Evolution of site-controlled GeSi nanostructures on scalable array of ordered Si micro-pillars

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1 Introduction

The precise positioning and controlled evolution of epitaxial Germanium quantum dots (QDs) on Silicon have progressed much by introducing substrate pre-patterning procedure which defines preferential nucleation sites and homogeneous evolution law for the self-assembly of Ge QDs during epitaxial growth. We report on the fabrication and characterization of site-controlled nucleation of Ge on large-area ordered Si micro-pillars. Three structures with different configuration like nanonecklace, fourfold symmetric enclosure and nanoring on the edge of Si pillars can be obtained by optimizing parameter during molecular beam epitaxy (MBE) growth process. Further the experiments clarify the surface morphology evolution regularity of Ge nanostructures.

2 Experimental details and Results

2.1 Fabrication of ordered Si micro-pillars

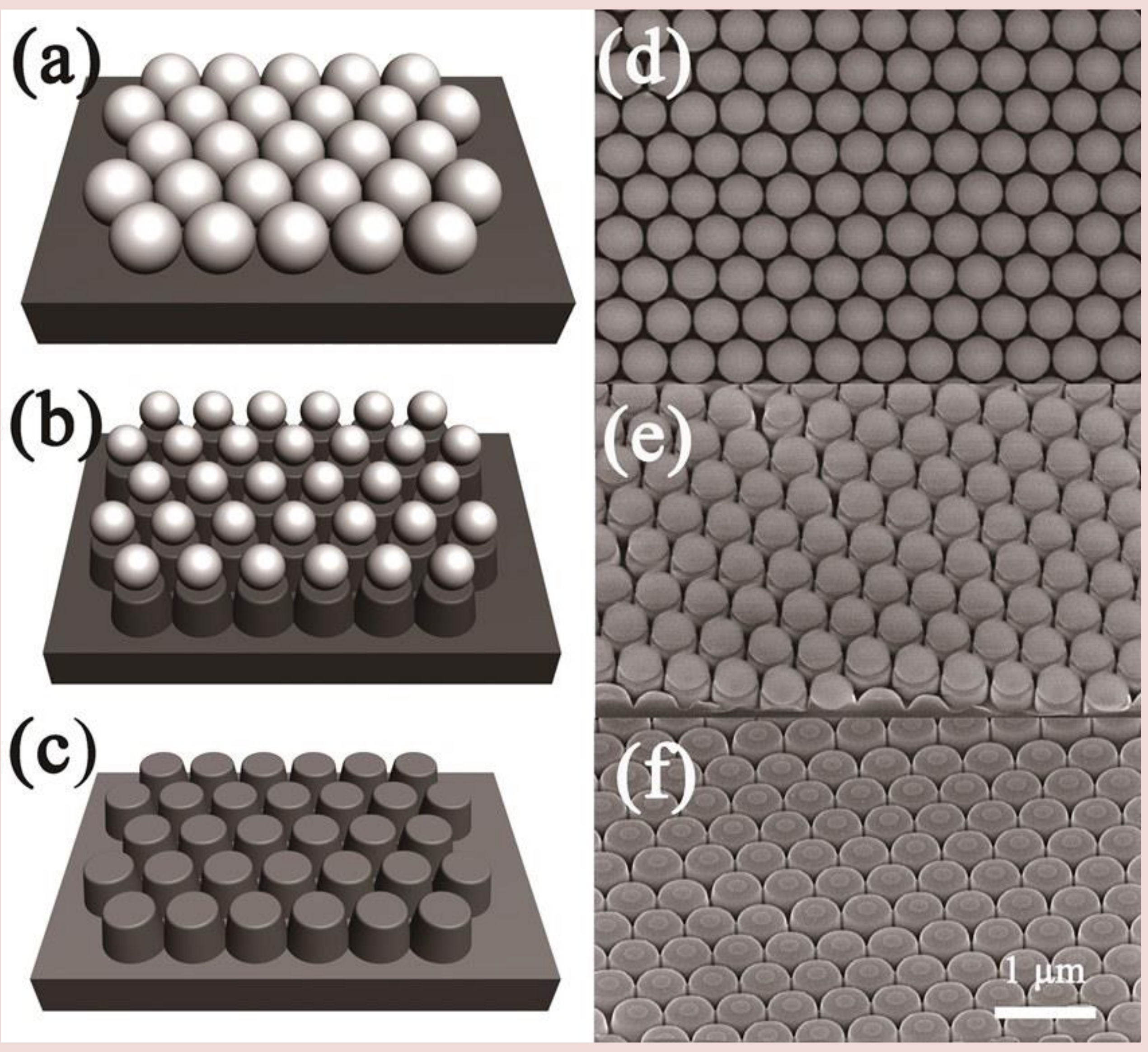

Figure 1. Schematic illustration of the formation procedure of ordered Si micro-pillars, (a) assembly of the nanosphere template on Si (001) substrate and (b) dry-etching of Si carried out by ICP-RIE. (c) removal of the nanosphere mask.(d)-(f) are the corresponding SEM image with 0°, 30° and 45° tilted view angle, respectively.

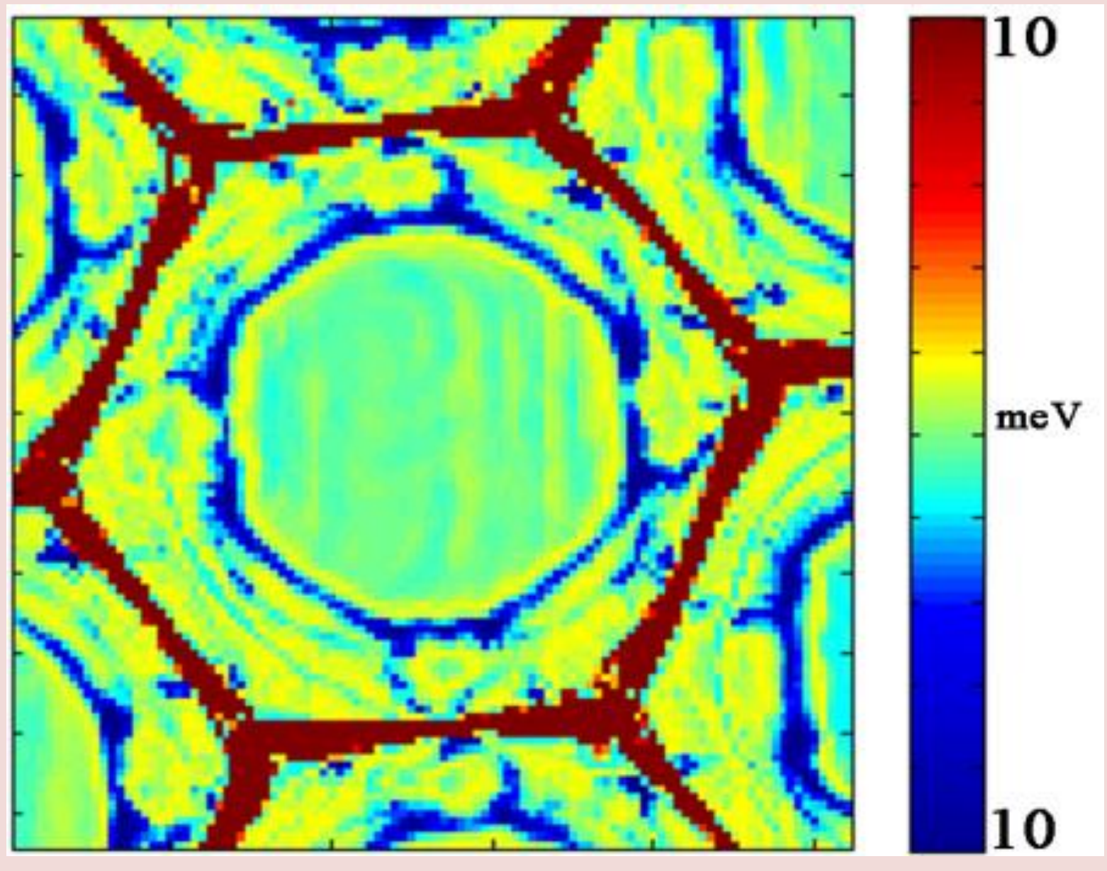

Figure 2. Calculated surface chemically potential distribution of a single Si micro-pillar covered with a Si buffer layer.

2.2 Ge nanostructures on Si micro-pillars

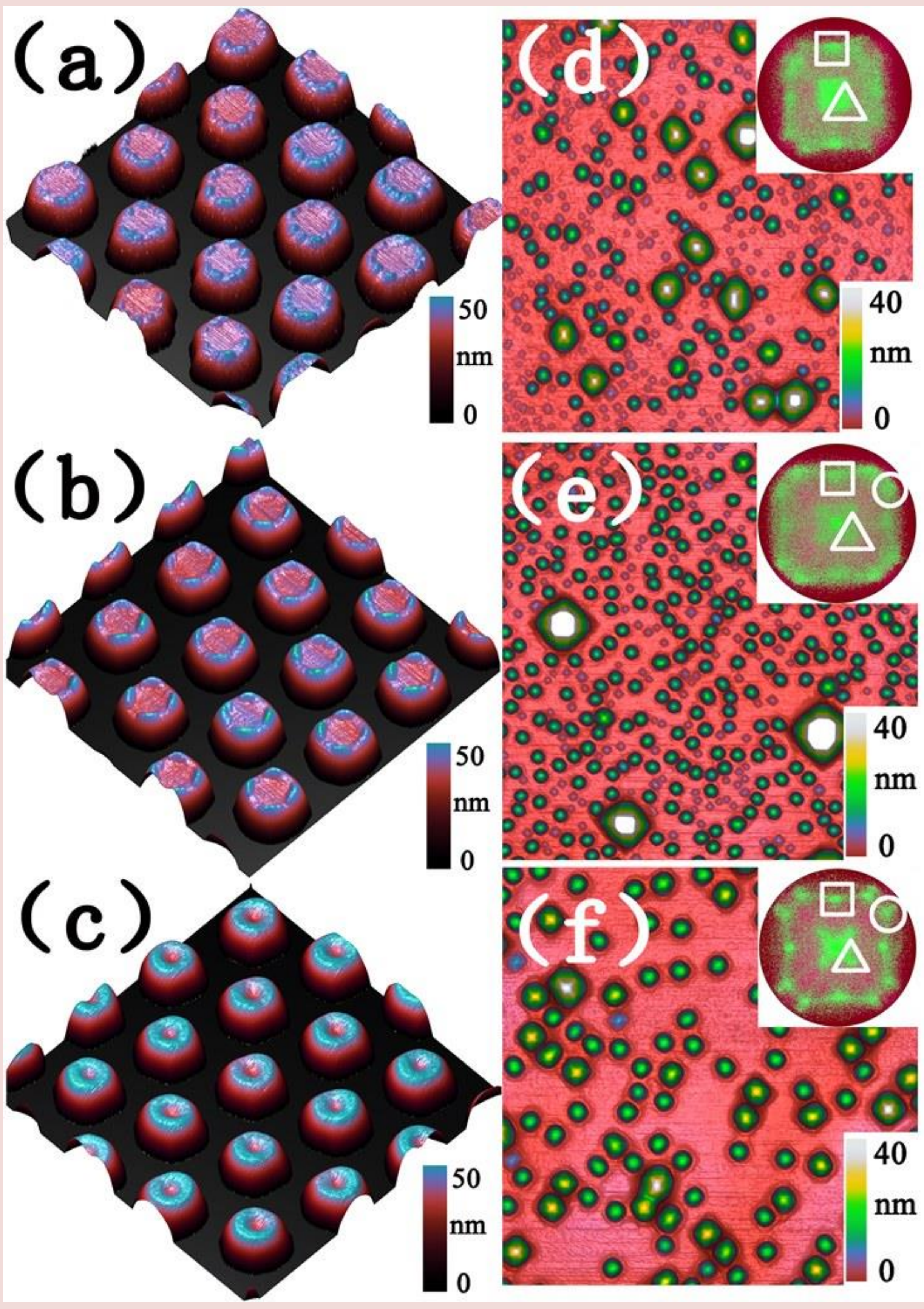

Figure 3. 3D AFM image ($2\times2\mu m^2$) of three different types of Ge nanostructures on Si micro-pillar arrays with period of 490nm after growth of 13 ML Ge: (a) nanonecklace, (b) quantum dot molecules, (c) quantum ring. (d) -(f) show their corresponding flat substrates, respectively. The surface orientation map (SOM) of each flat substrates acts as insets of AFM images with △ denotes {1 0 5} facet, □ denotes {1 1 3} facet and ○ denotes {15 3 23} facet.

2.3 Morphology evolution of Ge nanostructures

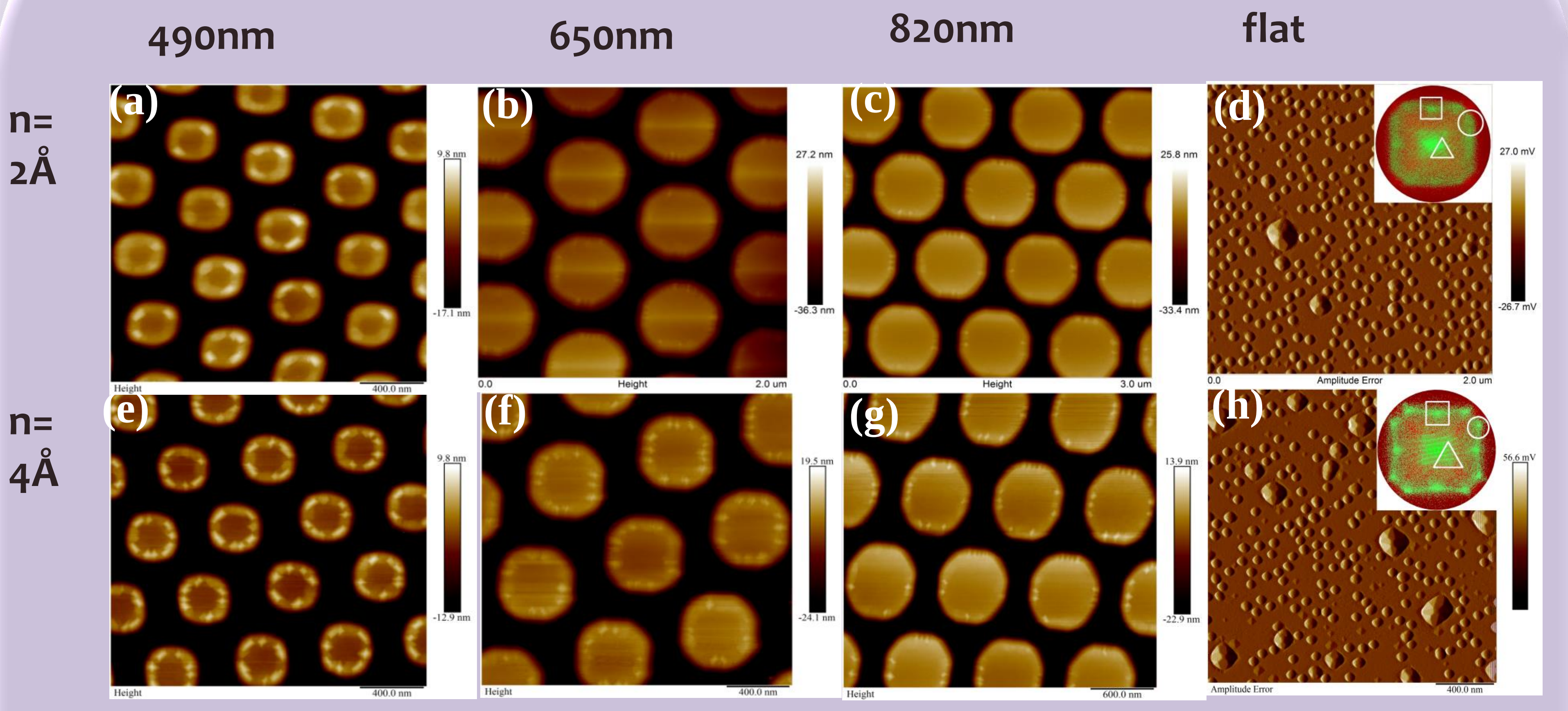

Figure 4. AFM image ($2\times2\mu m^2$) of surface morphology of epitaxial Ge on Si micro-pillar arrays with additional deposition thickness “n” marked on the left and variable period marked on the top compared to growth parameters of “nanonecklace”. (d) and (f) relate to the corresponding flat substrates with their surface orientation map (SOM) acting as insets.

3 Conclusion

In summary, we have presented a feasible hybrid quantum dots micro-cavity coupling system and an experimental investigation of the migration behavior and morphology evolution of epitaxial Germanium on discrete substrate. Three representative Ge nanostructures are regimented on large-area ordered Si micro-pillars. Future theoretical analysis attests that it is the surface chemical potential playing the leading role that drives the Ge atoms migrate to the rim of mesa, by which the experimental result is interpreted perfectly. What is more, this structure we suggests would devise new ways to exploit the optoelectronics properties and extend the range of potential applications of Si/Ge nanostructures.