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Cross-Sectional Study of Macrodefects in MBE Dual-Band HgCdTe on CdZnTe

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HgCdTe dual-band mid-wave infrared/long-wave infrared focal-plane arrays on CdZnTe are a key component in advanced electrooptic sensor applications. Molecular beam epitaxy (MBE) has been used successfully for growth of dual-band layers on larger CdZnTe substrates. However, the macrodefect density, which is known to reduce the pixel operability and its run-to-run variation, is larger when compared with layers grown on Si substrate. This paper reports the macrodefect density versus size signature of a well-optimized MBE dual-band growth and a cross-sectional study of a macrodefect that represents the most prevalent class using focused ion beam, scanning transmission electron microscopy, and energy-dispersive x-ray spectroscopy. The results show that the macrodefect originates from a void, which in turn is associated with a pit on the CdZnTe substrate.

Key words: MBE, HgCdTe, dual band, macrodefects, STEM, FIB

INTRODUCTION

Dual-band staring focal-plane arrays (FPAs) are a key enabling technology for high-performance infrared sensor systems. These structures consist of HgCdTe *n-p-n* triple-layer heterojunctions and are grown lattice-matched to CdZnTe substrates using molecular beam epitaxy (MBE). Earlier, RVS reported excellent control over MBE processing of dual-band wafers by showing very high compositional uniformity and uniformly low defect density across large lattice-matched CdZnTe substrates and lattice-mismatched Si substrates.[1] Both mid-wave infrared (MWIR)/long-wave infrared (LWIR) and LWIR/LWIR dual-band structures on CdZnTe showed superior FPA array performance, largely due to the low, $\sim 1 \times 10^5$ cm^{-2}, etch pit density of HgCdTe on CdZnTe as against $\sim 5 \times 10^6$ cm^{-2} to 10×10^6 cm^{-2} on Si.[1,2] On the other hand, the macrodefect density of HgCdTe grown on Si substrates is one or two orders of magnitude lower compared with that on CdZnTe substrates, as shown in Fig. 1. Our experience also indicated a larger run-to-run variation of HgCdTe macrodefect density on CdZnTe compared with that on Si.[1,3] Here the macrodefect density refers to the sum of the densities of voids and microvoids, i.e., generally all light-scattering objects >2 μm in size. Earlier, many studies established a direct correlation between the pixel inoperability and the macrodefect density measured on FPAs.[4–8] It is therefore essential to reduce the macrodefect density of HgCdTe on CdZnTe substrates in order to further enhance the pixel operability of FPAs.

In this paper, we present a characteristic macrodefect size versus density histogram of a MWIR/LWIR dual-band HgCdTe epitaxial layer on 6 cm $\times$ 6 cm CdZnTe substrate under highly controlled MBE growth conditions and a procedure for selecting a representative macrodefect for study. This paper also reports a detailed macrodefect cross-sectional study using scanning transmission electron microscopy (STEM) and energy-dispersive x-ray spectroscopy (EDX). Finally, some conclusions are drawn regarding the origin of these defects.

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