Si パターン基板上 Ge エピタキシャル層を用いた近赤外受光器 (2)

Near-infrared photodetector of Ge epitaxial layer on Si patterned substrate (2)

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1. Introduction

A Ge epitaxial layer on Si is employed as near-infrared photodetectors (PDs) in Si photonics. Recently, we have reported a pin PD of a Ge layer prepared on a Si surface patterned with an array of trenches of 500 nm in width and spacing [1]. The threading dislocation density in Ge is reduced by using such a patterned substrate [2]. As a result, the leakage current decreased with maintaining the responsivity at the wavelength of around 1550 nm when the trench depth was 100 nm. However, when the trench depth was increased to 200 nm, the responsivity was degraded [1]. In this study, the mechanism of the responsivity degradation is investigated based on X-ray diffraction (XRD) and scanning electron microscope (SEM) analyses.

2. Experimental procedure

Ge epitaxial layers were prepared as follows. Using i-line photolithography and dry etching, the surface of a bulk Si (001) wafer was patterned into an array of rectangular trenches in the [110] direction. The trench width and spacing are both 500 nm. Two different trench depths of 100 and 200 nm were used. On the patterned surface, a Ge layer of 500 nm in thickness was epitaxially grown at 700°C by ultra-high vacuum chemical vapor deposition (CVD) with GeH_4 as the source gas. A Si capping layer of 120 nm in thickness was subsequently grown in the same CVD chamber at 600°C with Si_2H_6. Then, a SiO_2 layer was deposited at 350°C by plasma-enhanced CVD. To structurally evaluate the Ge layer, XRD and SEM measurements were conducted.

3. Results and discussion

Fig. 1 shows typical XRD ω-2θ curves for the Ge layers on the patterned Si substrate. For the trench depth of 100 nm in Fig. 1(a), two diffraction peaks were observed at about 66.1° and 69.1°, which correspond to the 004 diffraction peaks from the Ge layer and Si substrate, respectively. On the other hand, for the trench depth of 200 nm in Fig. 1(b), a tailing to the side of the large diffraction angles up to about 67.3° was observed in the Ge peak. This indicates the formation of a significant amount of SiGe alloy. The SiGe formation is responsible for the reduction in the responsivity at 1550 nm observed for the Ge PD on the 200-nm-deep trenches [1] because of the blue shift in the absorption edge due to the widening of the direct bandgap. According to the cross-sectional SEM observation, a structural deformation was observed at the top corners of the trenches; the sharp edges of the top corners are energetically unstable, inducing a SiGe alloying.

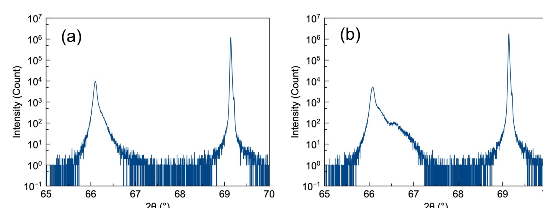

Fig. 1. (a) and (b) show XRD ω-2θ curves of the Ge layers on the Si patterned substrate with trench depth 100 nm and 200 nm, respectively.

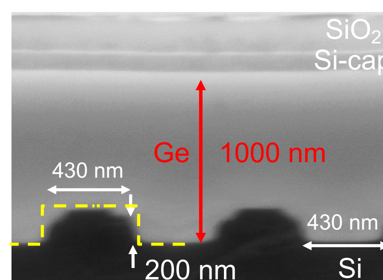

Fig. 2 Cross-sectional SEM image of Ge layer on 200 nm trench.

4. Summary

The mechanism of responsivity degradation around 1550 nm for the Ge PD on Si patterned substrate was investigated. The XRD analyses indicated the SiGe alloy to reduce the optical absorption.

Reference

[1] K. Tsutsumi et al., 2024 JSAP Fall Meeting, 19a-A35-2.

[2] M. F. B. Amin et al., Jpn. J. Appl. Phys. 63,02SP78 (2024).

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