

Introduction

On-chip light source based on Si remains a formidable roadblock due to the poor quantum efficiency originating from the indirect bandgap nature of silicon. GeSi alloy quantum dots (QDs) is a promising candidate for light source implemented in Si-based monolithic optoelectronic integrated circuits (MOEICs) thanks to the telecom-wavelength emission and the compatibility with the Si integration technology. In addition, thermal annealing plays a pivotal role in the lattice structure, morphological evolution, composition, strain and the optical properties of self-assemble GeSi alloy QDs.

Results & Discussion

Surface Morphology

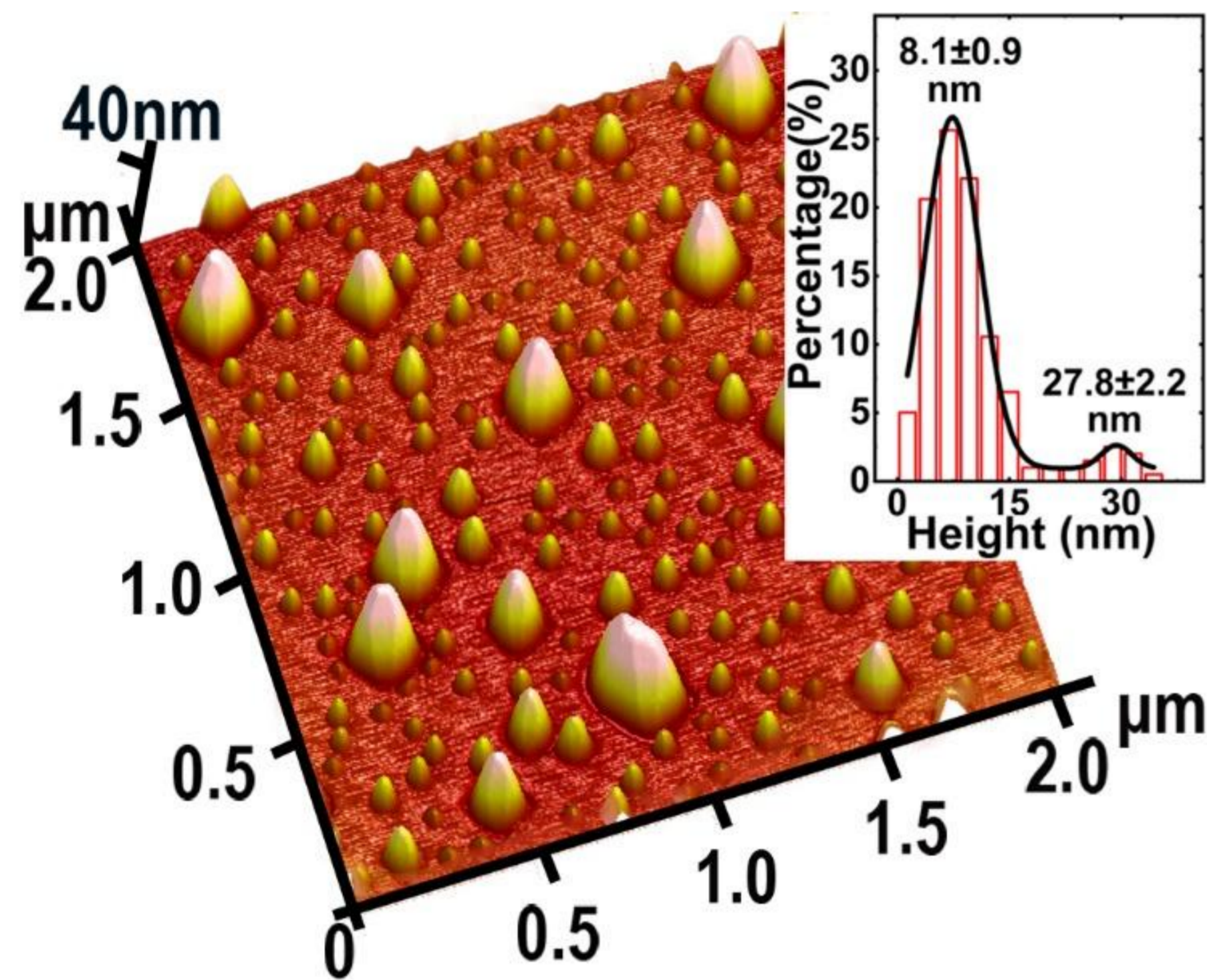


Fig. 1. AFM image of GeSi alloy QDs. The inset shows the height distribution of GeSi alloy QDs.

Raman spectra

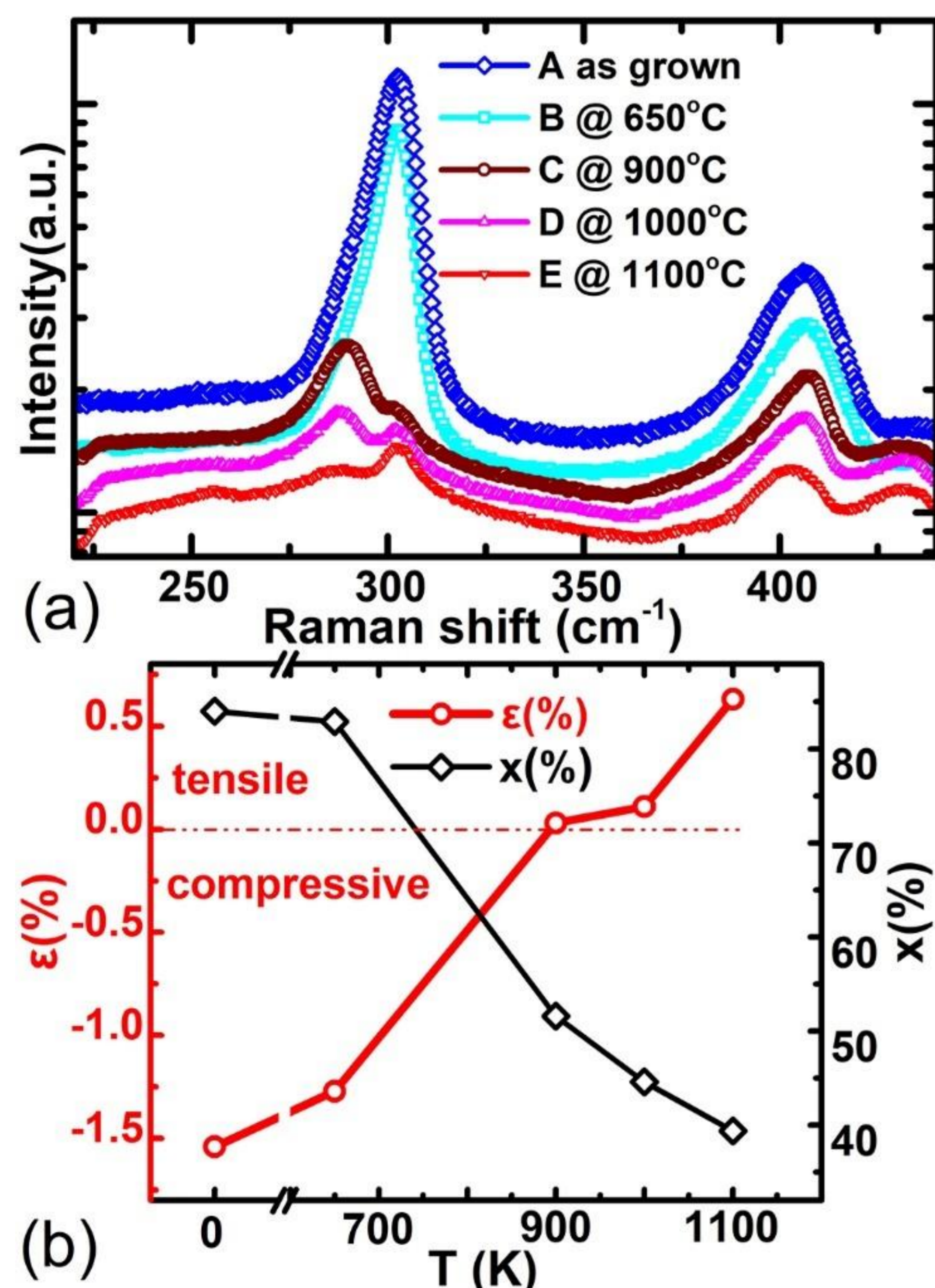
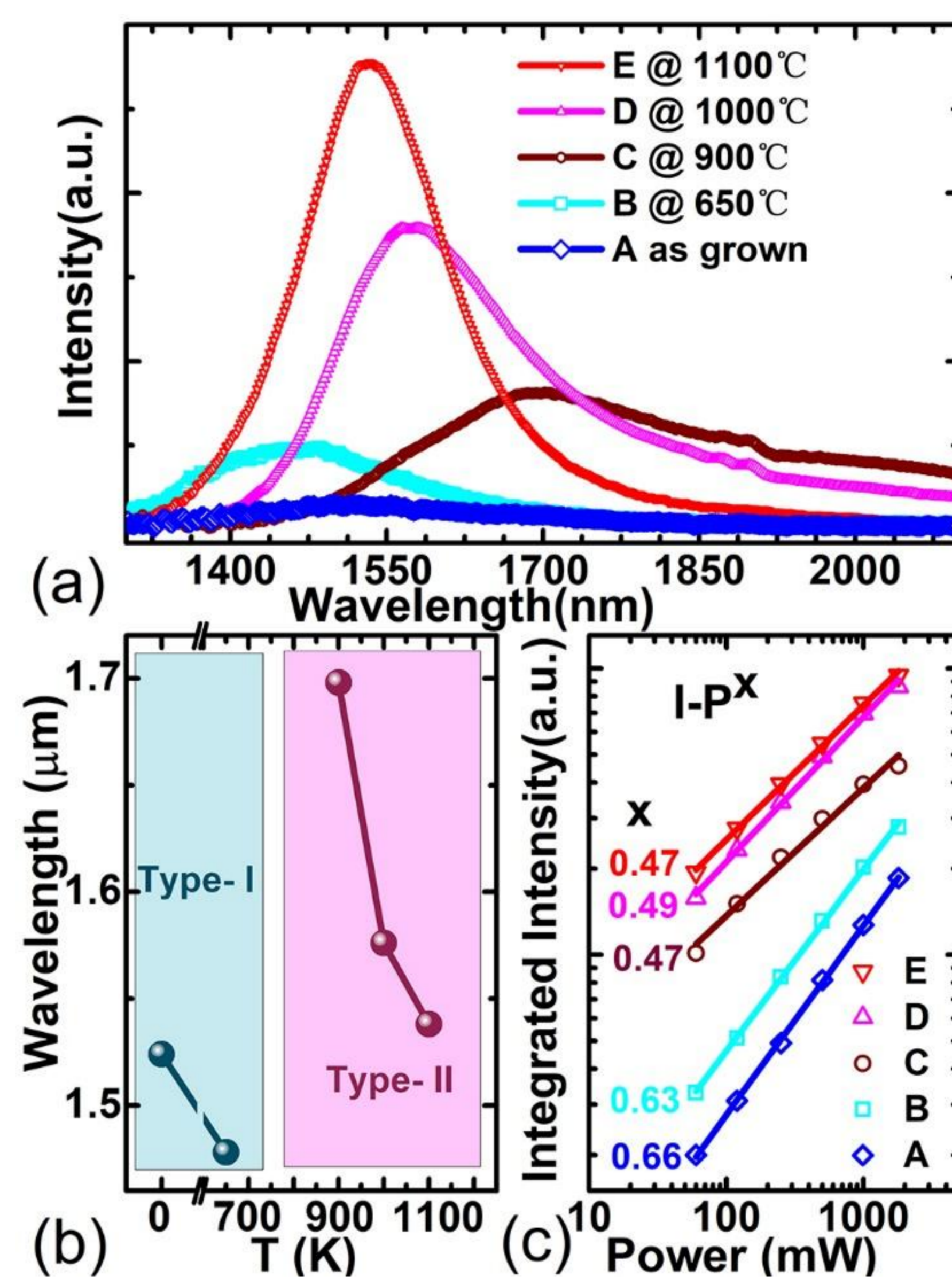


Fig. 3 (a) Raman spectra of all samples, (b) the Ge composition and the strain in QDs vs the annealing temperature in the samples A-E.

➤ The elastic strain ϵ transits from compressive (e.g. -1.2% @ 650°C) to tensile (e.g. $+0.63\%$ @ 1100°C) strain;

PL Spectra



For the sample E (1100°C for 45 s)
 ➤ The PL spectrum can be characterized as a **single peak** approximately;
 ➤ The peak position is located around **1550 nm**;
 ➤ The enhancement of intensity is nearly **20 times** with respect to sample A.

Fig. 2 (a) PL spectra of the samples A-E for an excitation power of 500 mW at 20 K, (b) the wavelength of PL peak vs annealing temperature, (c) the integrated intensity of PL peak vs excitation power for the samples A-E. The as-grown sample A is considered as annealed at 0°C .

Bandgap

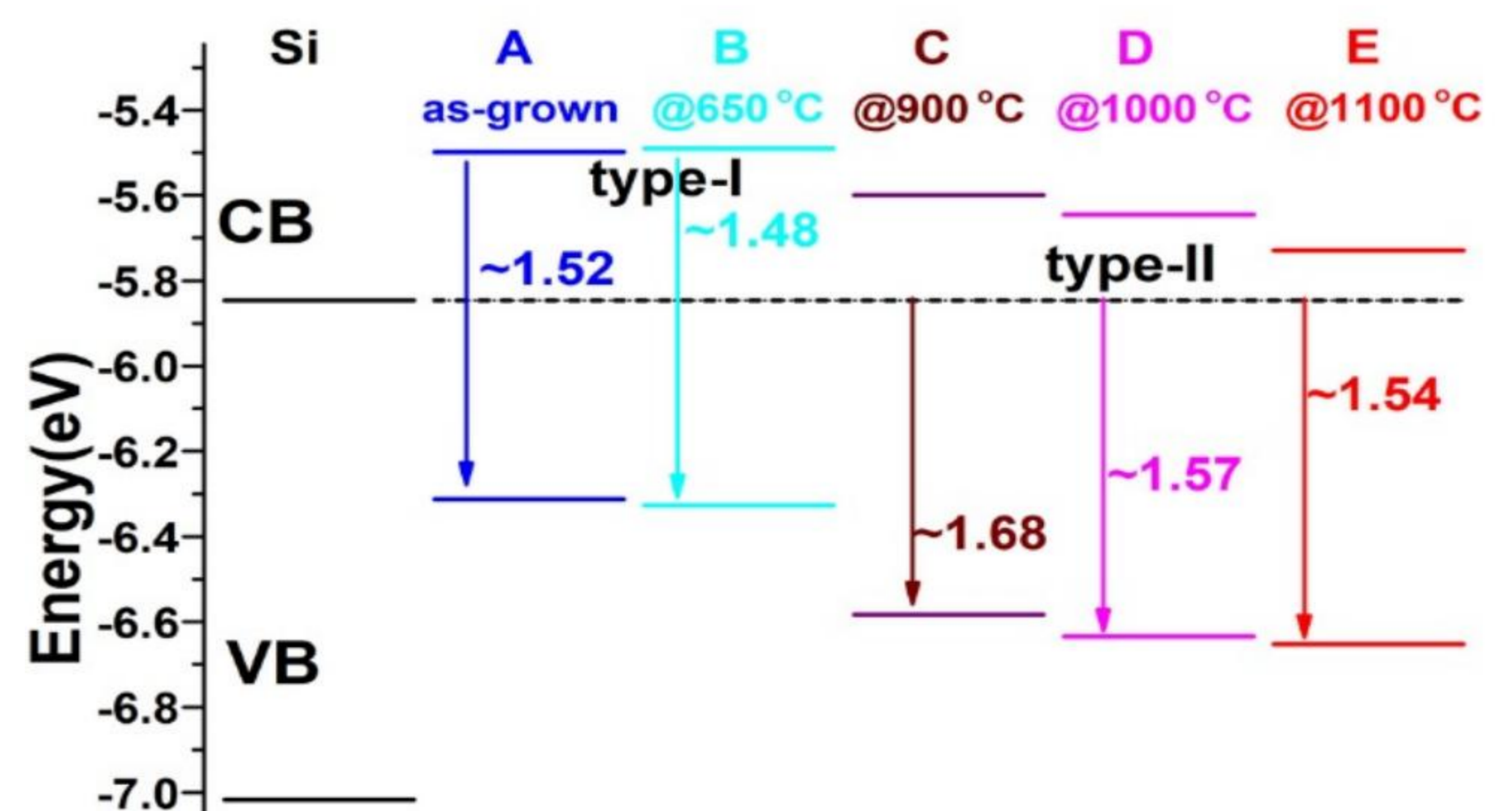


Fig. 4 The diagram of conduction band (CB) minimum and the valence band (VB) maximum of all samples and the Si via self-consistent calculations. The emission wavelengths (unit: μm) related to the type-I (for the samples A-B) and the type-II bandgap (for the samples C-E) are shown and denoted by arrows.

Conclusion

- Tensile strain can be induced with a red-shift of the Ge-Ge vibrational mode;
- High-temperature annealing leads to a pronounced enhancement of PL, exhibiting a relatively sharp single peak at telecom C-band of ~ 1550 nm accompanied by an enhancement in intensity of nearly five times;
- The band analyses based on the self-consistent calculations unveil the emissions related to the type-I and type-II bandgap with different recombination rates.

These results indicate that the high-temperature annealing can substantially modulate the properties of GeSi alloy QDs particularly for emission at $\sim 1.55 \mu\text{m}$, which is promising for Si-based innovative optoelectronic device compatible with COMS technology.