DARK CURRENT REDUCTION AND OPERATIONAL WAVELENGTH SHIFT IN NORMAL INCIDENCE InAs/GaAs QDIPs THROUGH THE INTRODUCTION OF AlGaAs LAYERS IN THE ACTIVE REGION OF THE DETECTOR

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Self-assembled Quantum Dots (SAQDs) are an attractive alternative to Quantum Wells (QWs) for near to longwavelength infra-red photodetector applications. Due to the 3-dimensional carrier confinement and lack of symmetry-imposed selection rules in SAQDs, these are intrinsically sensitive to normal incidence photoexcitation and predicted to have lower dark current and higher sensitivity compared to QW intersubband photodetectors [1], though the filling factor is substantially less for QDs than that for QWs. Initial reported results on normal-incidence QD intersubband photodetectors (e.g. [2]) offer encouragement for further investigations.

In this report we demonstrate the ability to reduce the dark current and to shift operational wavelength of InAs/GaAs QD infrared photodetectors (QDIPs) through the introduction of AlGaAs barriers in the active region of the detector structure. AlGaAs layers are placed in between of QD layers to act as blocking barriers for the dark current contribution through the region between the QDs. The presence of AlGaAs/GaAs around InAs QD layers can lead to increase in some intersubband oscillator strengths and a blue shift in the response wavelength of the QDIP.

Figure 1 demonstrates FTIR photocurrent measurement configuration (with normal incidence IR-light) for QDIP samples with and without AlGaAs layers. All QDIP samples examined in this report are MBE grown and based on 5 layers of 3ML InAs QDs grown via the innovative approach of PIG (punctuated island growth) reported in [3]. Our recent PL/PLE results as well as near-IR photocurrent measurements, along with theoretical guidance, have allowed us to identify the dominant electronic states involved in the intersubband transitions.

Results of temperature-dependent photocurrent measurements on a reference QDIP sample without AlGaAs layers are shown in Fig. 2. This structure was optimized for stronger mid-IR photocurrent response with respect to the active region doping, giving a photocurrent peak at 168 meV (7.4 μm) up to 100K, and demonstrating peak responsivity of 3.4 mA/W (see Fig. 3) with detectivity of 7.3×10^9 cmHz$^{1/2}$/W at 10K.

Addition of AlGaAs barriers to the active region of QDIP structure has led to a two-fold effect. First of all, AlGaAs layers act as blocking layers for the dark current. Considering that QD area is only 20% of the wetting layer area, we achieved up to 10 times improvement in the photocurrent to dark current ratio (I_{PC}/I_{Dark}) for the samples with AlGaAs layers. Secondly, a higher-energy photocurrent peak (6.7 μm) appeared on FTIR spectra as shown in Fig. 4. According to our model of electronic states for 3ML PIG InAs QDs, this photocurrent peak corresponds to an electronic transition from the ground QD state to a higher excited QD states. By implementing the confining potential of AlGaAs/GaAs heterostructure, we are able to access higher excited QD states for electronic transitions inside QDIP devices.

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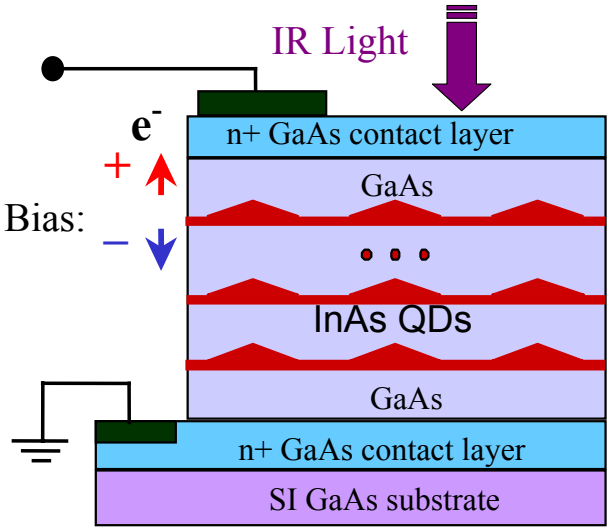

Figure 1. FTIR photocurrent measurements configuration

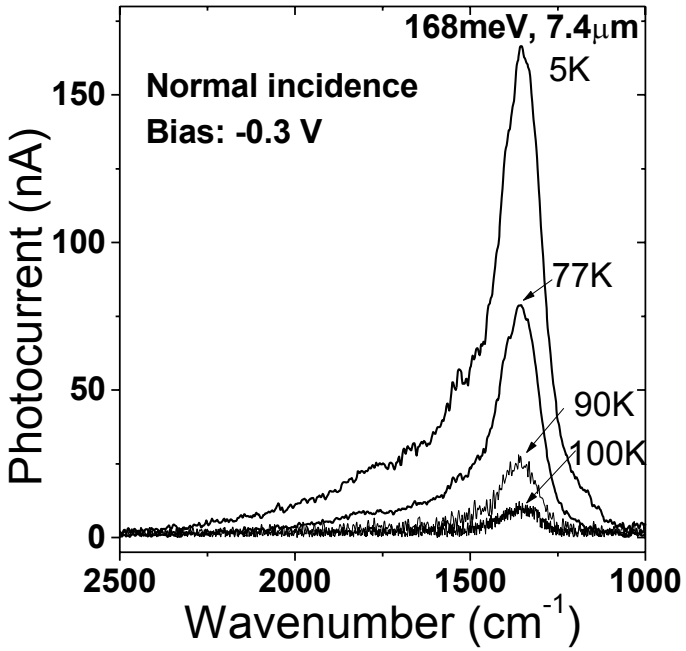

Figure 2. Temperature-dependant IR photocurrent results for QDIP structure without AlGaAs layers

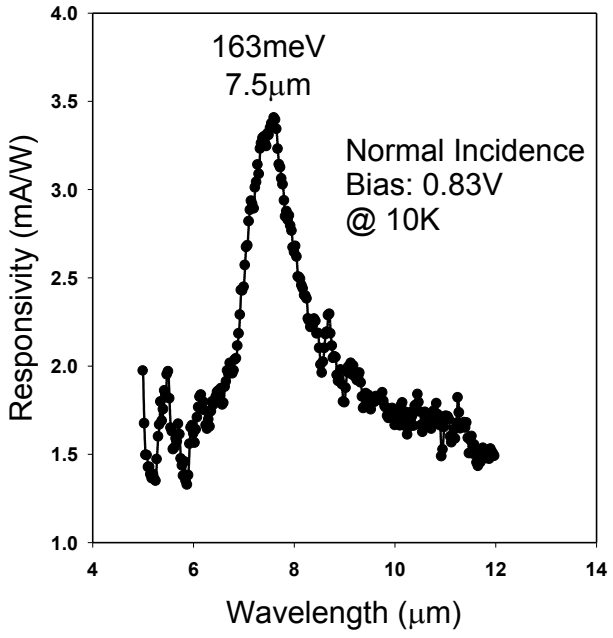

Figure 3. Responsivity measurements for QDIP structure without AlGaAs layers

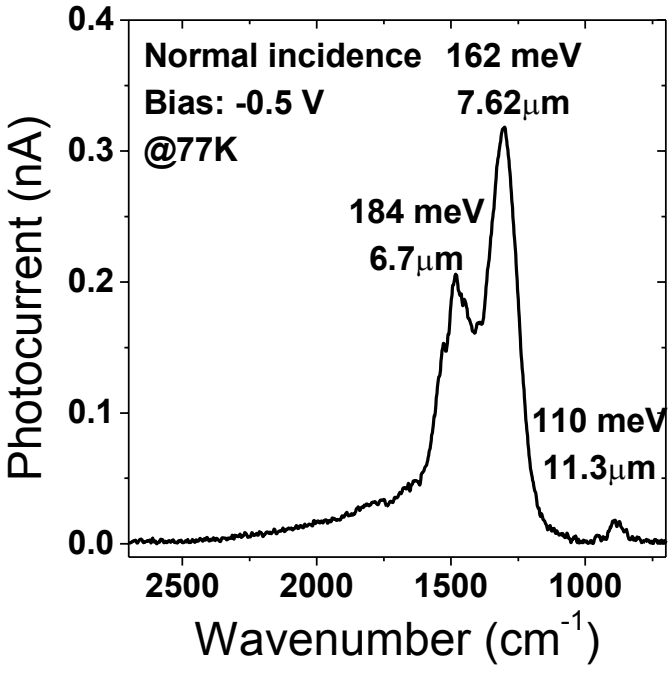

Figure 4. IR photocurrent results for QDIP structure with AlGaAs confining layers