GeSn Heterojunction Phototransistors on Silicon for High-Responsivity Short-Wave Infrared Photodetection

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1. Introduction

Si-based photodetectors (PDs) capable of operating in the short-wave infrared (SWIR) have attracted increasing research attention for a wide range of applications including fiber-optical communication, Lidar, and imaging [1,2]. Recently, GeSn alloys have been extensively investigated for efficient Si-based SWIR PDs because of its narrow bandgap and compatibility with standard complementary metal–oxide–semiconductor (CMOS) technology. Although GeSn-based PDs have been demonstrated with photodetection range covering the entire SWIR range, the responsivity is still not satisfactory, thereby limiting the performance. Several approaches have been proposed to improve the responsivity. In this paper, we experimentally demonstrate a high-responsivity SWIR GeSn heterojunction phototransistor (HPT) on silicon. The electronic and photonic properties of the GeSn HPT are studied.

2. Experiments

The samples were grown silicon substrates using molecular beam epitaxy. The HPT structure consists of (a) a 120-nm-thick fully strain-relaxed Ge virtual substrate, (b) a 200-nm-thick p-type Ge collector, (c) a 200-nm-thick intrinsic $Ge_{0.95}Sn_{0.05}$ active layer, (d) a 100-nm-thick Ge base, and (e) a 150-nm-thick Ge emitter. The samples were them fabricated into normal-incident devices in a floating-base configuration. A schematic of the fabricated GeSn HPT is displayed in the inset of Fig. 1.

3. Results and Discussion

Figure 1 shows the measured responsivity as a function of the collector-emitter voltage (V_{CE}) under an illumination of 1.5 µW at 1800 nm. The results show strong dependence of responsivity on V_{CE}: the responsivity increases with increasing at small V_{CE}, followed by a sharp decrease as V_{CE} increases further. Thus the optimal V_{CE} to achieve highest responsivity is ~3V. Figure 2 shows the measured responsivity measured with different V_{CE}. The responsivity decreases with increasing wavelength, and become small beyond 1980 nm, corresponding to the direct bandgap of 0.626 eV for the GeSn active layer in response to the Sn-alloying. As a result, the photodetection range covers a significant portion of SWIR range. In addition, it is noted the highest responsivity of 15.3 A/W at 1681 nm, which is considerably larger than these of GeSn PDs (~0.3 A/W) [3] because of the current gain provided by the HPT structures.

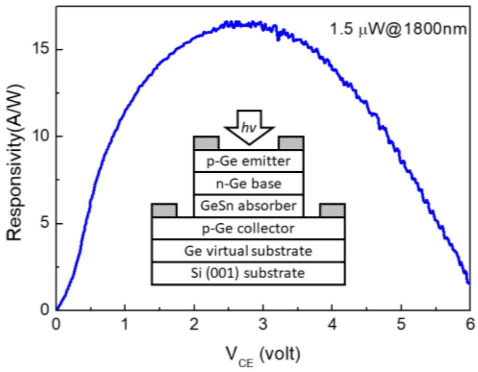

Figure 1. Measured responsivity in terms of collector-emitter voltage. The inset shows the schematics of the GeSn HPT.

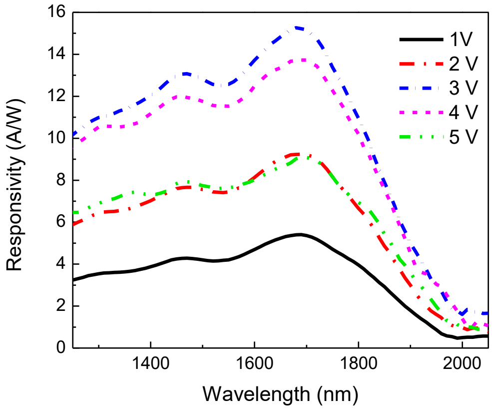

Figure 2. Measured responsivity spectra with different collector-emitter voltages.

3. Conclusions

We have demonstrated clear Franz-Keldysh effect in GeSn alloys. A wide range photodetection reaching 1980 nm with a high-responsivity is achieved for high-responsivity short-wave infrared photodetection.

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References

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