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Nanowire Superlattices

Charles M. Lieber

Department of Chemistry, Harvard University, 12 Oxford Street, Cambridge, Massachusetts 02138

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In this issue of *Nano Letters* and an upcoming issue of *Nature*, three groups report exciting developments in the growth of semiconductor nanowires with modulated structures.[1−3] Semiconductor nanowires are nanoscale building blocks that could through bottom-up assembly enable diverse applications in nanoelectronics and photonics.[4] Individual, homogeneous semiconducting nanowires have been previously used as field effect transistors, photodetectors, and bio/chemical sensors, while more sophisticated light-emitting diode and complementary logic devices have been realized by assembling both n- and p-type semiconducting nanowires into crossed junctions.[5−8] Moreover, one can make a straightforward analogy to the planar semiconductor industry to extrapolate that complex compositionally modulated—so called "superlattice" structures—could greatly increase the versatility and power of these building blocks in nanoscale electronic and photonic applications. The growth of superlattice structures represents the primary focus of the new work now reported in *Nano Letters* and *Nature*.

The synthesis of these new superlattice structures builds upon the general concept of nanocluster catalyzed nanowire growth elaborated several years ago.[9] In this process, a nanocluster serves as the critical point for nucleation and addition of reactants to a growing nanowire, and critically, enables design to be brought to the synthesis problem. One recognizes that a catalyst common to two different materials could be used grow a nanowire superlattice structure by modulating the reactants during growth. The essence of this concept was shown with the growth of a silicon nanowire/carbon nanotube structure.[10]

The new work represents an exciting advance over previous work. The studies of Wu et al. use a laser ablation growth to prepare silicon/silicon−germanium nanowire superlattices.[1] Low-resolution transmission electron microscopy

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images and spatially resolved composition analysis show unequivocally that these nanowires are compositionally modulated structures with a remarkably regular modulation period. An interesting outcome of these analytical measurements is that the composition of each period varies on the scale of nanowire diameter. Bjork et al. focused on the growth of InAs/InP superlattices, which have been well studied in planar structures.[2] Using nanocluster catalysts and molecular beam epitaxy techniques to generate reactants, they prepared modulated nanowire structures with periods ranging from 100 to just several nanometers. Significantly, their lattice-resolved transmission electron microscopy images suggest that the interfaces are atomically perfect. Gudiksen et al. describe growth superlattice structures of GaP/GaAs, n-type Si/p-type Si, and n-type Si/p-type Si.[3] Lattice-resolved imaging studies of these structures demonstrate atomically perfect interfaces similar to the studies of Bjork et al., although additional analytical studies show that the composition varies across this interface on a length scale comparable to the diameter. The abruptness of these interfaces, which is critical to many applications, is an issue that will deserve further study in the future. These studies clearly suggest that many of the "tricks" of planar devices might now be brought to the nanoscale regime with these materials. Moreover, as pointed out by Gudiksen et al., nanowire superlattices offer unique new features, including the potential to tolerate much larger lattice mismatches between components and the ability to achieve radial quantum confinement of carriers and excitons.

Where will the utility of these new structures lie? The three new papers suggest a diversity of possible applications, including thermoelectrics, nanobarcodes, injection lasers, and engineered one-dimensional waveguides.[1,3] Bjork et al., provide electrical transport data consistent with electron transport through modulated InAs/InP structures. Further evidence for the promise of these materials has been presented by Gudiksen et al. With single molecular imaging techniques they demonstrated localized luminescence from a GaAs quantum well within the GaP/GaAs superlattices. Moreover, they have used single nanowire transport and scanned probe microscopy to demonstrate unambiguous activity from localized p−n junctions in silicon and InP nanowires, where the latter have also been shown to be a unique source of polarized photons. For the immediate future, careful and critical studies of the properties of these new nanowire superlattices will be essential for understanding their limits and determining potentially novel science and applications. It is clear that these three new papers open an exciting new chapter in nanoscale research.

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