MWIR and LWIR InAs/GaSb Superlattice Infrared Photodetectors Grown by Molecular Beam Epitaxy

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BIOGRAPHY

Jianxin Chen received his BS degree with honor from the Electrical Engineering Department, Zhejiang University in 1990 and his PhD degree in Semiconductor Physics and Device Physics from Shanghai Institute of Metallurgy, CAS in 1995. He was with Shanghai Institute of Metallurgy, CAS from 1995 through 2000, with Swiss Federal Institute of Technologies (EPFL) from 2000 through 2001, with Bell Labs at Murray Hill, NJ, USA from 2001 through 2009, and with Princeton University from 2007 through 2009. He joined Shanghai Institute of Technical Physics in 2009 and is charge of the type II superlattice infrared photo-detector research activities at SITP.

TECHNICAL ABSTRACT

InAs/GaSb type-II superlattices have attracted significant attentions due to their promising properties for detection of infrared radiation. These heterostructures are leading candidates for the next generation of infrared photodetectors. They theoretically have important advantages over existing material systems, primarily HgCdTe alloys, especially at long wavelength and very long wavelength regime. However, to realize their inherent potential, superlattice materials with abrupt interface, low defect density must be demonstrated.

We established a molecular beam epitaxy (MBE) based growth process to facilitate the development of InAs/GaSb type-II strained superlattice infrared detection technologies at Shanghai Institute of Technical Physics, Chinese Academy of Sciences. We will report our works on optimizing the MBE growth parameters, including shutter sequences, substrate temperature, and V/III beam flux ratios to tune lattice-mismatch, improve interface quality, and to reduce material defect density.

High quality InAs/GaSb superlattice materials with sharp X-ray diffraction peaks were obtained. As shown in Fig.1, the 0th order satellite peak position has an angle distance of 16” to that of the substrate peak, corresponding to a lattice-mismatch of 1.5×10^{-4}. The full width at half maximum (FWHM) of the 0^{th} order satellite peak is 28”, indicating excellent crystalline quality. We further simulated the measured rocking curves using a four-layer model including an InAs layer, a GaSb layer and two interface (IF) layers. The results show that the two IF layers are ternary compounds InAsSb. The Sb (or As) composition of the two ternary alloys depend on the specific interfaces. We also demonstrated that changing the growth condition, such as the As beam equivalent pressure (BEP) can affect the InAsSb composition as well, which provides an effective way to tune the strain in the superlatice structure.

Materials with P-I-N structures were used to fabricate single element mid wavelength and long wavelength infrared (MWIR/LWIR) detectors. Contact photo-lithography was employed for device fabrication. The mesas were wet etched with mixed solution of citric acid, phosphoric acid, and hydrogen peroxide. Multi-layers of Ti, Pt and Au were deposited by electron-beam evaporation onto both the p-type GaSb bottom layer and the n-type InAs top layer as electrical contact. The detectors were mounted onto home-made cold fingers in Dewar, which were cooled to 77K with liquid nitrogen.

I-V characteristics, and spectral and blackbody response were measured at 77K to characterize the detectors. MWIR photodiodes (8 ML InAs/8 ML GaSb) have a 50% cutoff wavelength of 5.4μm at 77K, as shown in Fig.2. A measured J-V curve and its associated RA-V curve from a 80μm×80μm device are shown in Fig. 3. The dark current density at -20mV bias is $3.8\times10^{-7}A/cm^2$ and a R_0A value of $7.5\times10^4\ \Omega\cdot cm^2$ has been reached. From blackbody response measurements the photodiode has a current responsivity of 0.51A/W and a blackbody detectivity of $7.6\times10^{11}cmHz^{1/2}/W$. LWIR (15 ML InAs/7 ML GaSb) photodiodes with a 50% cutoff wavelength of 12.5μm at 77K have also been fabricated, as shown in Fig. 4. A peak detectivity of $2\times10^9cmHz^{1/2}/W$ has been achieved.

Keywords: InAs/GaSb, superlattice, Infrared, Detector, Molecular beam epitaxy

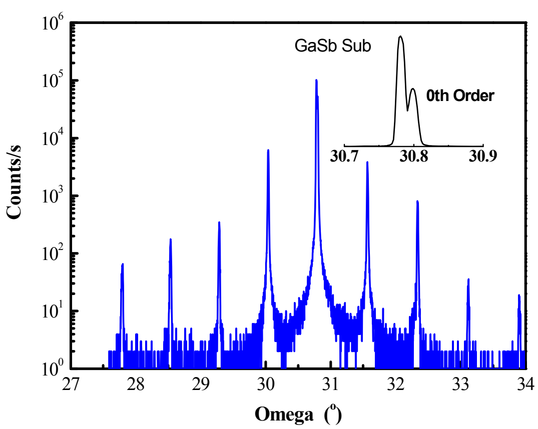

Fig.1 The double crystal X-ray rocking curve of an InAs/GaSb superlattice

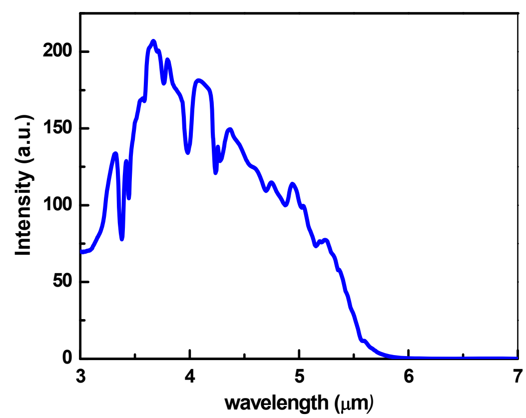

Fig.2 Response spectra of an InAs/GaSb MWIR photodiode

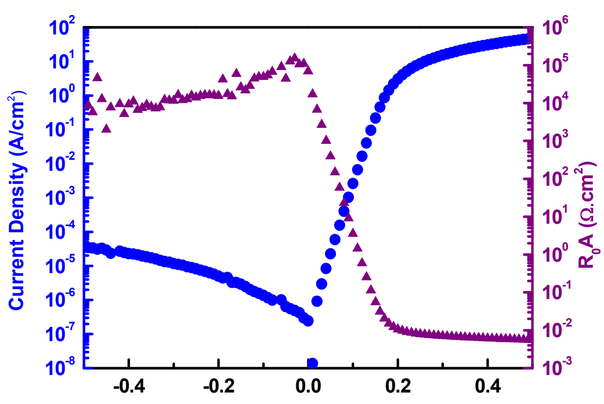

Fig.3 Current density-bias relation of an InAs/GaSb MWIR photodiode

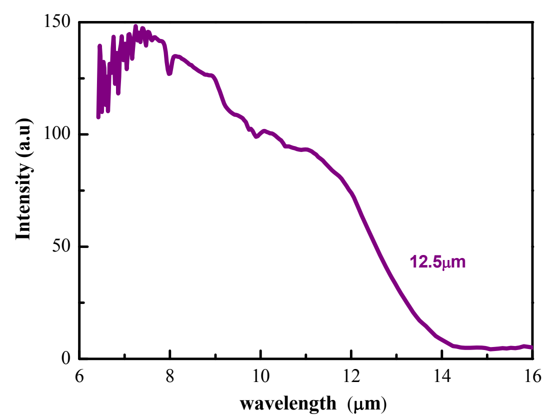

Fig.4 Response spectra of an InAs/GaSb LWIR photodiode