A new class of semiconductors using quantum confinement of silicon in a dielectric matrix

Martin A. Green
University of New South Wales, Australia

The use of silicon in photovoltaics is booming, with the *area* of silicon wafers used in this application now exceeding the use in integrated circuits. Silicon has a number of attractions for on-going use in photovoltaics, including abundance, stability and non-toxicity, but is constrained by less material design flexibility than available, for example, in the III-V material system.

In photovoltaics, bandgap control and strengthened absorption properties would be ideal in terms of reaching the ideal of low-cost, thin-film, high-performance, silicon-based photovoltaic devices. This would allow implementation of advanced designs such as those based on stacked or tandem cells of differing bandgap. An approach demonstrated by Zacharias and co-workers[1] and illustrated in Fig. 1 is being explored as a way of synthesizing silicon-based semiconductor material of controlled bandgap and improved optoelectronic properties.

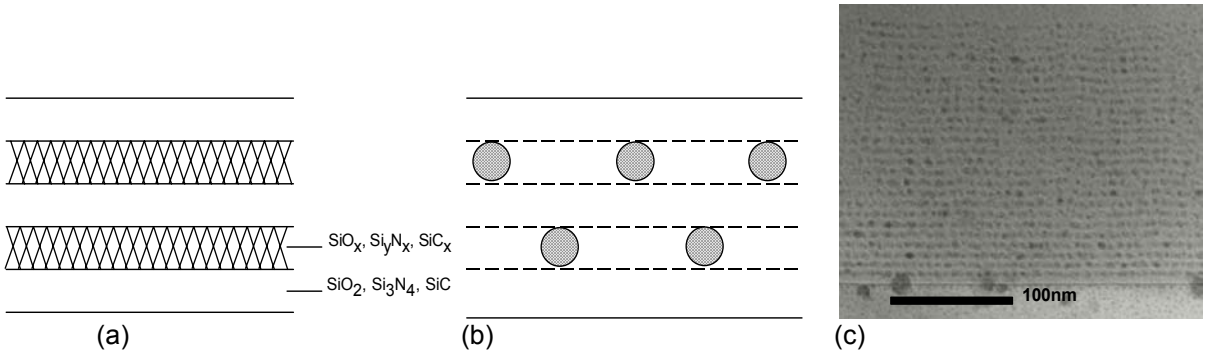

FIG. 1. (a) Precursor stoichiometric and non-stoichiometric, Si-rich layers for forming Si quantum dots; (b) precipitation of dots within the Si-rich layers; (c) TEM image (cross-sectional view) of Si quantum dot layers prepared in an oxide matrix.

The precursor material is formed by depositing alternating thin layers of stochiometric followed by Si-rich silicon oxide, nitride or carbide. On heating, silicon in the Si-rich material precipitates out as quantum dots with diameter controlled by the initial layer thickness. Work to date has shown that the optical bandgap in such synthesized material using both oxide and nitride matrices can be controlled over the range required for tandem cells (1.7 eV) and that optical properties initially strengthen as dot size decreases. Present work is directed at characterising transport in such layers, where mobilities of around 1 $cm^2/V{\cdot}s$ are sought for the targeted application. Other issues such as doping and *pn* junction formation in such synthesized material is being explored both experimentally and theoretically, using tools such as *ab initio* atomic cluster simulations.

1. M. Zacharias, J. Heitmann, R. Scholz, U. Kahler, M. Schmidt, and J. Blasing, "Size-controlled highly luminescent silicon nanocrystals: A Si/SiO_2 superlattice approach", Appl. Phys. Lett. **80**, 661 (2002).