Nanocrystalline Silicon Superlattices: Novel Structures for Electron Device Applications

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Nanoscale electron devices are approaching few nanometer sizes. Standard photolithography does not have many options at the length scale of < 100 nm. Non-lithographic techniques mainly rely on self-organization, where statistical deviation of nanometer-sized objects is unavoidable. However, a combination of self-organization with precise control over at least one dimension has shown strong advantages compared to traditional techniques.

This presentation will discuss the most recent development in Si nanocrystal fabrication: it has been initiated by a simple idea that solid phase crystallization of Si can be performed in a layered structure where layers of initially amorphous, nanometer-thin Si are separated by nearly atomically flat layers of amorphous SiO_2. Combining the state-of the art deposition techniques with precisely controlled post-treatment steps (i. e., rapid thermal annealing and low-rate oxidation), we show that nc-Si superlattice periodicity and interface abruptness are approaching that of conventional, MBE-grown superlattices. Focusing on detailed structural characterization (TEM, XRD, inelastic light scattering, etc.), we demonstrate [1] that control over the Si nanocrystal size, shape and crystallographic orientation is achievable (Fig. 1). In addition, the exceptional quality of the interface between Si nanocrystals and an a-SiO_2 layers and recent demonstration of Si nanocrystal vertical self-alignment (Fig. 2) has triggered exploratory work toward applications of nc-Si/a-SiO_2 superlattices in electron devices utilizing sequential resonant tunneling and other features of quantum transport [2].

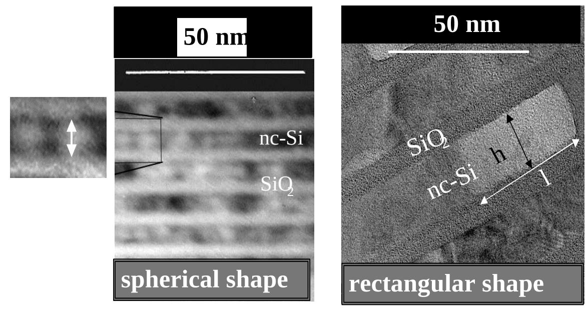

Figure 1. Two distinct types of nc-Si superlattices with (a) spherical Si dots and (b) rectangular Si bricks.

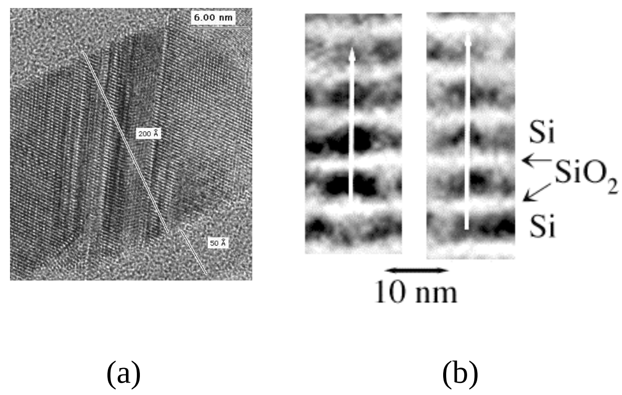

Figure 2. High resolution TEM micrograph showing (a) the Si/SiO_2 interface flatness in a nc-Si superlattice with rectangular Si bricks and (b) vertical alignment in pyramid-shaped Si nanocrystals.

References

1. G. F. Grom, *et. al.*, Nature **407**, 358 (2000).
2. L. Tsybeskov *et. al.*, Europhysics Letters **55**, (4), 2001, p.552-558.