Photoluminescence in Si/SiO_2 Single Quantum Wells

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Introduction

The interest in optical communication has been increasing in the last years for its high speed, high density and low energy consumption. For this purpose, silicon photonics has been considered due to integration with current technologies, broad industrial knowledge as well as relative low cost. Therefore, Si would be the most suitable material but its indirect bandgap makes it an ineffective light source. One form of making the light-emission from Si efficient is by quantum confinement effects, which enable direct recombination [1]. Also, the confinement allows to adjust the peak energy of the emission by altering the thickness of the quantum well. Light-emitting devices with a Si quantum well (< 5 nm) sandwiched between two layers of SiO_2 are fabricated on a Si on insulator (SOI) wafer and their optical properties are observed by photoluminescence (PL).

Experiment

The superficial Si layer of the SOI wafer was 70 nm thick, (100) oriented, p type, and with a resistivity of 5–50 Ω cm. In the process of thinning the Si layer, the wafer went through dry thermal oxidation at 1000 °C repeatedly. Amidst the oxidation steps, the wafer was cleaned with H_2SO_4 and H_2O_2, and the oxide was etched in a dilute HF solution. Finally, the wafer went once more through dry thermal oxidation to form an oxide layer on the quantum well, so that the Si layer was between two SiO_2 layers. The Si layer thickness was measured by spectroscopic ellipsometry.

The subsequent device was excited using an argon laser (514.5 nm), causing the emission of photons. Lenses and mirrors were used to direct the emission from the device, which was focused on a monochromator and the luminescence spectrum was measured using a CCD camera.

Results and Discussion

Each device produced an emission spectrum comprising two energy bands. One band varies its peak energy when the Si thickness is altered, occurring due to quantum confinement effects. The other is approximately constant, attributed to recombination at the Si/SiO_2 interface [2]. The light emission peaks for different Si thickness can be observed in Fig. 1.

The intensity also depends on the thickness of the quantum well (see Fig. 2). As the Si becomes thinner, the PL intensity increases because the quantum confinement effects intensify, which permit more efficient photon emission.

The PL depends on the Si well dimension, the peak is shifted toward the blue when the thickness is decreased, implicating that quantum confinement effects were successfully observed.

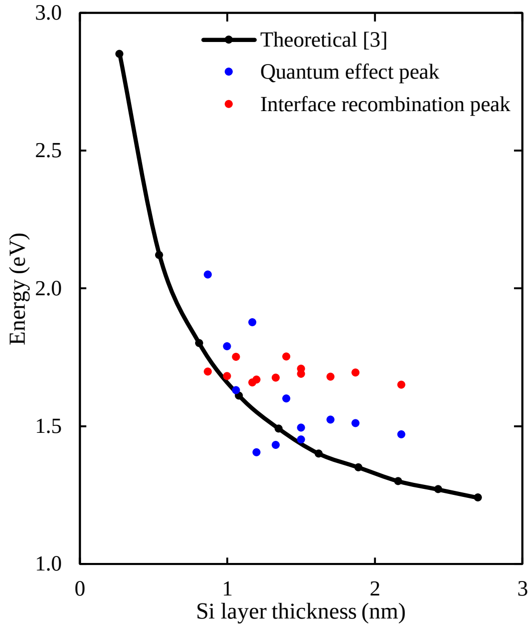

Fig. 1. Variation of PL peak energy with Si layer thickness.

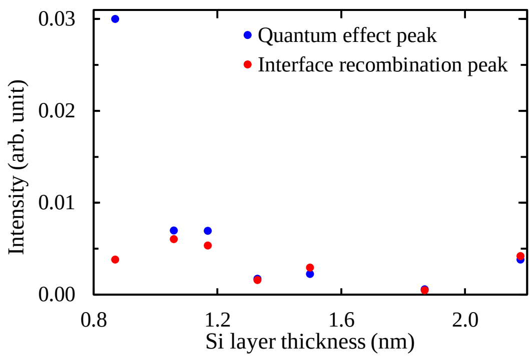

Fig. 2. Variation of PL intensity with Si layer thickness.

Acknowledgement

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