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InAs/GaSb Superlattice Photodiode Array ns-Response

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Abstract : InAs/GaSb type-II superlattice (T2SL) Mid-wave infrared (MWIR) focal plane arrays (FPAs) have recently seen rapid development. However, in small pixel size large format FPAs, the occurrence of high mesa sidewall surface leakage current is a major constraint necessitating proper surface passivation. A simple pixel isolation technique in InAs/GaSb T2SL detector arrays without the conventional mesa etching has been proposed to isolate the pixels by forming a more resistive higher band gap material from the SL, in the inter-pixel region. Here, a single step femtosecond (fs) laser anneal of the T2SL structure of the inter-pixel T2SL regions, have been used to increase the band gap between the pixels by QW-intermixing and hence increase isolation between the pixels. The p-i-n photodiode structure used here consists of a 506nm, (10 monolayer {ML}) InAs:Si ($1x10^{18}cm^{-3}$)/(10ML) GaSb SL as the bottom n-contact layer grown on an n-type GaSb substrate. The undoped absorber layer consists of 1.3µm, (10ML)InAs/(10ML)GaSb SL. The top p-contact layer is a 63nm, (10ML)InAs:Be($1x10^{18}cm^{-3}$)/(10ML)GaSb T2SL. In order to improve the carrier transport, a 126nm of graded doped (10ML)InAs/(10ML)GaSb SL layer was added between the absorber and each contact layers. A 775nm 150fs-laser at a fluence of ~6mJ/cm^2 is used to expose the array where the pixel regions are masked by a Ti(200nm)-Au(300nm) cap. Here, in the inter-pixel regions, the p+ layer have been reactive ion etched (RIE) using CH_4+H_2 chemistry and removed before fs-laser exposure. The fs-laser anneal isolation improvement in 200-400µm pixels due to spatially selective quantum well intermixing for a blue shift of ~70meV in the inter-pixel regions is confirmed by FTIR measurements. Dark currents are measured between two adjacent pixels with the Ti(200nm)-Au(300nm) caps used as contacts. The T2SL quality in the active photodiode regions masked by the Ti-Au cap is hardly affected and retains the original quality of the detector. Although, fs-laser anneal of p+ only etched p-i-n T2SL diodes show a reduction in the reverse dark current, no significant improvement in the full RIE-etched mesa structures is noticeable. Hence for a 128x128 array fabrication of 8µm square pixels and 10µm pitch, SU8 polymer isolation after RIE pixel delineation has been used. X-n+ row contacts and Y-p+ column contacts have been used to measure the optical response of the individual pixels. The photo-response of these 8µm and other 200µm pixels under a 2ns optical pulse excitation from an Optical-Parametric-Oscillator (OPO), shows a peak responsivity of ~0.03A/W and 0.2mA/W, respectively, at λ~3.7µm. Temporal response of this detector array is seen to have a fast response ~10ns followed typical slow decay with ringing, attributed to impedance mismatch of the connecting co-axial cables. In conclusion, response times of a few ns have been measured in 8µm pixels of a 128x128 array. Although fs-laser anneal has been found to be useful in increasing the inter-pixel isolation in InAs/GaSb T2SL arrays by QW inter-mixing, it has not been found to be suitable for passivation of full RIE etched mesa structures with vertical walls on InAs/GaSb T2SL.

Keywords : band-gap blue-shift, fs-laser-anneal, InAs/GaSb T2SL, Inter-pixel isolation, ns-Response, photodiode array
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