Integrating GaSb-based infrared detectors with Si substrates via interfacial misfit arrays

Trent A. Garrett,[1] Jacob A. Tenorio,[1] Madison Drake,[1] Pooja Reddy,[2] Kunal Mukherjee,[2] Kevin A. Grossklaus,[3] Shimon Maimon,[4] and Paul J. Simmonds[1, 5]

[1]*Micron School of Materials Science & Engineering, Boise State University, ID 83725, USA*
[2]*Materials Science & Engineering, Stanford University, CA 93405, USA*
[3]*Department of Electrical and Computer Engineering, Tufts University, Medford, MA 02155, USA*
[4]*NetzVision LLC, Rochester, NY 14618, USA*
[5]*Department of Physics, Boise State University, ID 83725, USA*

With applications from night vision and aerial target acquisition, to space telescope operation, infrared (IR) detectors are of great interest to the defense and scientific communities alike. The functionality of these detectors hinges on achieving a high signal-to-noise ratio so that weak signals can still be resolved. Of the many IR detector designs, the nBn device has emerged as a leading choice. As the name suggests, nBn detectors comprise an electron-blocking barrier between *n*-type absorber and contact layers [1]. nBn-based IR detectors are typically grown on GaSb substrates, which are expensive and only widely available up to 4–6" diameter. In addition, integrating a detector grown on a GaSb substrate with the Si-based ROIC via direct bonding interconnect processing is difficult. nBn detectors produced directly on Si substrates would overcome these problems. However, this approach comes with its own set of challenges, primarily due to the large lattice mismatch between GaSb and Si. We therefore adopt the use of interfacial misfit (IMF) arrays grown by molecular beam epitaxy (MBE) to manage strain at the III-Sb/Si heterointerface. IMFs consist of the spontaneous formation of a 2D array of 90º dislocations that lie in the plane of the heterointerface. Previous studies show that thin initiation AlSb layers between the GaSb and Si are critical. GaSb deposited onto an AlSb/Si IMF heterostructure has dramatically improved material quality and lower threading dislocation density (TDD) [2]. We will discuss how choices regarding AlSb growth initiation, substrate temperature, annealing, AlSb thickness, and AlSb growth rate affect the quality of GaSb overlayers. By optimizing these MBE growth parameters, initial results suggest that we can grow GaSb layers with quality comparable to the current state-of-the-art, giving us a benchmark against which to measure further improvements. We will discuss the performance of nBn devices integrated with our optimized GaSb-on-Si buffers. Promising initial results include background limited infrared photodetection (BLIP) at 150 K (Fig. 1), and the ability to carry out thermal imaging with a 300 K blackbody background. This work is supported by the Office of Naval Research through grant #N00014-21-1-2445 and by the National Science Foundation grant GRFP #1946726.

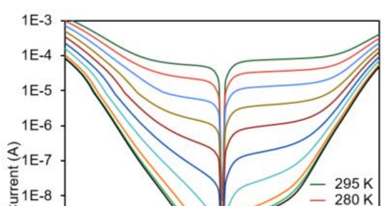

Figure 1: Temperature dependent IV curves for an nBn device on a Si(100) substrate. We see BLIP at 150 K, while 10× dark current decrease per 30 K of cooling indicates good material quality.

[1] S. Maimon and G.W. Wicks, Applied Physics Letters **89**, (2006).
[2] K. Akahane, N. Yamamoto, S.-I. Gozu, and N. Ohtani, Journal of Crystal Growth **264**, 21 (2004).

Supplementary Page

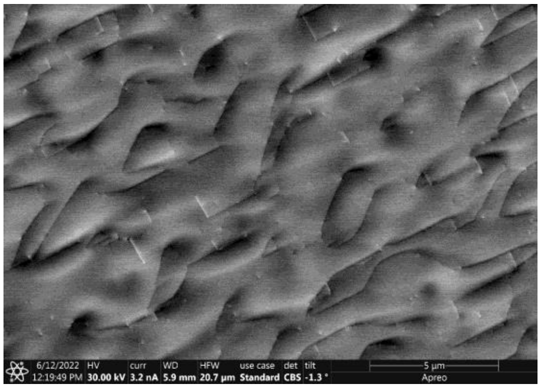

Figure 1 supp.: Electron channeling contrast imaging scan showing threading dislocations in a sample containing a dislocation filtering superlattice. For this sample we found TDD = 2.8×10^7 cm^{-2}

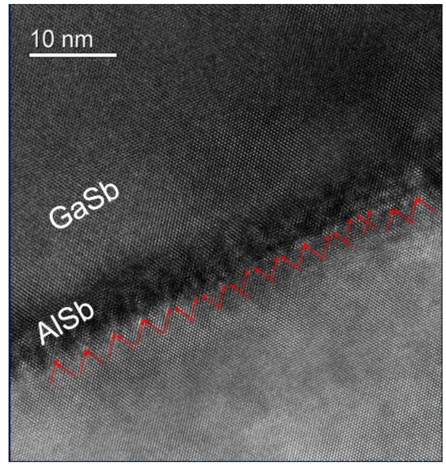

Figure 2 supp.: High resolution transmission electron microscopy image displaying the III-Sb/Si heterointerface where red arrows indicate the location of periodic misfit dislocations forming the IMF array.

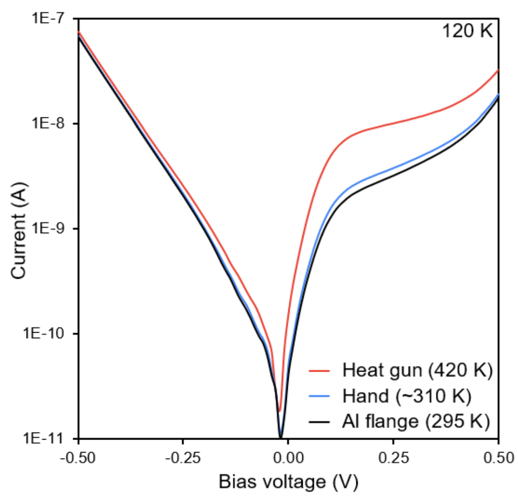

Figure 3 supp.: IV response at 120 K of a single-element nBn detector fabricated on a Si(100) substrate, to illumination with: a room temperature Al metal flange (~295 K, 10% emissivity), a hand at ~310 K (90% emissivity), and a heat-gun at ~420 K. Critically, the ability to distinguish the hand from the flange suggests we could use this device for thermal imaging with a 300 K blackbody background.