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SiGe self-assembled quantum dots and quantum dot molecules patterned using a focused ion beam

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Many proposed nanoelectronic device architectures rely on the ability to place quantum dots at specific locations. However, the ability to arrange quantum dots with specific compositions and in any arbitrary pattern or layout is extremely challenging at these dimensions. We have explored using the combination of a gallium focused ion beam (FIB) and limited growth kinetics as a method of laterally controlling the nucleation positions of quantum dot arrangements on silicon substrates. The FIB can be used to directly modify surface topography at specific sites on the surface of a substrate in order to create a topographical template. Shallow features on the order of only a few nanometers in depth, will remain even after ex-situ chemical cleaning and deposition of a thin Si buffer layer. This template can be used to influence nucleation of islands during subsequent SiGe epitaxial growth on the template. Using kinetically limited growth conditions that reduce surface diffusion, island formation can be suppressed, that would otherwise occur at random locations on the surface in order to relax the strain. A shallow faceted pyramidal pit with four edges will instead form first at each previously modified FIB site, followed by nucleation of islands only at the energetically favorable pit edge sites. The size of the islands and the pit, can be tuned by varying the strain in the film. If the size of the islands can be reduced sufficiently to allow for quantum confinement effects, the resulting structure can be considered a "quantum dot molecule". This "molecule" consists of four closely spaced quantum dots arranged precisely around a central pit that are remarkably uniform in size. The characteristics of these self-assembled arrangements of quantum dots are of particular interest for potential applications where electron tunneling between dots would be required.