# The growth and characteristics of low-temperature germanium on $Si_xGe_{1-x}$<111> and coupling with microdisk

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## Introduction

Si-based light-emitting materials are fundamental in optoelectronic integration. However, silicon has an indirect band gap, which makes it difficult to produce effective luminescence at room temperature. A lot of work has been done[1][2]. The indirect band gap characteristics of germanium are determined by its diamond structure. Many researchers have found that germanium has a hexagonal structure, in which the L-valley of Germanium is folded into the position of Γ-Valley (*k* space), making it a direct band gap.

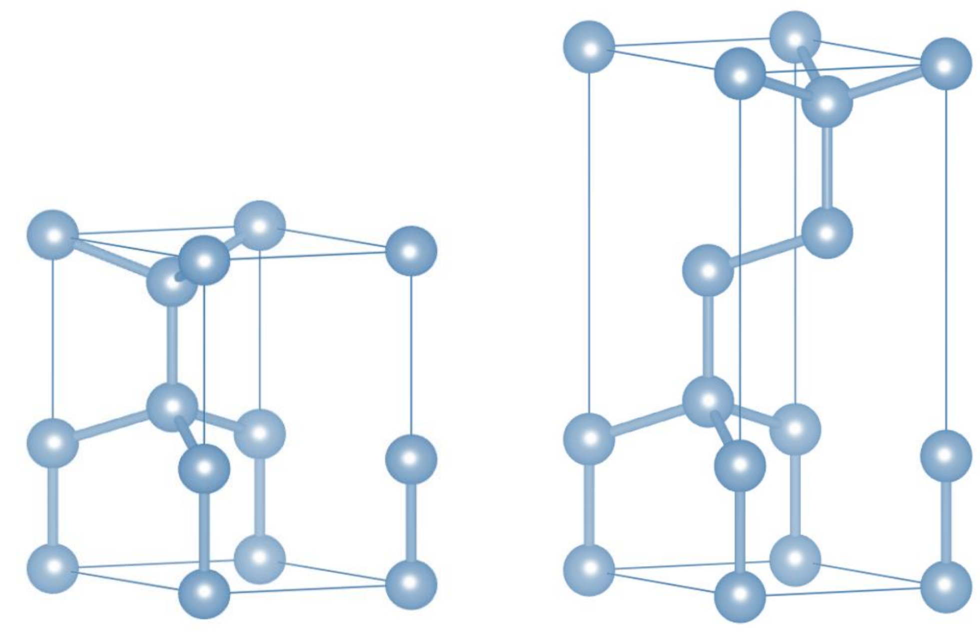

Figure 1. The hexagonal structure(left) and diamond structure(right).

## Results

- Nanosphere lithography was used. The Si<111> crystal surface was prepared on Si<100> substrate.
- Use different sizes of PS balls, and control the thinning time, to control the size and period.

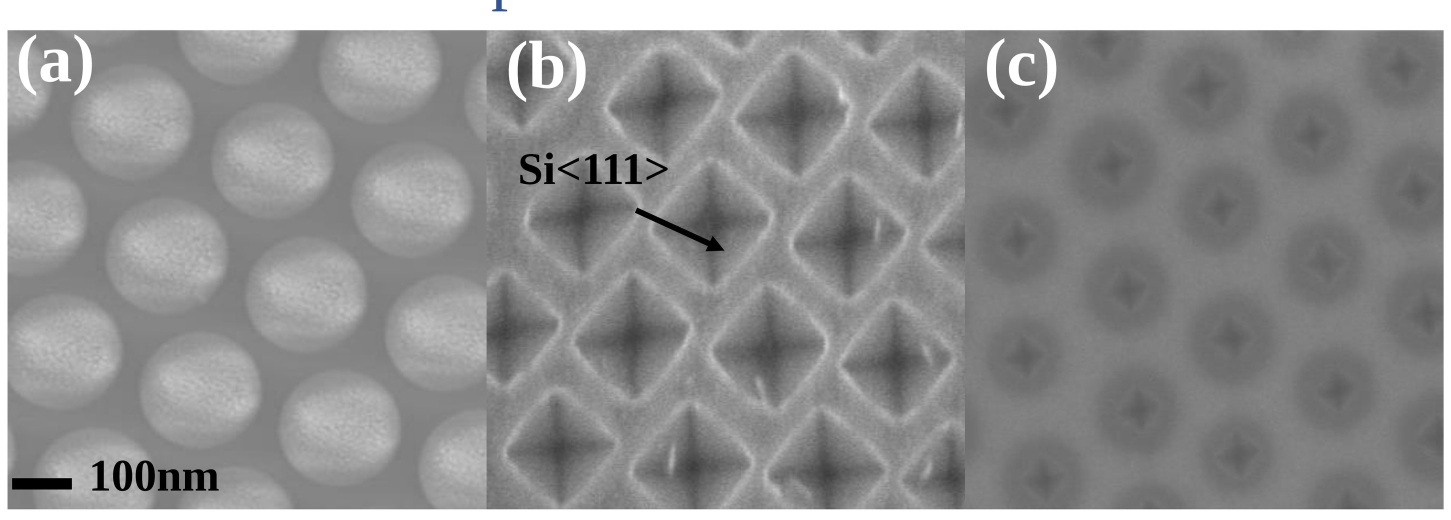


Figure 2. (a) SEM image of PS on Si<100>. (b)(c) RIE oxygen etching was used to thin the pellets. Using KOH selective etching, the exposed Si 111 was obtained.

- The sample was prepared by molecular beam epitaxy(MBE) equipment.
- Information about the microdisk has been reported[3].

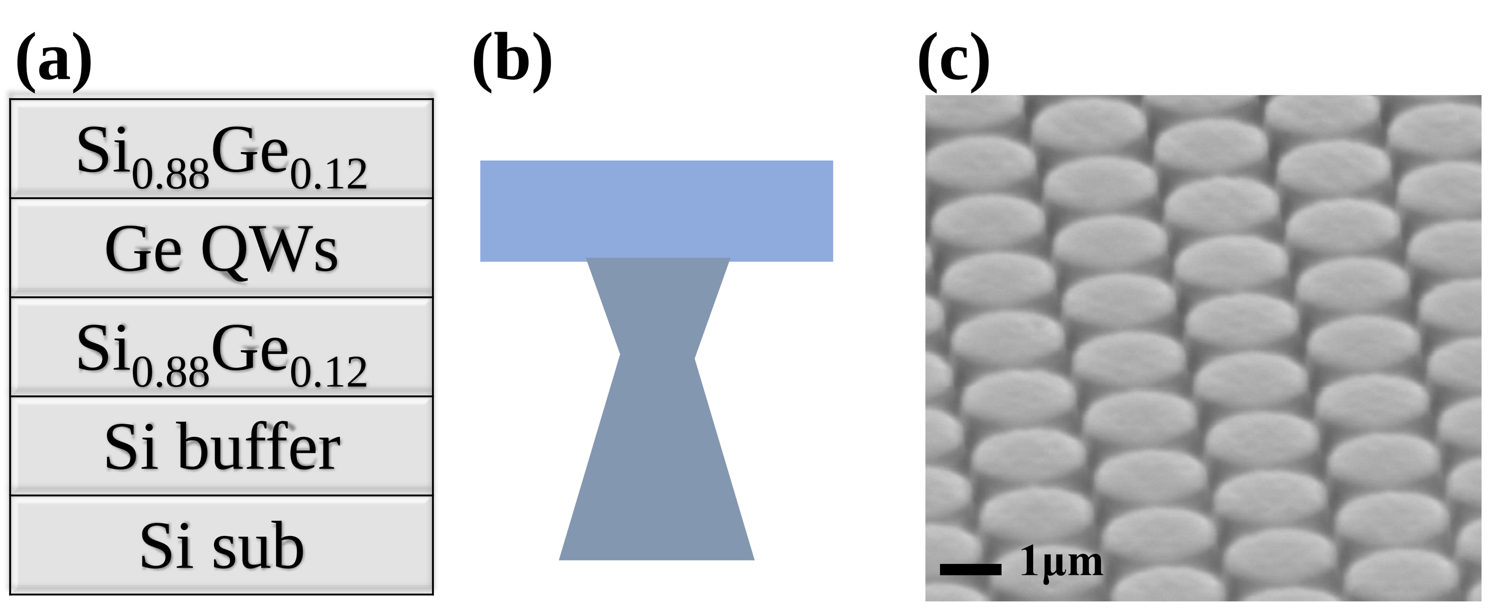


Figure 3. (a) Diagram of sample. (b)(c) Diagram of a microdisk(side view) and SEM of a microdisk array.

- The surface morphology was characterized by atomic force microscope (AFM).

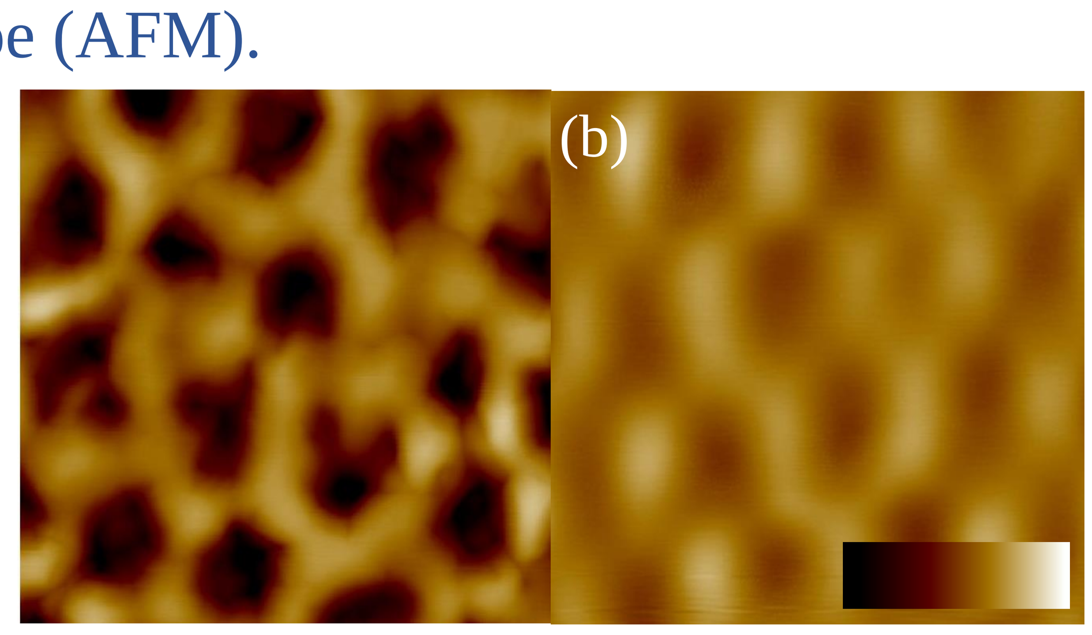


Figure 4. AFM images of samples, which are grown at 150℃ (a) and 250℃ (b).The scale is from -30nm to 50nm.

## Discussion

- The peak on the left is produced by the cL-HH(Ge) transition.
- The peak on the right requires more experiments and testing to determine.

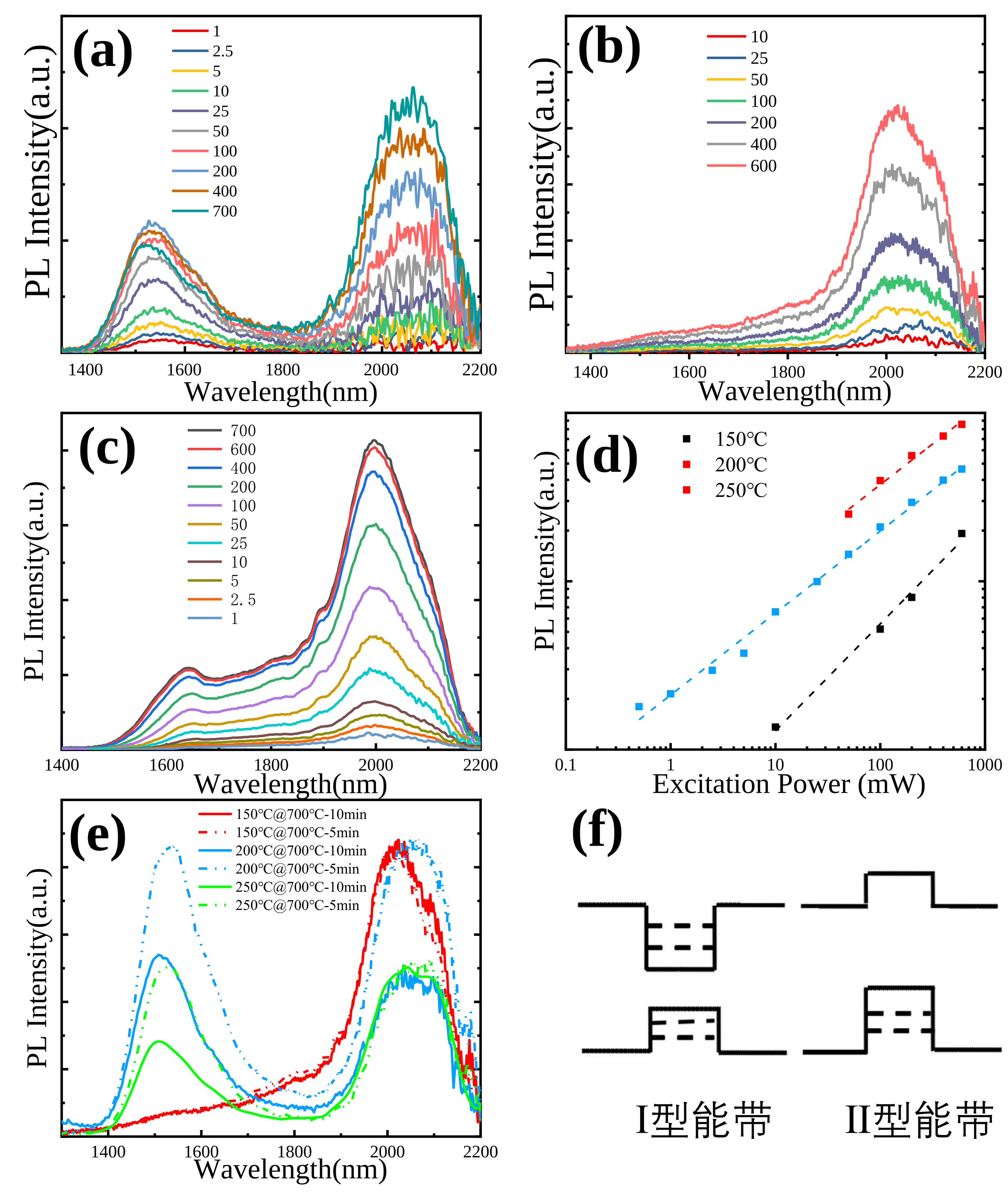


Figure 5. (a)(b) PL of sample grown at 150℃(a), 250℃(b). (c)20nm Ge films instead of Ge QWs, grown at 200℃. (d) Relationship between luminescence intensity and excitation power. (e) PL spectra of different annealing conditions. (f) Diagram of type I band and type II band, the dashed lines represent the energy levels in the well.

- Effect of microdisk on luminescence performance.

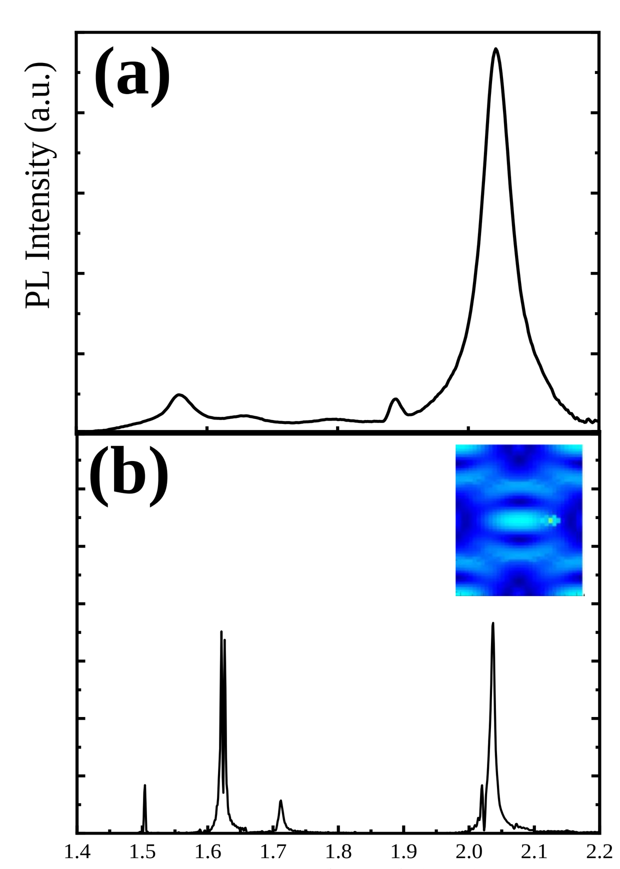


Figure 6. (a)PL spectrum of mirrodisk grown on 250℃. The microdisk is 1μm in diameter. (b) Simulation of 1μm microdisk by FDTD. The illustration shows the E field distribution of P2. In this structure, there is a significant emission from peak P2 and the opposite from peak P1. This is related to the resonant mode and the peak wavelength. We want to have a strong emission around 1550nm.

## Conclusion

- In previous experiments, a small amount of 2H-Ge was observed in low temperature germanium samples. So far, many reports have been made about the preparation of 2H-Ge, but most of them require the introduction of III-V group elements.
- We expect that the direct band gap characteristics of 2H-Ge can be demonstrated at room temperature by means of microdisk mode luminescence.
- For existing samples, more analysis and testing, such as Raman spectroscopy, is needed to analyze the composition and strain. Explore the most appropriate growth parameters