Ge/SiGe Quantum-Well Photoconductors on Si for C-band Telecommunications

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1. Introduction

Ge/SiGe quantum-well (QW) systems have attracted increasing attention for Si-based integrated photonics [1]. With the features of type-I alignment at Γ-valley, quasi-direct bandgap, and compatibility with Si-technology, photonic devices based on Ge/SiGe QW systems such as modulators [1] and photodetectors [2] have been demonstrated [1-2]. Unfortunately, the effects of compressive strain and quantum confinement significantly increase the direct bandgap energy from 0.8 eV to 0.88 eV, shifting the operation of these devices to ~1440 nm [1, 2]. To be compatible with the Erbium window of the telecommunication C-band (1530-1565 nm), the use of tensile strain is proposed [3]. In this paper, we show primary results on the development of photodetectors based on tensile-strained Ge/SiGe QWs for telecommunication C-band applications.

2. Sample structures

The samples used in this study were grown (001) Si substrates by molecular beam epitaxy. The structure consists of (1) a 60-nm-thick Ge seed layer grown at 350℃, (b) a 60-nm-thick Ge buffer layer grown at 500℃, followed by *in-site* annealing at 800℃ for 5 min, and (c) five pairs of Ge/$Si_{0.1}Ge_{0.9}$ QWs with thicknesses of 7/10 nm. The 120-nm-thick Ge layer serves as the virtual substrate (VS) and has a tensile strain of 0.21% revealed by Raman experiments. This tensile strain is attributed to the *in-situ* annealing process during the cooling from the elevated growth temperature to room temperature due to the mismatch between the thermal expansion coefficients of Ge and Si. The Ge/$Si_{0.1}Ge_{0.9}$ quantum wells are pseudomorphically grown on the tensile-strained Ge, inducing a tensile strain of 0.21% and 1.01% in the Ge wells and $Si_{0.1}Ge_{0.9}$ barriers, respectively. The samples were fabricated into normal incident photoconductors using processing that can be implemented in standard CMOS process flow. A schematic plot of the devices is shown in Fig. 1.

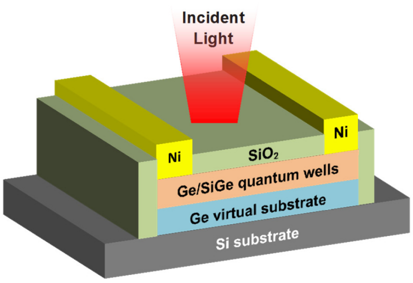

Figure 1. Schematic plot of the Ge/SiGe QW photoconductors.

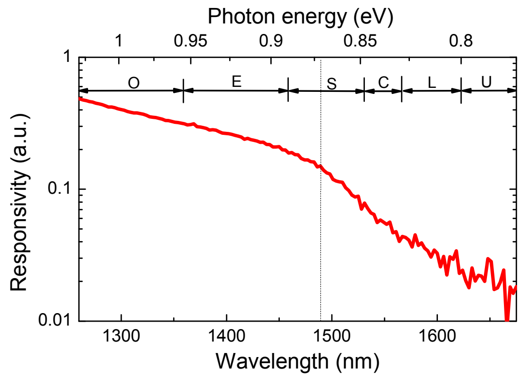

Figure 2. Responsivity spectra of the fabricated photoconductor.

Figure 2 shows the measured responsivity spectra of the photoconductors under 3 V bias. The device shows a broad and slowly-decreasing responsivity spectrum and the detection range can cover the telecommunication C-band. The responsivity spectrum sharply drops above 1490 nm, corresponding to the direct bandgap of the Ge/$Si_{0.1}Ge_{0.9}$ QWs (0.832 eV). The extended photodetection range is attributed to the 0.21% tensile strain in the Ge wells that shrinks the direct bandgap. Further extension of the photodetection range is possible by increasing the Ge well thickness and/or tensile strain to enhance the optical response beyond the telecommunication C-band for Si-integrated photonics.

3. Conclusions

We have demonstrated tensile-strained Ge/SiGe QW photodetectors on Si platforms. With 0.21% tensile strain in the Ge wells, the photodetection range is extended, showing promise for use in Si photonics for C-band optical communications.

Acknowledgements

This work at CCU was supported by the Ministry of Science and Technology of Taiwan under Grant No. MOST 102-2221-E-194-053-MY3.

References

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