Varying MBE growth conditions to limit droplet formation and improve the material properties of TlGaAs films

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TlGaAs may serve as a promising material for optoelectronic devices for the near to mid-IR range. $Tl_xGa_{1-x}As$ films of approximatley x=0.07 Tl have been achieved using solid-source MBE [1,2]. However, production of films with greater Tl content, device relevant thickness, and high material quality is limited by group III droplet formation, incorporation of excess arsenic, defect formation, and epitaxial breakdown. These detrimental effects result from the very low temperatures and high As fluxes needed for TlGaAs growth. Moving towards device quality TlGaAs films will require a better understanding of the trade-offs between conditions that produce high Tl incorporation and those that result in improved film quality.

In this work we have examined the structural, optical, and electrical properties of $Tl_xGa_{1-x}As$ films, with the goal of identifying process conditions that improve film properties. In particular, we focused on the conditions that led to the formation of Tl rich droplets on the film surface and the effects of those droplets on the film. TlGaAs films were grown at low temperatures in a Veeco GENxplor MBE system using a valved As-cracker and solid source effusion cells for the group-III elements. After growth the surface and structural properties of the films were examined by AFM, SEM, XRD and TEM. TlGaAs optical properties were studied by spectroscopic ellipsometry. Select samples were annealed after growth to examine the effect on their optical properties. Droplet formation was suppressed by decreasing growth temperature and increasing arsenic flux. When droplets do form they can produce a variety of different morphologies which depend on the film surface and growth conditions. TlGaAs films without droplets were found to be of uniform composition.

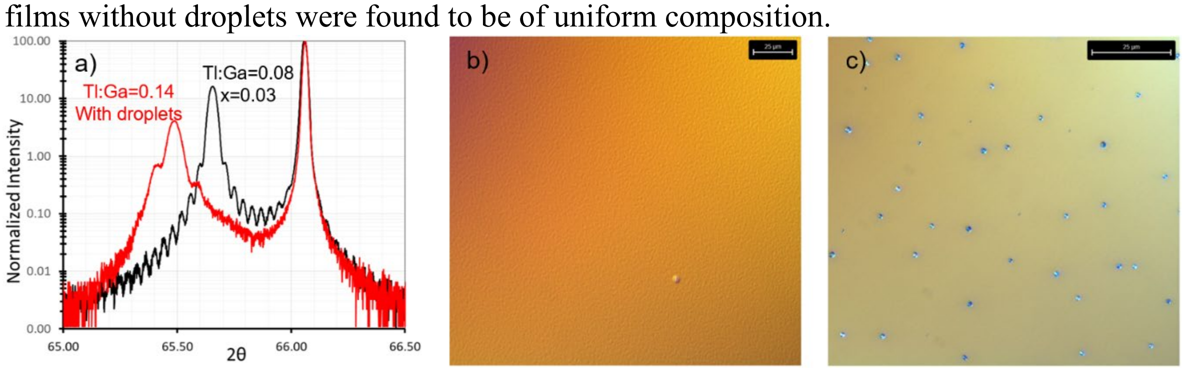

Figure 1: a) HRXRD 004 2θ-ω scans of a $Tl_{0.03}Ga_{0.97}As$ film grown with low Tl:Ga BEP ratio (black) and a TlGaAs film grown with high Tl:Ga (red). The high Tl:Ga BEP ratio produced films with compositional variation and surface droplets. b) and c) show DIC optical images of the surface of each sample respectively. Samples were grown at 190°C.

[1] Y. Kajikawa, H. Kubota, S. Asahina, and N. Kanayama, J Cryst Growth 237-239, 1495 (2003)
[2] 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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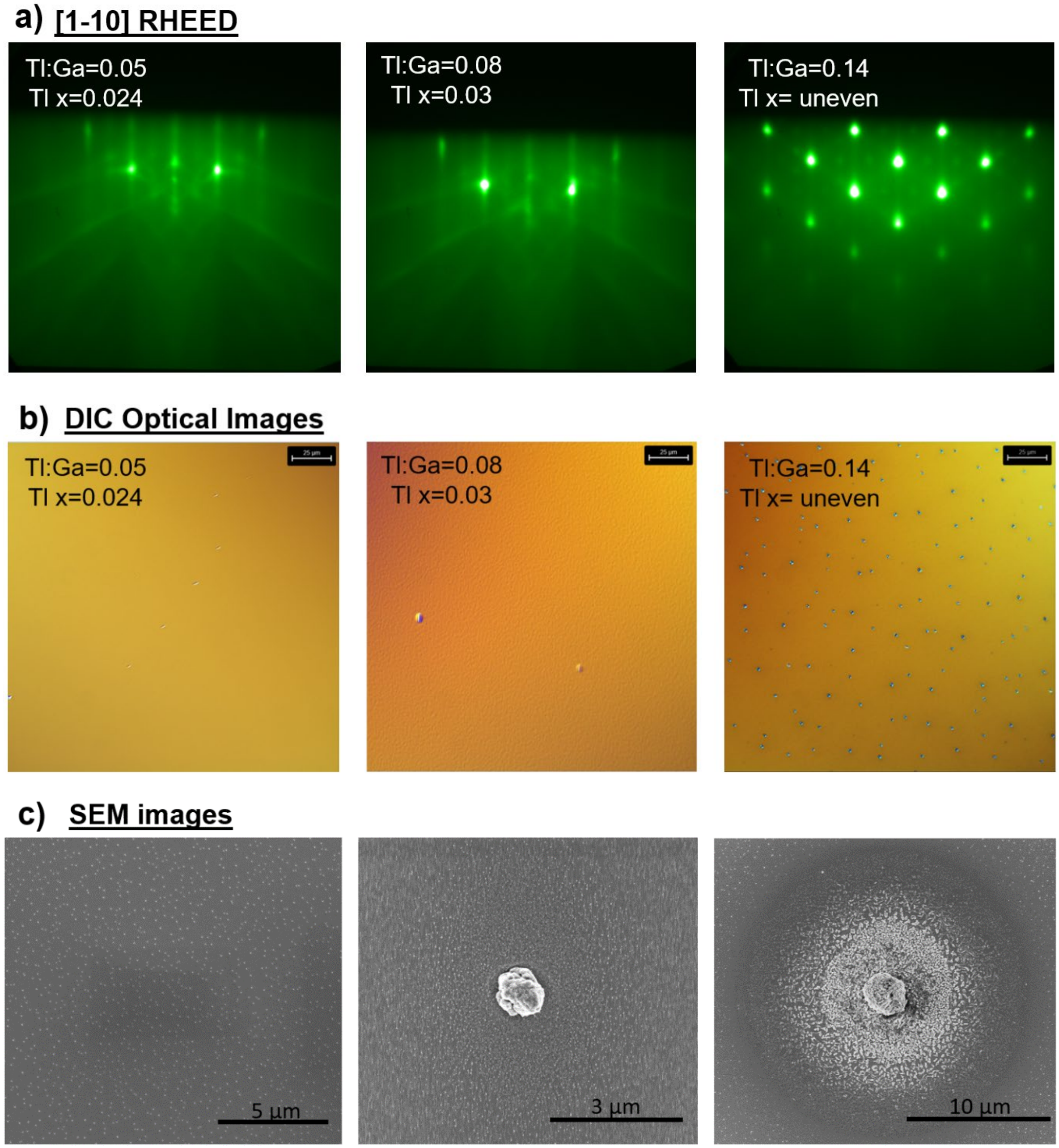
Supplementary Pages



a) RHEED patterns of three samples grown with increasing Tl flux and otherwise matched growth conditions. The Tl:Ga BEP ratios and resulting $Tl_xGa_{1-x}As$ composition for each sample are indicated. With increasing Tl flux, Tl content increases until droplets form, past which the film surface roughens and through-film composition becomes inhomogenous.

b) DIC/Nomarski optical micrographs of the surfaces of the same three samples shown in a)

c) SEM images of some of the different Tl-rich droplet morphologies that can occur on TlGaAs surfaces. Each image shows a sample grown under different conditions.