Large-Format HgCdTe Dual-Band Long-Wavelength Infrared Focal-Plane Arrays

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Raytheon Vision Systems (RVS) continues to further its capability to deliver state-of-the-art high-performance, large-format, HgCdTe focal-plane arrays (FPAs) for dual-band long-wavelength infrared (L/LWIR) detection. Specific improvements have recently been implemented at RVS in molecular-beam epitaxy (MBE) growth and wafer fabrication and are reported in this paper. The aim of the improvements is to establish producible processes for 512 × 512 30-μm-unit-cell L/LWIR FPAs, which has resulted in: the growth of triple-layer heterojunction (TLHJ) HgCdTe back-to-back photodiode detector designs on 6 cm × 6 cm CdZnTe substrates with 300-K Fourier-transform infrared (FTIR) cutoff wavelength uniformity of ±0.1 μm across the entire wafer; demonstration of detector dark-current performance for the longer-wavelength detector band approaching that of single-color liquid-phase epitaxy (LPE) LWIR detectors; and uniform, high-operability, 512 × 512 30-μm-unit-cell FPA performance in both LWIR bands.

Key words: HgCdTe, infrared detectors, molecular-beam epitaxy (MBE), dual-band long-wavelength infrared (L/LWIR)

INTRODUCTION

Missile seekers are designed to acquire targets of interest at long ranges and discriminate targets from clutter. The use of dual-band long-wavelength infrared (L/LWIR) detector technology provides the ability for these seekers to combine these operations into the same package with enhanced performance. Increasing the format size of dual-band LWIR FPAs and tailoring the detector design for specific LWIR bands enables seekers to be designed for larger fields of view, longer target acquisition ranges, and improved accuracy.

To facilitate these system-level improvements, RVS has demonstrated large-wafer molecular-beam epitaxy (MBE) growth and fabrication of triple-layer heterojunction (TLHJ) dual-band LWIR detector designs.1–4 An increase to a 6 cm × 6 cm wafer size from 5 cm × 5 cm is enabling a greater number of yielded detector array die per wafer, with the ultimate aim to reduce FPA cost. Figure 1 provides a representation of the number of 256 × 256 30-μm and 512 × 512 30-μm detector array die that can be printed on 5 cm × 5 cm and 6 cm × 6 cm wafer sizes. RVS has also developed dual-band infrared FPA architecture that is similar to the existing second-generation FPA architecture currently in production for numerous US Department of Defense (DoD) programs.1,5–8 For commonality with RVS single-color, large-volume factory processes, RVS two-color manufacturing utilizes similar detector and FPA fabrication methods. This manufacturing synergy leverages mature single-color FPA production processes to meet the requirements for third-generation, dual-band HgCdTe infrared FPA systems.9

The RVS dual-band FPA architecture achieves nearly simultaneous temporal detection of two spectral bands while still being producible for pixel dimensions between 30 μm and 20 μm, or even smaller. Dual-band detectors extend the single-color process by simply growing a second n-type absorbing
Fig. 1. Representation of the number of $256 \times 256$ 30-µm and $512 \times 512$ 30-µm detector array die that can be printed on 5 cm x 5 cm and 6 cm x 6 cm wafer sizes.

Fig. 2. Schematic cross-section of the RVS single-contact, single-mesa, dual-band detector architecture, and a scanning electron microscopy (SEM) image of a dual-band detector with indium bumps used for interconnection of the detector array to a readout integrated circuit (ROIC).

Fig. 3. Representative 300-K Fourier-transform infrared (FTIR) wafer cutoff maps for 5 cm x 5 cm and 6 cm x 6 cm wafers in molecular-beam epitaxy (MBE) growth campaigns in 2007, 2008, and 2010, illustrating the improvements achieved in wafer composition uniformity. The contour lines are 0.02 µm, and areas shaded light grey represent compliance with a 300-K FTIR 6.27 ± 0.10 µm specification. The $512 \times 512$ 30-µm detector array size is overlaid on the wafers, and the percentage of die per campaign that met the 300-K FTIR 6.27 ± 0.10 µm specification is shown.