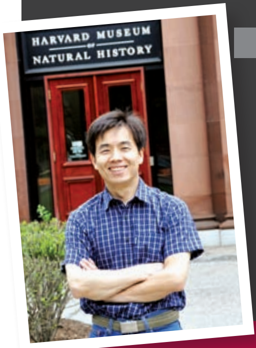

Building Our Big Future from Small Things

In front of Harvard Museum of Natural History, 2009

There is a consent that nanoscience and nanotechnology were inspired by Nobel Laureate physicist Richard Feynman's prospective lecture "There is plenty of room at the bottom" during an American Physical Society annual meeting in 1959 at Caltech. Since then, a variety of exciting breakthroughs have been demonstrated, especially in exotic nanomaterials such as 0-dimensional fullerenes, nanocrystals and nanoparticles, 1-dimensional carbon nanotubes and nanowires and 2-dimensional graphenes. Our human hair has a diameter of about 100 micrometers; a nanometer is one hundred thousandth of it! At such a length scale, some physics laws that govern in macroscopic world would no longer be applicable in nanoscale world. Every student in physics and engineering learns particle-in-a-box model in Quantum Mechanics, nanomaterials would form such "boxes", or in a physical terminology "confinement potential wells" in certain directions for electrons, photons, excitons and phonons etc. Therefore, certain physical properties in nanoscale world are remarkably different from the macroscopic world. We are extremely interested to study those fundamental properties, not only driven by curiosity but also motivated by the dream that our big future can be built from such small things! For example, researchers have demonstrated exciting achievement in nanoelectronics, nano-photonics and nano-biological interface devices.

After nearly ten years' Ph.D. study and postdoctoral training in USA, Dr. Qihua Xiong recently joined Nanyang Technological University as Nanyang Assistant Professor with the prestigious National Research Foundation fellowship support. He is building a strong group bridging interdisciplinary research on synthesis of novel nanomaterials, their fundamental properties and their advanced applications, which exhibit great potential to advance future electronics, photonics, energy and healthcare. Although still subject to final approval from SCDF, his main lab in SPMS is already in a good shape which hosts a full line of state-of-the-art equipment for materials synthesis, nanofabrication, electrical transport measurement and optical spectroscopy characterizations. He has also acquired a low pressure chemical vapor deposition (LPCVD) system, which is scheduled to be installed in Nanyang Nanofabrication Center hosted in EEE around April 2010. This system is configured in such a way to grow Si and Ge nanomaterials in large scale on 4 inch wafers.

Dr. Xiong is a well known expert in spectroscopy of nanomaterials; he had made significant contribution in phonon properties of nanowires such as phonon confinement, surface phonons and nano-antenna effect. His research elucidated how phonon properties of one-dimensional nanowires depend on the size, anisotropic shape, surface symmetry and surrounding dielectric environment. He also discovered twinning superlattices in compound nanowires and studied nanomechanical properties. His recent postdoctoral research extends to high speed and high performance 3D integrated nanoelectronics and biosensing. Besides this National Research Foundation fellowship award, Dr. Xiong has also won Pan-American Advanced Studies Institute (PASI) fellowship, Graduate Award for Academic Excellence from Pennsylvania State University and several other fellowship awards during his post-graduate studies.

Having settled down his family in NTU garden campus, Dr. Xiong is ready to lead his group to compete in the world-wide enterprise in nanotechnology.

Semiconductor Nanowires for Future Electronics and Optoelectronics

Prof Cesare holds a joint appointment in the Division of Physics and Applied Physics (SPMS), and the Division of Microelectronics (EEE) under the Nanyang Assistant Professorship scheme. Hear him talk about his research work which may have an impact on technology for renewable energy.

The fundamental properties of semiconductors change drastically if their dimensionality is reduced. When characteristic dimensions are shrunk to few and to tens of nanometers, quantum mechanical effects cannot be neglected, and the optical and electronic properties become strongly size dependent. Furthermore, the increase of surface-area-to-volume ratio has other important effects, for instance the enhancement of chemical sensitivity or catalytic properties in nanostructured materials.

We are interested in the properties of materials with small dimensionality and large interface area. Understanding these properties is essential to exploit them in emerging technologies, such as renewable energy sources. In particular we focus on III-V nanowires fabricated by bottom-up techniques, in which we make use of self-assembly to induce the growth of crystalline structures with 5-100 nm diameter and 1-10 microns length.

One of the most interesting aspects is that since the lateral dimensions are so small, we are not limited to heteroepitaxial growth (i.e. growth of one material on an identical substrate), but we can realize unlikely combinations of crystalline materials, such as InAs nanowires on silicon, with an extremely large lattice mismatch. This opens up many opportunities for direct integration of high performance III-V electronic and photonic devices into mainstream silicon technology.

Furthermore, we are able to add functionality to each individual nanowire by introducing p-n junctions or heterostructures during the growth, either in the axial or in the radial direction, by alternating materials (axial junctions) or by conformal coating with different materials (core-shell junctions). Depending on design and material combinations, such nanostructure can replicate a variety of functions commonly achieved in thin-film technologies, ranging from charge transport modulation (FETs) and light emission (lasers and light-emitting diodes) to light detection (photodetectors) and power generation (photovoltaics).

Combining the bottom-up growth techniques with conventional nanolithographic techniques, it is possible to predefine the location where nanowires are grown, and therefore obtain ordered arrays of vertical nanowires. Such arrays are an ideal platform for 3D device architectures, such as surround-gate FETs (which promise better control of the channel electrostatic and denser integration) or photovoltaic arrays (which may exploit photonic properties of the ordered array for light trapping and improve charge extraction in core-shell architectures).

Finally, we will explore the combination of inorganic nanowires with organic semiconductors, particularly conjugated polymers, for photovoltaic applications. This is a natural step connecting the work on conjugated polymers done at the University of California, Santa Barbara with the work on nanowires done at the University of California, San Diego prior to joining NTU.