figure 3). Our results show that while the (2x4) InAs/InP surface reconstruction produces a stress anisotropy causing the formation of wires, the (2x8) GaSb/GaAs surface reconstruction minimizes the stress anisotropy leading to the formation of dots under relaxation.

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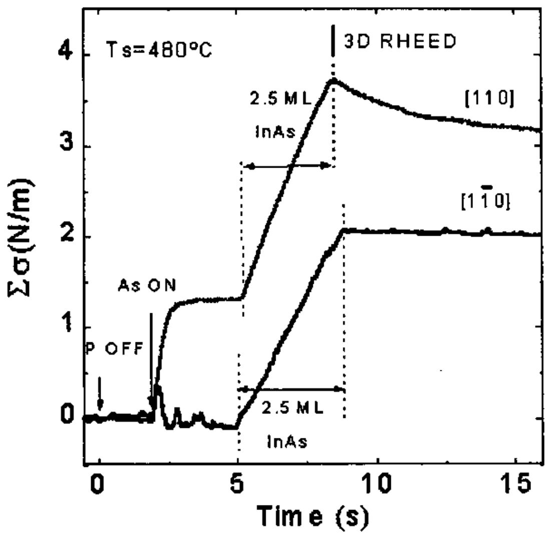
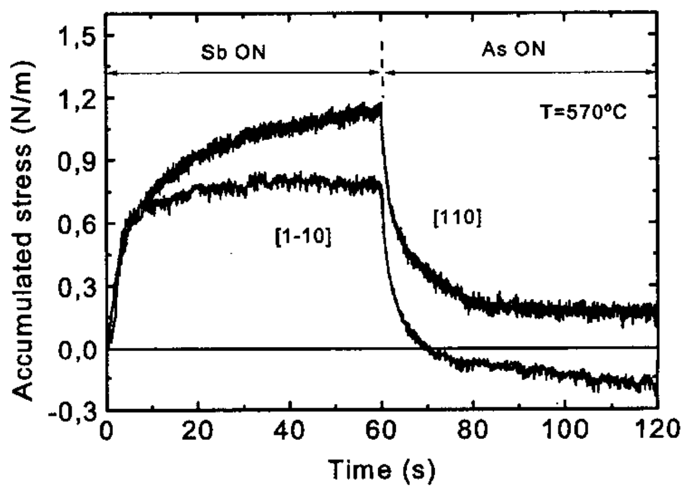


Figure 1. In situ stress measurement during InAs/InP(001) growth. The stress anisotropy between both directions is clearly observed. After 2.5ML, relaxation takes place only in [110] direction due to quantum wire formation.

Figure 2. Accumulated stress evolution of GaAs(001) surface at 570°C under Sb flux (BEP=1×10^{-6} mbar) and recovery under As flux (BEP=4×10^{-6} mbar) for [110] and [1-10] directions.



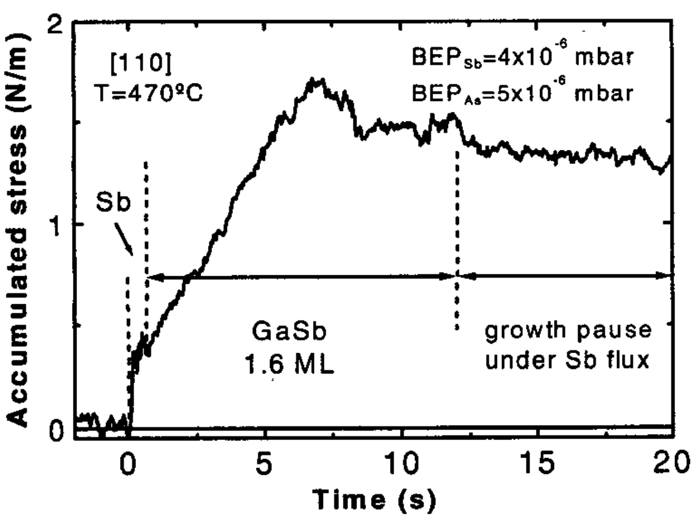


Figure 3. Stress evolution in [110] direction during deposition of 1.6ML GaSb on GaAs(001) at 470°C. Large stress relaxation during quantum dot formation is observed. A similar evolution is observed for [1-10] direction.