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微細梁構造を用いた Si 上 Ge のバンドギャップ制御

Bandgap Control of Germanium on Silicon Using Microbeam Structures

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A near-infrared (NIR) light emission with the peak wavelength beyond 1700 nm is presented for Ge epitaxial layers on Si under an externally applied tensile stress. Ge epitaxial layers on Si have been widely studied for near-infrared (NIR) photodetectors and light emitters in Si photonics. Tensile lattice strain is known to reduce the direct bandgap energy of Ge, leading to the device operation with the wavelength beyond 1550 nm. Moreover, under a biaxial tensile strain (stress) as large as 1.4% (2.0 GPa) [1] or a uniaxial tensile strain (stress) as large as 3.8% (3.8 GPa), a transition from the indirect semiconductor to the direct one is theoretically expected; the direct bandgap of Ge is reduced to ~0.6 eV under those strain. Therefore, tensile-strained Ge should be useful for mid-infrared (MIR) active photonic devices. Those photonic devices are important for the optical sensing applications.

So far, we have proposed the micro-mechanical structures of Ge with an elastic deformation [2] to introduce such large tensile strain. In this work, by applying tensile stress of 0.75GPa, a large red shift up to the wavelength of ~ 1710 nm is presented.

In the experiment, Ge layer (300nm) was grown at 600°C on a Si-on-insulator (001) wafer (250-nm-thick top Si layer and 3-µm-thick buried SiO2) by ultrahigh-vacuum chemical vapor deposition with GeH_4. After the growth, a biaxial tensile strain of ~0.15% should be accumulated in the Ge layer at room temperature due to the thermal expansion mismatch between Ge and Si. Electron-beam lithography and dry etching were performed to transfer the pattern of microbeam (cantilever) along [100] crystallographic direction. Finally buried SiO_2 region was removed by wet etching with HF solution. The width and the length of fabricated microbeams are 5µm and 15µm respectively (see FIG. 1.).

Finite element simulation shows that uniaxial tensile strain (stress) ~0.75% (0.75GPa) is introduced around the fixed edge by 3µm bending down of the free edge of microbeam. Taking into account the grown-in biaxial tensile strain of 0.15%, the direct bandgap should be reduced from 0.785 eV (1580 nm) to 0.730 eV (1710 nm). In the micro-PL measurement, an area with the diameter of ~2 µm around the fixed edge was pumped to measure the PL spectra. The PL spectra showed that the emission peak was shifted to 1710 nm with bending (FIG. 2.). This result shows a good agreement with the theoretical calculation. Further red shifts, required for the MIR devices, should be realized by optimizing the micromechanical structures.

[1] Fischetti and Laux, J. Appl. Phys. 80, 2234 (1996).

[2] Lim et al., Opt. Express 17, 16358 (2009).

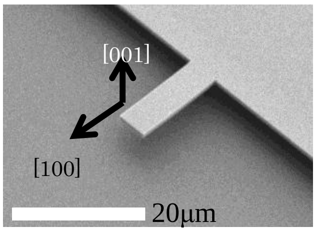

FIG. 1. Scanning electron micrograph of fabricated Ge microbeam

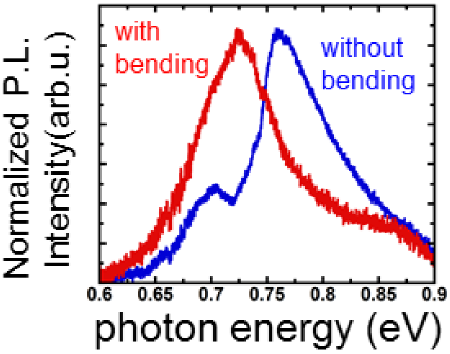

FIG. 2. PL spectra from Ge microbeam