NANO HIGHLIGHT NANO HIGHLIGHT
Creating and Aligning Single Crystal Silicon Nanoparticles

NSF NIRT Grant 0304211

PIs: **Stephen A. Campbell, C. Barry Carter, Heiko O. Jacobs, Uwe R. Kortshagen**
University of Minnesota

Single crystal semiconductor nanoparticles would allow the construction of three-dimensional circuits and the integration of otherwise chemically and structurally incompatible single-crystal materials on a single substrate. This would dramatically reduce interconnect delay and allow the fabrication of high performance Si devices on any substrate. This NIRT will attempt to develop the technologies needed to demonstrate such devices. In this highlight we report that two of the most difficult steps needed have been demonstrated.

The production of highly perfect single crystal Si nanoparticles has been achieved using a constricted capacitively coupled plasma. The discharge is a striated, high-luminosity plasma filament that rotated close to the wall at ~150 Hz. The particles were highly monodisperse with a size distribution of a peak size of 35 nm and a standard deviation of 4.7 nm. TEM studies showed that the particles were perfect single crystals without twin boundaries or dislocations and had (100) faces (Fig.1). To gain insight into the properties of the constricted plasma, we recently developed a simple plasma model and found that the main heating mechanism is likely electron-ion recombination at the particle surface. in our plasma this mechanism may lead to particle heating of several hundred Kelvin above the background gas temperature. We expect that this nonequilibrium of particle and gas temperature is essential for the efficient formation of silicon nanocrystals.

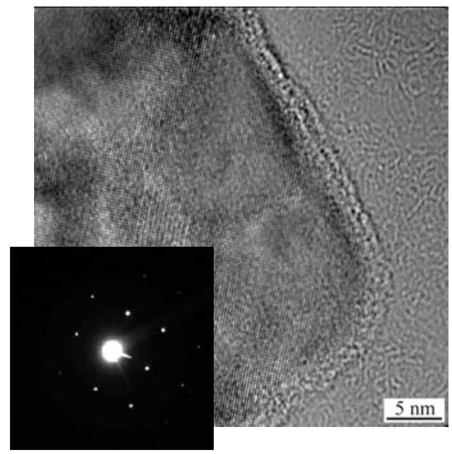

Figure 1 – C_S corrected HRTEM image. Insert shows selected area diffraction of the diamond structure and (001) faces.

A charge patterning process, referred to as electric nanocontact printing, has been developed. We form multiple electric nanocontacts of different size and shape to transfer charge in a single step. We have demonstrated charge patterning using flexible thin silicon electrodes and nanoxerographic printing. Using this technique with single crystal nanoparticles has proven challenging. Deceleration techniques have been developed and localization of the single crystal nanoparticles has been achieved. As shown in Fig 2, we have achieved almost perfect alignment of 40 nm single crystal particles. The technique to do this involves the use of fields created by resist coated field regions outside the developed lines.

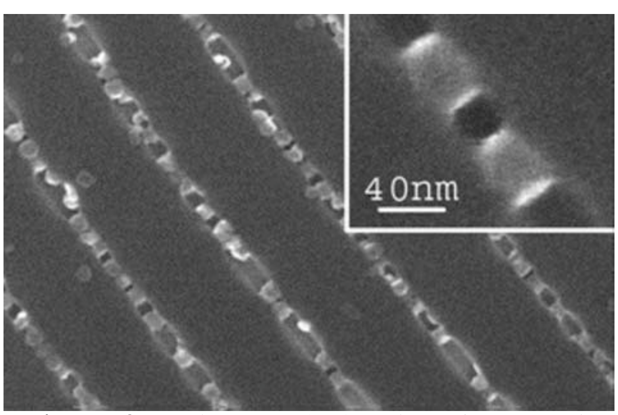

Figure 2 – Micrograph showing electrostatic localization of cubic nanoparticles using microstructure to assist the electric field.