**Effect of excitation power density on micro-photoluminescence for Ge**

**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**

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.

**REFERENCES**


---

**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.