MBE growth of HgCdTe on CdZnTe and alternative substrates, and status of HgCdTe-based nBn technology

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The rapid development of infrared (IR) imaging applications require next generation IR detectors and associated focal plane arrays to have features of lower cost, larger array format, and higher operating temperature. However, the deployment of current state-of-the-art photovoltaic HgCdTe IR detectors based on MBE grown HgCdTe on CdZnTe substrates is restricted by their relatively high cost, limited array format size, and low operating temperature (usually 77K), primarily due to the low device yield, small wafer size availability, and large device dark current.

Over the past two decades, significant effort has been devoted to the MBE growth of HgCdTe materials on large-area Si, Ge and GaAs alternative substrates in order to lower the cost and increase the array format size. However, the large lattice constant mismatch between these alternative substrates and HgCdTe results in a high density of dislocations (mid-10^6 ~ low 10^7 cm^{-2}), which seriously degrades the device performance of fabricated IR detectors, especially long-wave IR (LWIR) imaging focal plane arrays. To achieve high performance HgCdTe LWIR detectors, the dislocation density in the HgCdTe must be controlled below the level of $5\times10^5 cm^{-2}$.

In an effort to improve the yield and raise the operating temperature of IR detectors, a new n-type-barrier-n-type (nBn) structure has been proposed, which is relatively insensitive to point defects and suppresses dark currents, thus enhancing the operating temperature of IR detectors. However, the development of a suitable nBn architecture for HgCdTe presents a serious challenge, primarily due to the difficulty in realizing an ideal nBn band diagram using CdTe or HgCdTe materials: that is, a zero valence band offset combined with a large conduction band offset.

This presentation we will describe our recent efforts in HgCdTe MBE growth, aimed at reducing the cost, increasing the array format size, and enhancing the operating temperature of HgCdTe detectors, by developing new GaSb alternative substrates for MBE growth, as well as superlattice barrier-based nBn device architectures. Compared with Si, Ge and GaAs, GaSb has a much smaller lattice mismatch with HgCdTe. More importantly, our recent preliminary effort at MBE growth of CdTe buffer layers and HgCdTe directly on GaSb has demonstrated that this technology can already provide material of comparable quality to that on well-established GaAs substrates. Theoretically, the use of a HgTe/CdTe superlattice as the barrier layer has the potential to achieve an ideal nBn band diagram. Despite the challenges associated with growth of HgTe/CdTe superlattices, our recent efforts have shown that high quality HgTe/CdTe superlattices can be achieved. These results demonstrate the great potential of GaSb as an alternative substrate for the MBE growth of HgCdTe, and the potential of superlattice barrier-based nBn device architectures for developing next generation HgCdTe infrared detectors.

Biography

Professor Faraone is a Member of the Order of Australia (AM), and a Fellow of the Institute of Electrical & Electronic Engineers (FIEEE), the Australian Academy of Science (FAA), and the Australian Academy of Technological Sciences and Engineering (FTSE). He has published more than 200 international journal papers on his research work, and supervised more than 30 PhD student completions. He is currently Head of the Microelectronics Research Group (MRG) at The University of Western Australia (UWA), and Director of the WA Centre for Semiconductor Optoelectronics and Microsystems (WACSOM). Prior to joining UWA in 1987, he worked primarily in the area of CMOS-based microelectronics and non-volatile memory technology with RCA Labs in Princeton, NJ, USA. Since joining UWA he has worked on compound semiconductor materials and devices, including AlGaN/GaN HEMTs, HgCdTe-based infrared sensor technology and MBE growth, as well as optical MEMS technologies for infrared applications. The research activities of the MRG also include the application of mobility spectrum techniques for magneto-transport studies in advanced semiconductor nanostructures.