High responsivity InGaAsSb/InP p-i-n photodetectors operating at wavelengths exceeding 1.8 μm

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BIOGRAPHY
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TECHNICAL ABSTRACT
Photodetectors (PDs) operating at a wavelength around 2 μm are beneficial for environmental monitoring and as infrared image sensors. An InGaAs PD has the advantage of being able to employ mature processing technologies, however its responsivity decreases rapidly as the incident light wavelength increases beyond 1.65 μm. To solve this problem, we have proposed employing InGaAsSb as a PD absorption layer [1] since it can have a bandgap wavelength longer than 1.8 μm under nearly lattice-matched conditions with an InP substrate. Here we describe the growth of InGaAsSb and its application as a PD absorption layer.

The samples were grown using metalorganic molecular beam epitaxy (MOMBE) on InP substrates at 500-510°C. For the application of InGaAsSb as a PD absorption layer, both a bandgap reduction and a low background carrier concentration are crucial. When using group-III metalorganic sources, carbon (C) impurity incorporation often leads to an increase in the carrier concentration. The use of tris-dimethylaminoantimony (TDMASb) as an antimony (Sb) source is effective in suppressing the C incorporation [1]. Figure 1 shows the dependence of the SIMS counts of C and Sb for InGaAsSb on the beam equivalent pressure (BEP) of TDMASb. The TDMASb supply greatly reduced the C count to the detection limit, corresponding to a C concentration of 5 × 10^16 cm^-3. In contrast, the Sb count increased with the TDMASb supply, and the incorporated Sb resulted in an increase in the photoluminescence (PL) peak wavelength (Fig. 1(b)). Figure 2(a) and (b) show the carrier concentration profiles of the unintentionally doped InGaAs and InGaAsSb layers. In the region away from the interface with the n-InP layer, the background carrier concentration of the InGaAsSb layer decreased to 2 × 10^15 cm^-3, which was about one twentieth that of the InGaAs layer. This is due to the low C impurity incorporation as shown in Fig. 1(a). We introduced a small strain (+0.1%) into the InGaAsSb, and then used it as the absorption layer of a p-i-n PD.

The PD structure was grown on a semi-insulating InP substrate, with a 2-μm-thick InGaAsSb absorption layer sandwiched between a top p-InGaAsP and a bottom n-InP contact layers. Circular mesa devices were fabricated using wet chemical etching, and antireflection coating was used on the surface. Figure 3 shows the spectral response of the fabricated PD. The 50% and 10% cutoff wavelengths were 1.8 and 1.85 μm, respectively, under a reverse bias voltage of 1 V. These values are more than 0.1 μm longer than those of a conventional InGaAs PD. The responsivity was almost constant at 1 A/W over a wide wavelength range of 1.4 to 1.7 μm. The responsivity versus reverse bias voltage of the PD is plotted in Fig. 4, with an incident wavelength of 1.65 μm. The responsivity of about 1 A/W remained unchanged even when the reverse bias voltage was reduced from 3 to 0.1 V. This means that the depletion layer is thicker than the 2-μm-thick InGaAsSb absorption layer even at a low reverse bias voltage. The low bias operation results from the low background carrier concentration of the InGaAsSb layer, shown in Fig. 2. In addition to the high responsivity, the cutoff wavelength of the PD is expected to exceed 2 μm by adding a larger strain and/or a small amount

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of nitrogen [2] to the InGaAsSb absorption layer.


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