Process Optimization of Sulfur Passivated Interband Cascade Infrared Photodetectors

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Type-II superlattice InAs/GaSb interband cascade infrared photodetectors (ICIP) are promising candidates for high temperature operating detectors without the need of excessive cooling. One important aspect is to reduce the sidewall leakage currents which result from additional surface states and conductive oxides. One approach is the treatment of etched surfaces with sulfur. We investigate the impact of the process routine on a sulfur passivation in terms of surface resistivity. An ICIP with type-II (InAs/GaSb) superlattice absorbers having 4 stages (each 375 nm) with a cutoff wavelength of 7.27 µm was processed into circular mesa structures ranging from 30 µm to 530 µm in diameter. The surface was passivated using aqueous ammonium sulfide ($(NH_4)_2S$) solution and the sulfur atoms covalently bond to the atoms on the surface of the sample [1]. The first result is related to the passivation degradation with higher process temperatures. If sulfur passivated surfaces are exposed to process temperatures higher than 105°C, the surface starts oxidizing and the surface resistivity drops. The sulfur passivation is not stable in ambient air, therefore, an encapsulation layer is required to protect it from oxidation [1]. An rf-sputtered physical vapor deposition (PVD) of Si_3N_4 was carried out. It was found that the sulfur passivated surfaces cannot sustain high rf-powers and are etched, resulting in considerable drop in the surface resistivity (R_s) as shown in Figure 1. Both the temperature degradation and high rf-power lower the ICIP detectivity D*. This is especially significant for smaller photodiodes (<100 µm) as the surface currents are the dominant dark current mechanism due to higher perimeter to area ratio [2]. The Johnson noise limited detectivity and its dependence on temperature is presented in Figure 2. The increase in detectivity from 300 K until 100 K is attributed to the increase in diffusion length of the photo-excited carriers and therefore the responsivity increases, resulting in higher D*. The second factor resulting in enhanced D* at low temperatures is due to increase in the resistance of the device due to suppression of various dark current components (e.g., diffusion current, g-r current etc.) [3].

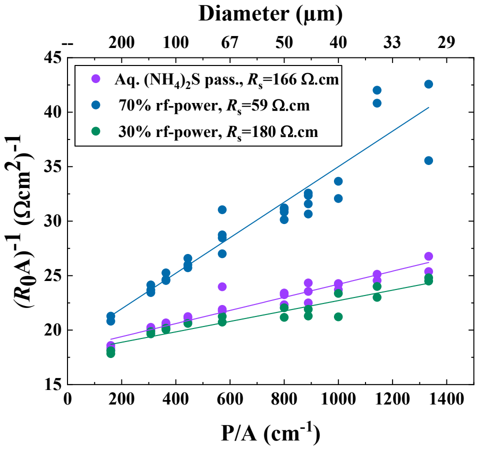

Figure 2: $(R_0A)^{-1}$ vs P/A for sulfur passivated samples with PVD passivation at different rf-powers.

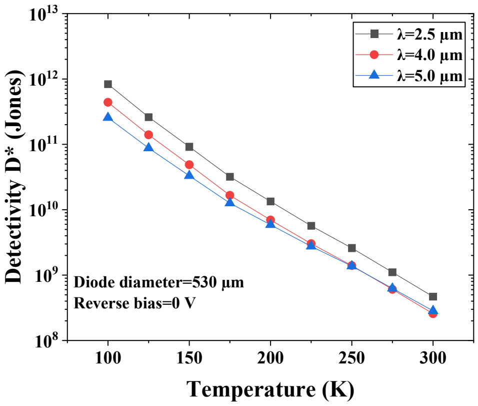

Figure 1: Detectivity vs temperature for different wavelengths.

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