Fabrication of Ordered Ge Quantum Dots Arrays on Prepatterned SOI Platform for Waveguide Photodetectors and Emitters

G. Chen, V. Lavchiev, F. Schäffler, G. Bauer, and W. Jantsch

Institut für Halbleiter- und Festkörperphysik, Johannes-Kepler-Universität Linz, A-4040 Linz

Introduction

Silicon-on-insulator substrates offer opportunities for integrated optics and micro photonic applications. A thick buried oxide covered by a crystalline silicon layer leads to a very high difference of refractive index, which is as large as two in the near-infrared spectral range. With such a large variation, strong optical confinement can be easily achieved in the transparency window of silicon, and in particular, in the spectral windows around 1.3 and 1.55 µm corresponding to the telecommunication wavelengths. Meanwhile Ge/Si self-assembled islands with their high-Ge content are good candidates to operate at telecommunication wavelengths. They can be epitaxially covered by silicon and offer the advantage of silicon-terminated surfaces, thus keeping the compatibility with silicon standard processing. Moreover, our recent work shows that the ordered Ge quantum island arrays could be obtained by growth on a prepatterned Si substrate. The ordered Ge quantum island arrays could provide high homogeneity in both size and height of the Ge islands, which might lead to a narrowing of the photo emission.

In this work, we report on the fabrication of a set of ordered Ge self-assembled quantum dots arrays on prepatterned SOI platforms. Structural and optical as well as electronic analyses of the arrays are presented.

Experiment and Results

Silicon-on-insulator substrates offer opportunities for integrated optics and micro photonic applications. To explore their advantages, in this work, we fabricated of a set of ordered Ge self-assembled quantum dots arrays on prepatterned SOI platforms, as shown in Fig. 1 and Fig. 2. This design exhibits the compatibility with current Si-based VLSI technology. The rib waveguide and RCE detectors can also improve the quantum efficiency by increasing equivalent absorption length. Furthermore, the incorporation of the multilayer of ordered Ge-QDs can improve the moderate oscillator strength of optical transition when precisely located at places with high photonic density of states [1].

To achieve this aim, the main challenge we were facing is to fabricate ordered Ge-QDs on the rib waveguide. We have successfully achieved the Ge-QDs arrays on the patterned flat Si (001) substrate [2], [3]. Based on these results, we tried two different approaches.

The first try is to deposit 7ML Ge under 620 °C, at a fixed growth rate of 0.03 A/s on the rib waveguide, which has been pit-patterned by electron beam lithography and reactive etching. Atomic Force Microscopy shows most of the Ge islands nucleate at the edge of the waveguide instead of the pit site prepared by patterning, as shown in Fig. 3.

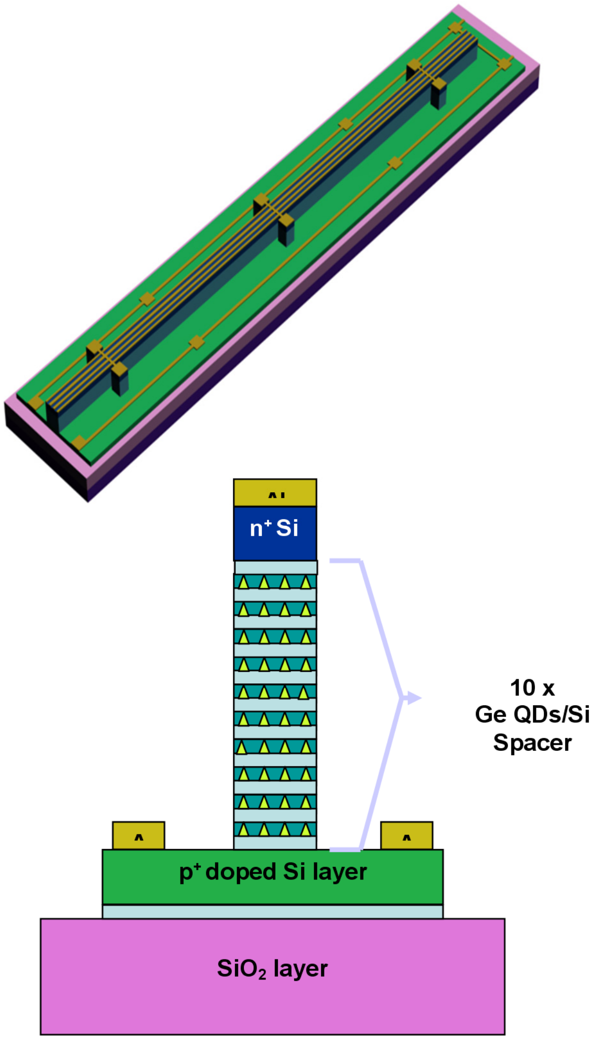

Fig. 1: Scheme of rib-waveguide integrated p-i-n Ordered Ge-QDs Photodetector

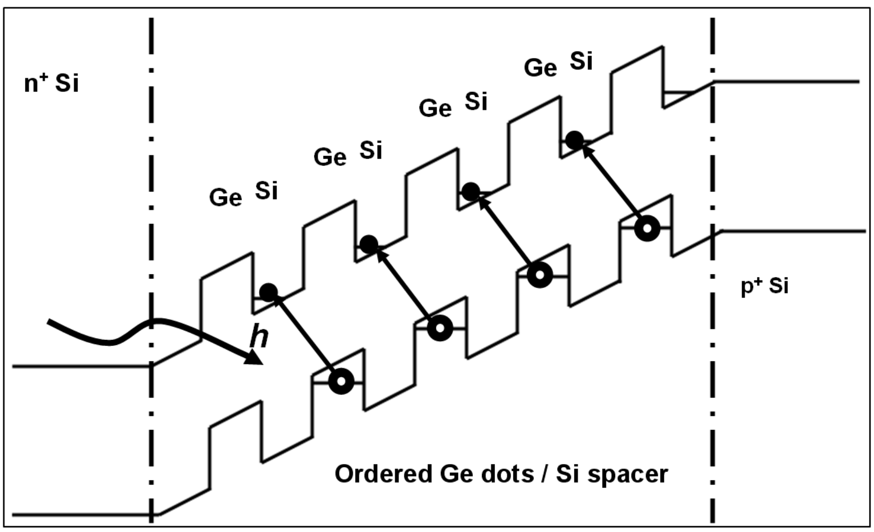

Fig. 2: Simplified bandgap diagram for rib-waveguide integrated p-i-n ordered Ge-QDs photodetector under bias.

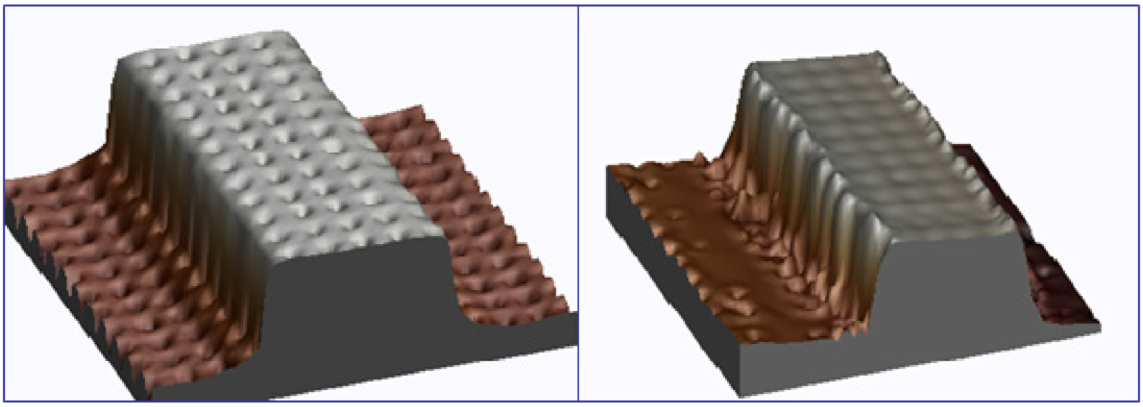

Fig. 3: AFM image of the patterned waveguide before and after Ge deposition.

This phenomenon could be explained by the fact that the edge is the energetically most favorite site.

Another try was performed by changing the sequence of the above experiment, i.e., first an array of ordered Ge islands was prepared on the flat Si substrate, and then a waveguide was prepared through electron beam lithography and reactive ion etching. This approach is quite successful, as shown in Fig. 4.

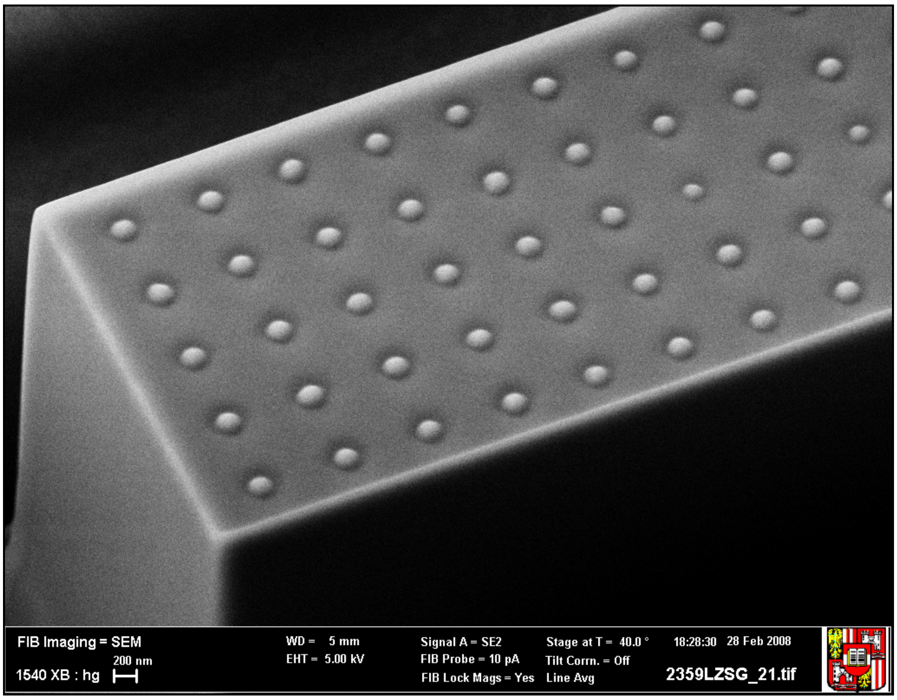

Fig. 4: SEM image showing the ordered Ge array sits on the rib-waveguide.

The temperature dependence of photoluminescence of the patterned Ge dots array has been measured. A UV cw-Ar+ laser was used for the excitation. A LN-cooled Ge detector with lock-in amplifier was used for detection. We observed a red-shift of the Ge dots peak with increase of temperature.

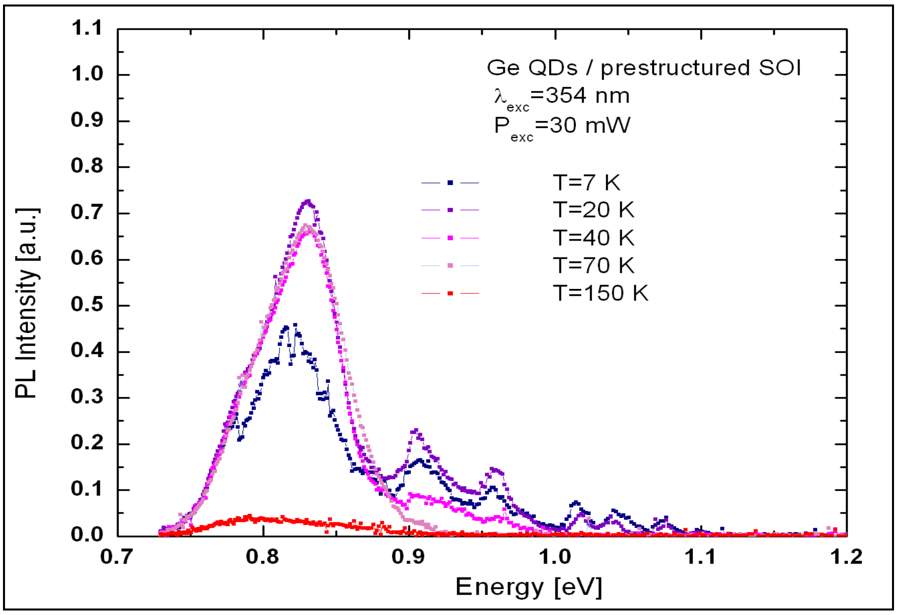

Fig. 5: Temperature dependence of the photoluminescence of the patterned Ge dots array.

References

[1] C. B. Li, et. al., Appl. Phys. Lett. 85 2697 (2004).

[2] G. Chen, et. al., Phys. Rev. B 74 035302 (2006).

[3] G. Chen, et. al., Appl. Phys. Lett. 92 113106 (2008).