Ge の顕微フォトルミネセンスにおける励起光強度密度の影響

Effect of excitation power density on micro-photoluminescence for Ge

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1. Introduction

Si photonics has attracted interests in high-speed optical communications with a low-cost fabrication and a low-power consumption. Ge has been investigated as a material for near-infrared (NIR) light sources on Si [1] as well as photodetectors [2] and optical modulators [3] in spite of the indirect band structure. In this work, NIR light emission from Ge is studied using micro-photoluminescence (μ-PL) spectroscopy at room temperature (RT). Particularly, effects of power density of 457-nm excitation laser light are studied. As a result, a suppression of PL emission from Ge is observed in the longer wavelength region (> 1.6 μm) under relatively high-power excitations. Similar suppression is observed for InGaAs on InP with the PL peak at ~1.6 μm, although such a suppression is not seen for Si and GaAs with the peak located at much shorter wavelength (1.1 μm and 0.87 μm) than those for Ge and InGaAs.

2. Experimental

PL spectra were taken at RT for a Ge (001) wafer using an excitation light source of 457-nm laser. The penetration depth is estimated to be ~20 nm for Ge. The excitation power density (photon flux density) on the surface was changed in two ways. One is to change the objective lens with different magnifications of ×20, ×50 and ×100 under almost the same excitation power of 3.5±0.3 mW. The power density is increased with increasing the magnification because of the change in the laser diameters on the surface. The nominal diameters are 5, 2 and 1 μm for the magnifications of ×20, ×50 and ×100, respectively. The other way is to change the laser power by using ND filters with fixing the objective lens (×50). Similar measurements were done for other semiconductor materials of InGaAs on InP, bulk Si and bulk GaAs with the (001) surface.

3. Results and discussions

Figure 1(a) shows typical μ-PL spectra for Ge obtained using different objective lenses with the magnification of ×20, ×50 and ×100 under the excitation power of 3.5±0.3 mW. For the ×20 lens, PL emission peaks were observed at ~1.54 μm and ~1.78 μm, which correspond to the direct and indirect transitions in Ge, respectively. With increasing the magnification, the PL emission was suppressed particularly in the longer wavelength region of > ~1.6 μm. Such a suppression was also observed for InGaAs showing a single PL peak at ~1.6 μm due to the direct transition. As in Figure 1(b), the peak position for InGaAs was red-shifted with increasing the magnification, indicating the suppression of PL emission in the longer wavelength region. On the other hand, such a suppression is not seen for indirect-gap Si and direct-gap GaAs with the peak located at much shorter wavelength (1.1 μm and 0.87 μm) than those for Ge and InGaAs. Under higher excitation power density, a certain phenomenon should take place in the longer wavelength region for Ge and InGaAs, and a possible reason would be the free-carrier absorption, since the optical absorption due to the free-carrier absorption is increased with the square of wavelength [4]. Further experiments will be performed using different conditions such as the use of different wavelength of excitation laser light.

4. Summary

A suppression of PL emission was observed for Ge in the longer wavelength region of > ~1.6 μm. Such a phenomenon was also observed for InGaAs, although such a suppression was not seen for Si and GaAs with the peak located at shorter wavelength.

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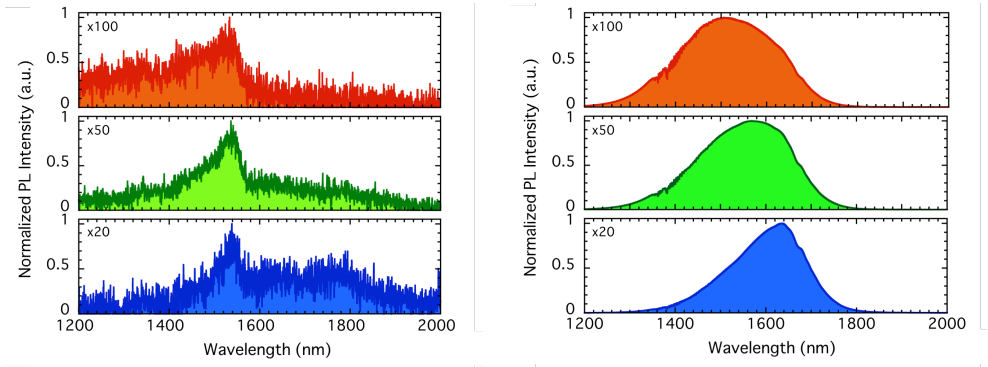

(a) bulk Ge (b) InGaAs

Fig. 1. PL spectra for (a) bulk Ge and (b) InGaAs on InP at RT, measured using objective lenses with different magnifications of ×20, ×50 and ×100 under an excitation power of 3.5±0.3 mW