Growth and photoluminescence characterization of ordered GeSi quantum dots on patterned Si (001) substrates

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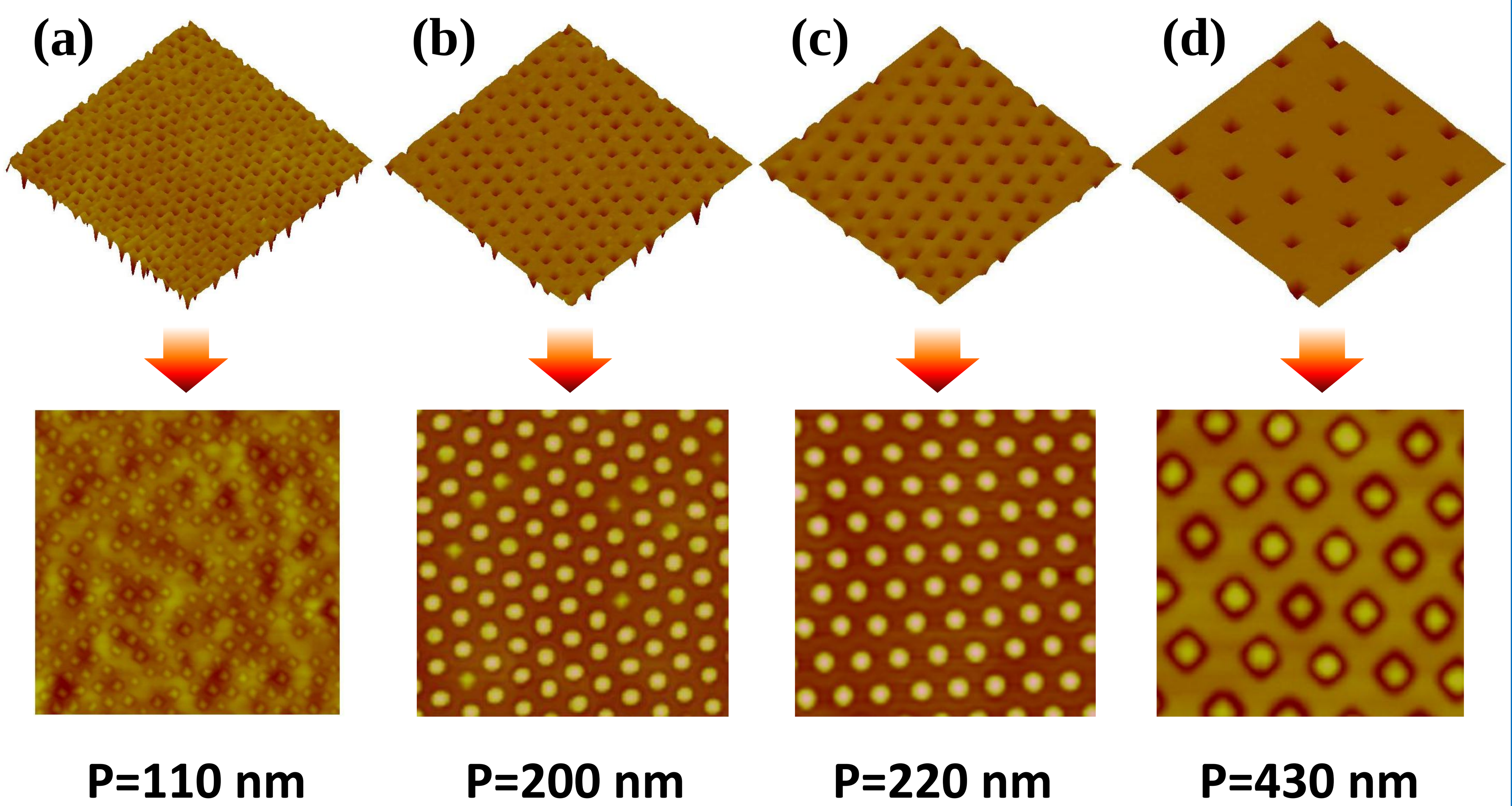
Template-assisted preferential growth of self-assembled quantum dots (QDs) on pre-patterned substrates is an effective route to fabricate ordered quantum dot (QD) arrays with controllable size, density and spatial alignment. In this poster, we will present the growth of highly ordered GeSi QDs and the manipulation of QD size, period and areal density. Photoluminescence dynamics of the 3-dimensional ordered GeSi QDs are shown and discussed.

I Template assisted growth of ordered Ge QD arrays



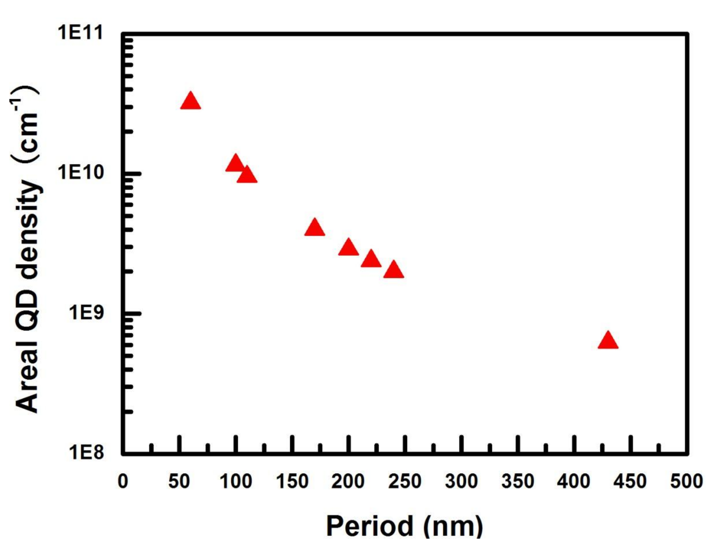


Fig. 1 Up panel: 3D AFM image of pit-patterned Si (001) substrates via NSL and RIE with the periods of 110 nm (a), 200 nm (b), 220 nm (c) and 430 nm (d). Down panel: The ordered Ge quantum dots grown on the corresponding pit-patterned Si substrates by MBE. The scan size of the images is 2 μm x 2μm.

The regulation and control of the size, period and areal density of the Ge QDs can be realized by template-assisted MBE growth. The magnitude of the areal density of the ordered Ge QDs can be controlled from 10^8 to 10^{11}.

II 3D quantum dot crystal structures

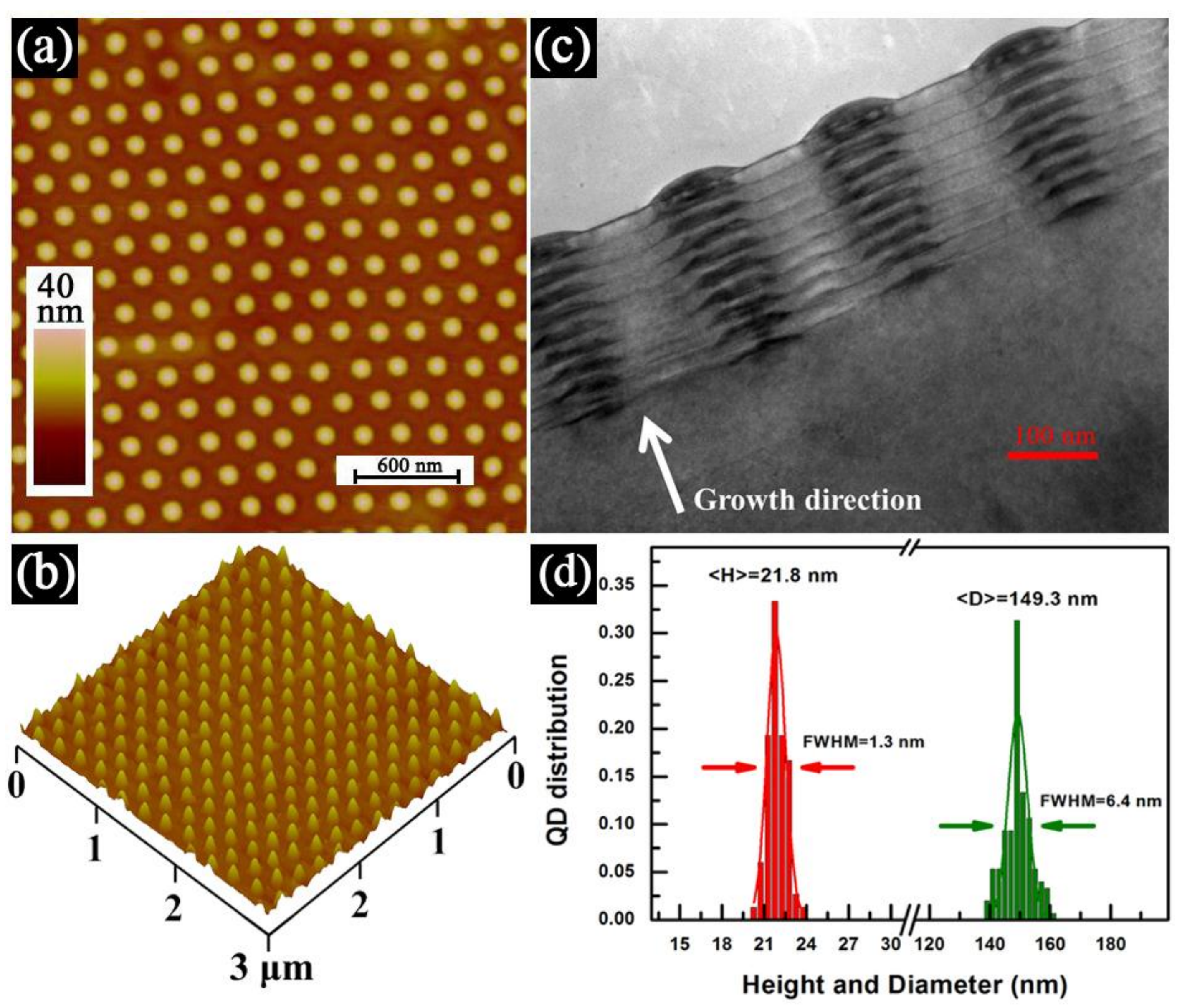


Fig. 2 (a) The surface morphologies of the ordered GeSi QDs with a period of 220 nm. (b) Cross-sectional TEM image of 10-layer ordered GeSi QDs. (c) 3D AFM image of the order-ed GeSi QDs. (d) Statistical QD size distribution.

The ordered Ge QDs show highly laterally and vertically ordering and small size dispersion. Such three dimensional spatially ordered quantum dot lattice can be regarded as 3D quantum dot crystal.

III Photoluminescence dynamics

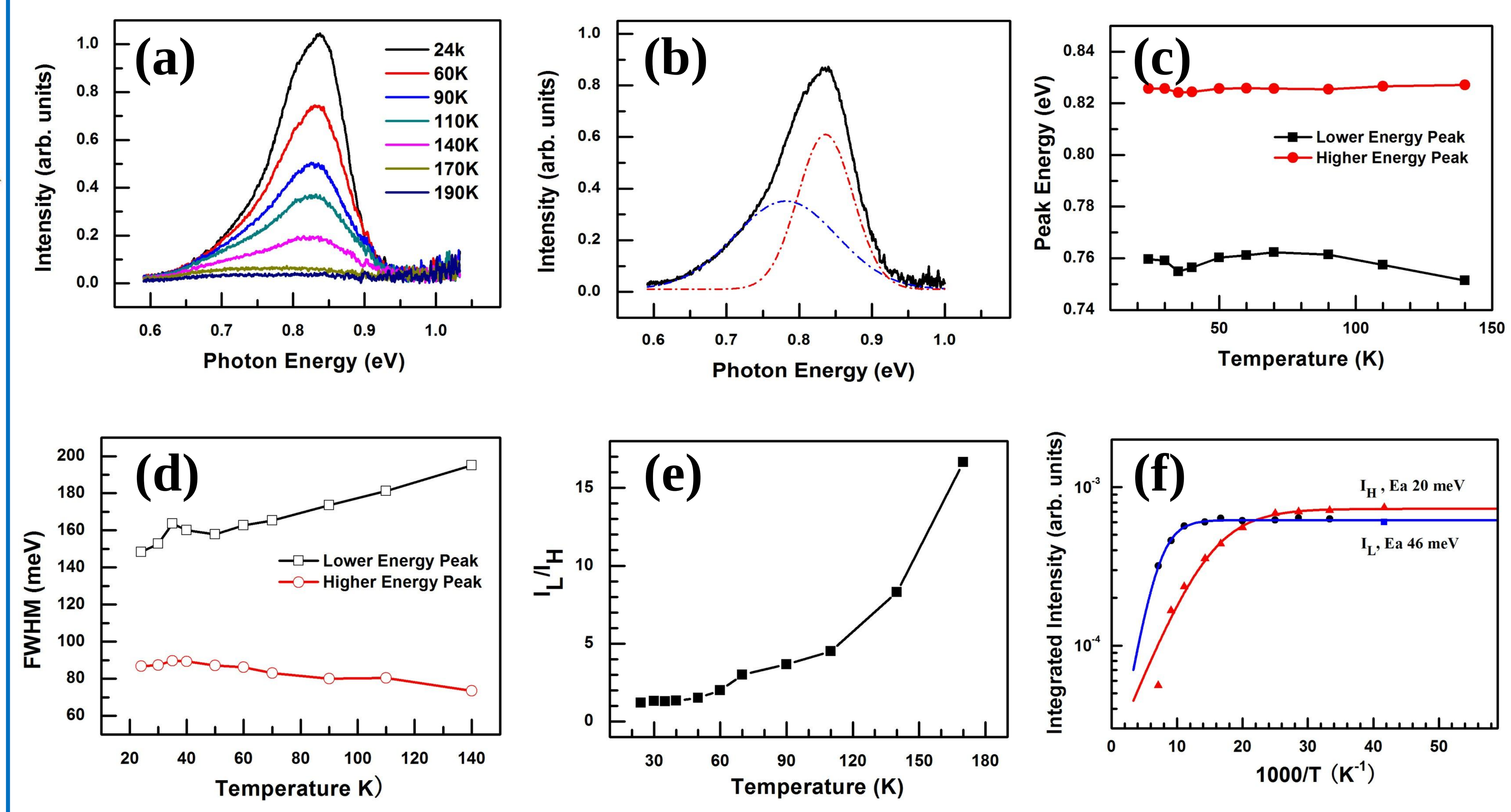


Fig. 3 (a) Temperature dependence PL spectrum. (b) Schematic peak deconvolution method. Deconvoluted peak energy (c) and FWHM (d) dependence. (e) The ratio of integrated intensity between the deconvoluted low and high energy peaks as a function of temperature. (f) The fitted activation energy of the two deconvoluted PL peaks.

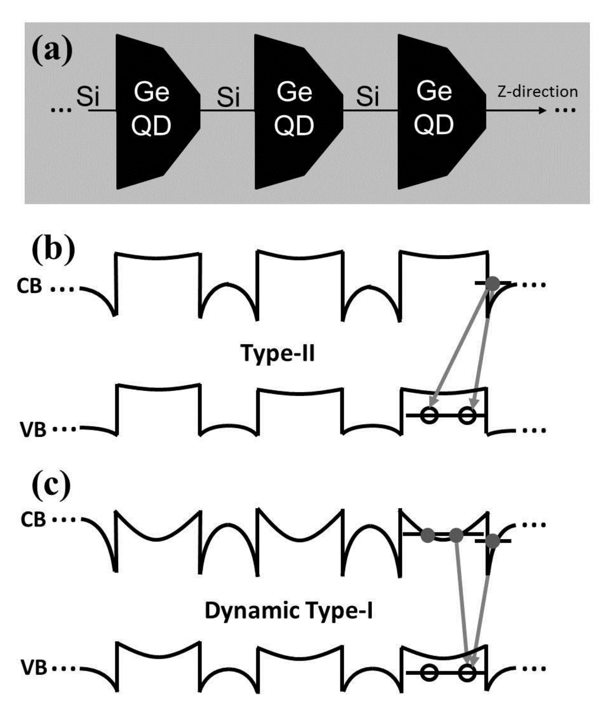


Fig. 4 Dynamic band alignment of stacked GeSi QDs.

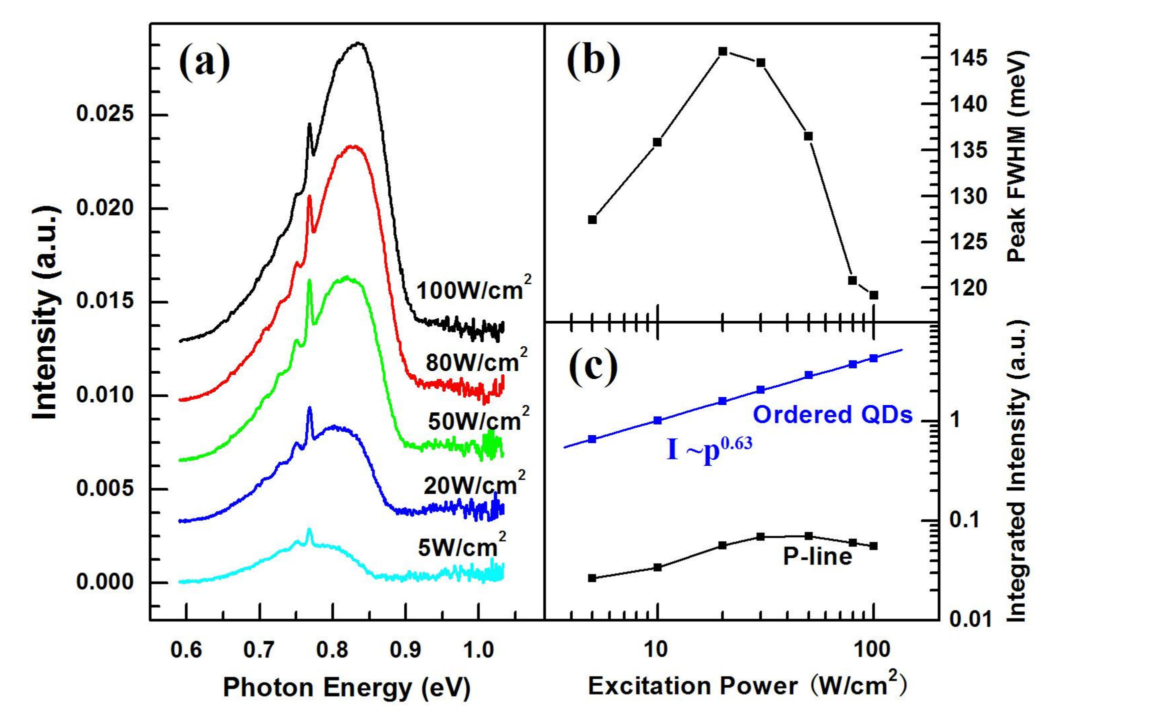


Fig. 5 (a) PL spectra of 15-layer ordered Ge QDs with a period of 220 nm. The QD peak FWHM (b) and integrated PL intensity (c) as a function of excitation power.

The two deconvoluted peaks are attributed to the spatially direct and indirect transition of GeSi QDs, respectively. Type-II/dynamic type-I band alignment model is introduced to interpret both the temperature and excitation power PL dependences of the multi-layer ordered GeSi QDs.

IV Conclusions

- The manipulation of the size, period and areal density of the GeSi QDs has been achieved by NSL template-assisted MBE growth.
- The ordered GeSi QDs show nearly perfectly 3D ordering and can be regarded as 3D quantum dot crystals.
- Type-II/dynamic type-I band alignment model is introduced to interpret both the temperature and excitation power PL dependences of the multi-layer ordered GeSi QDs.