Examining the effects of strain and Tl content on the properties and structure of TlGaAs films.

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Tl containing III-V semiconductor compounds have been put forth as a promising material set for small band-gap optoelectronic devices active in the mid to far-IR. However, it has been found that only low concentrations of Tl may be incorporated into III-V alloys. In the $Tl_xGa_{1-x}As$ system, using solid-source MBE only up to x=7% Tl has been successfully incorporated into a single crystal TlGaAs film without Tl droplets appearing, and this required growth at low temperatures (200°C) and in a narrow growth window in order to prevent defects from forming in the films[1]. Difficulty in incorporating Tl into the III-V films of sufficient quality for device use has limited the practical application of Tl containing alloys.

In this work, we have examined the impact of film strain and Tl content on the properties and structure of $Tl_xGa_{1-x}As$ films, with the goals of improving film quality and examining the effect of strain on the amount of Tl that can be incorporated into TlGaAs. TlGaAs films were grown at low temperature in a Veeco GENxplor MBE system using a valved As-cracker and solid source effusion cells for group-III elements. TlGaAs growth was monitored by RHEED. Films were grown on GaAs, InGaAs, and AlGaAs underlayers of varying lattice parameter in order to examine the effect of compressive and tensile strain on the films. After growth HRXRD 004 2theta-omega scans and 224 RSMs were used to characterize film strain and to estimate Tl content. Spectroscopic ellipsometry was used to measure film optical properties and estimate band gap. TEM was used to examine defect formation in film stacks and to examine alloy segregation in the TlGaAs. We propose that strain engineering through underlayer substrate choice may be used to improve TlGaAs film quality.

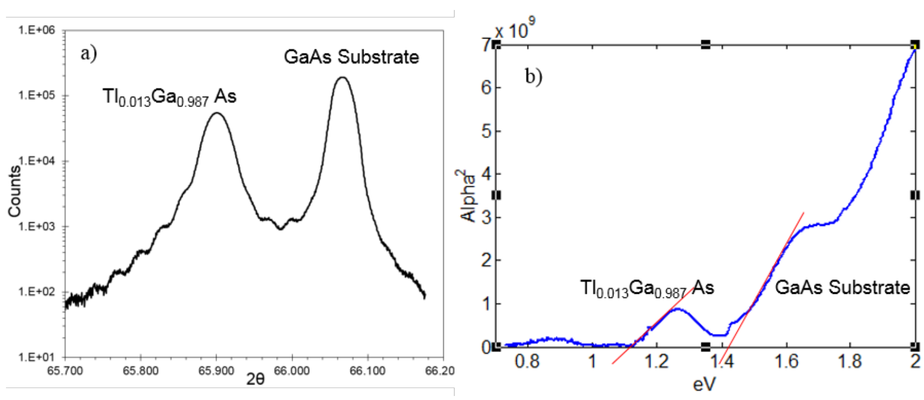

Figure 1: a) HRXRD 004 2θ-ω scan of pseudomorphic $Tl_xGa_{1-x}As$ x=0.013 film on GaAs. b) Absorption (α) squared vs. energy curve measured by ellipsometry for the same film, with red lines indicating curve fits to show absorption edges. The TlGaAs film has an estimated absorption edge of 1.11eV.

[1] R. Beneyton, G. Grenet, Ph. Regreny, M. Gendry, G. Hollinger, B. Canut, and C. Priester, Phys Rev B 72, 125209 (2005)

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Supplementary Pages

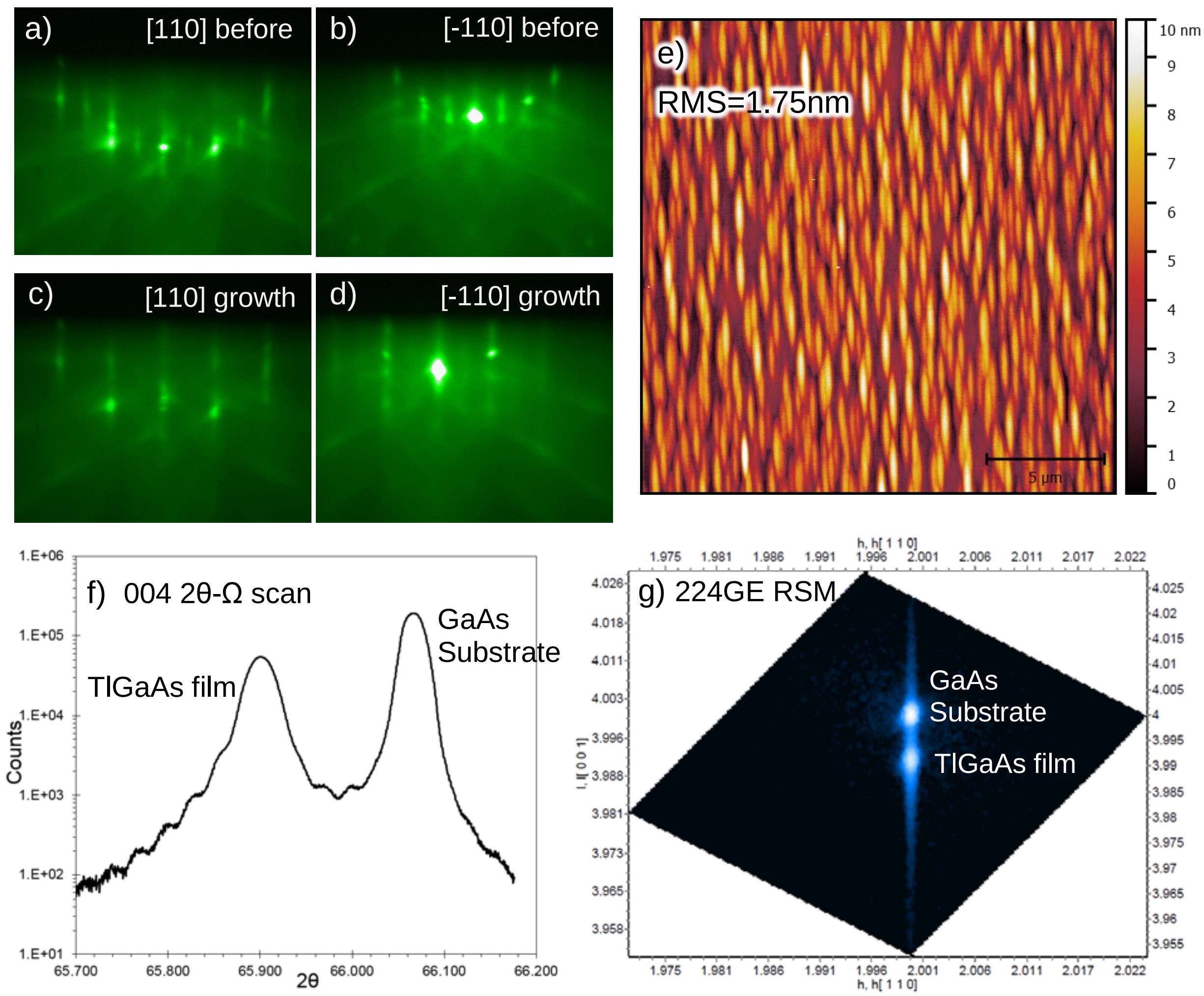

Figure 2: Characterization of a 375nm thick $Tl_xGa_{1-x}As$ film grown on GasAs. a) and b) are RHEED patterns taken down the [110] type directions before the start of low temperature TlGaAs film growth at 212°C, with the pattern corresponding to the GaAs c(4x4) reconstruction. c) and d) are RHEED patterns down the same directions during the growth of the TlGaAs films showing the transition to a (1x2) type reconstruction. e) is an AFM micrograph of the TlGaAs films surface after growth, with an RMS roughness of ~1.75nm and a surface morphology similar to what is expected for LT-GaAs growth under similar conditions. f) is the plot of a HRXRD 004 2θ-Ω scan of the TlGaAs film and substrate, and g) shows a 224 glancing exit reciprocal space map which indicates the TlGaAs film is fully strained in-plane to the GaAs substrate and thus grew pseudomorphically. From the HRXRD 004 and 224 data the Tl content can be estimated as approximately x=0.0126.