Enhanced Responsivities of InAs/GaSb Type-II Superlattice Infrared Photodetectors with Graphene Transparent Electrodes

Hsuan-An Chen[1, 2], Hsuan-You Chen[2] and Shih-Yen Lin[1, 2]

[1]Graduate Institute of Electronics Engineering, National Taiwan University, Taipei, Taiwan
[2]Research Center for Applied Sciences, Academia Sinica, Nankang, Taipei, Taiwan
shihyen@gate.sinica.edu.tw

Abstract

Type-II InAs/GaSb superlattice infrared photodetector (T2SL) has emerged its potential as the next-generation infrared photodetector in the MW- (3-5 μm) and LW- (8-12 μm) infrared ranges. However, the major disadvantage of this device lies on its low quantum efficiency resulted from its type-II band alignment. In this case, hundreds of superlattice structures are usually required for the T2SL photo-diodes, which will be very difficult for molecular beam epitaxy (MBE). In our latest publication, we have demonstrated that with increasing device areas, decreasing responsivity values will also be observed for the device due to the longer carrier transport paths [1]. The results suggest that the high carrier recombination probability is the other mechanism responsible for the low quantum efficiency of the T2SL infrared photodetector. However, with no suitable material as the transparent electrodes in the infrared range, this issue remained unsolved in previous studies. In this report, similar contact resistance of graphene with Ti/Au metal electrodes is observed on p-type GaSb substrates. High transmittance > 95 % is observed for graphene in both MW- and LW- infrared ranges. By using graphene as the transparent electrodes of T2SL, over tem-times responsivity enhancement is observed for the device. The results have demonstrated the potential application of graphene as transparent electrodes in the infrared range. The sample discussed in this report is prepared by a REBER C21 solid-source MBE system. A 30-periods InAs (5 MLs) / GaSb (5 MLs) superlattice structure with InSb (1 ML) strain compensator is inserted in a GaSb PIN structure with p-GaSb as the top contact layer [1]. The resistances of 100 × 200 μm^2 graphene/200 nm Au and 20 nm Ti/200 nm Au metal electrodes with different separations on a p-GaSb substrate are shown in Fig. 1. The graphene film is prepared by CVD. The contract resistances of graphene and Ti/Au electrodes on p-type GaSb extracted from transmission line method are 22.1 and 91.7 Ω, respectively. Since Ti/Au is commonly adopted as the Ohmic contact metal on p-type GaSb, the similar contact resistance of graphene with Ti/Au electrodes on p-type GaSb substrates suggests that graphene can also act as a Ohmic contact metal on p-type GaSb. The transmittance curve of graphene in the infrared range is obtained by attaching the graphene film to a Ge window and performing the transmission measurement is a fast Fourier transform infrared spectroscopy. The curve is shown in Fig. 2. As shown in the figure, > 95 % transmittance is observed for graphene in the wavelength range 1.3 - 22.2 μm. Considering the ~ 90 % transmittance of ITO for blue/green LEDs, the high transmittance of graphene in the long wavelength range has demonstrated its potential for the application of infrared transparent electrodes. The fabrication procedure of T2SL infrared photodetectors with graphene as the transparent electrode is shown in Fig. 3. Graphene is transferred to the T2SL infrared photodetector after the passivation procedure and pattered after the metal deposition procedure. Since the top p-type GaSb layer contacts with graphene instead of the metal electrode, graphene acts as Ohmic transparent electrode covering the T2SL infrared photodetector. The 10 K spectral responses of the devices with and without graphene as the transparent electrode are shown in Fig. 4. The device area is 300 × 300 μm^2. As shown in the figure, over ten-times responsivity enhancement is observed for the device with graphene electrodes. The results suggest that with graphene as the transport electrodes, photo-excited carriers can be vertically collected by the electrodes instead of flowing to the metal rim, which has effectively reduced the carrier transport paths. We have demonstrated that graphene is promising for the application of infrared transparent electrodes.

References

[1] H. A. Chen, T. C. Shih, H. Y. Chen and S. Y. Lin, Jpn. J. Appl. Phys., accepted for publication.

Figures

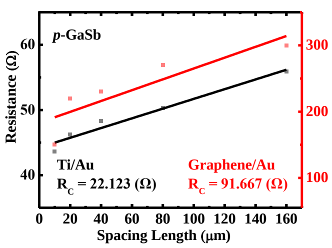

Fig. 1 Resistances of graphene and Au/Ti electrodes with different separations.

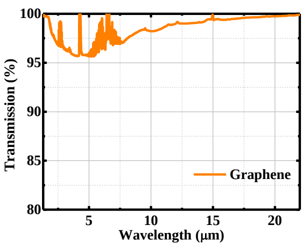

Fig. 2 1.3 - 22.2 μm trans-mittance of graphene.

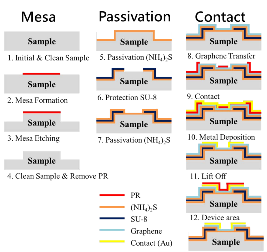

Fig. 3 Device fabrication flow of T2SL infrared photodetectors with graphene electrodes.

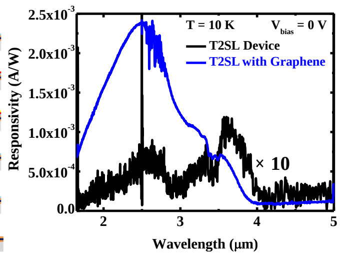

Fig. 4 T2SL infrared photodetectors with and without graphene electrodes.