Stevens Institute of Technology

Nanotechnology Graduate Program

Prospects of Nanoscience

Wednesday February 24, 2010
Babbio 122, 4 pm

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My personal involvement with nanoscience started when Esaki and I launched the man-made superlattice at IBM Research Center 40 years ago. The basic idea is so simple: Electrons reaching the Brillouin zone boundary are Bragg reflected, resulting in high frequency oscillations. Most of the rapid technological developments in this field owe their successes to modern deposition techniques and new diagnostic tools such as AFM and HRTEM, etc. The same tools that enable such rapid development of the field are leading nanoscience and technology to new commanding roles in material science, robotics and even in biological and medical sciences. My personal view is that physics is the core science underlying the various engineering disciplines, as well as chemistry and, importantly, biology. As such, it provides us the basis for the successful development of new nano-initiatives. Successful new nano-initiatives need to be nested in a focused group with broad vision which can include the nanodynamics of living things. Present technical impediments and near term objectives include:

- When Quantum wells further confine electrons to Quantum dots, serious problems develop: the dielectric constant reduction leads to problems in doping; increased coupling to defects leads to optical blinking and electrical switching; and the overall problems with contacts due to the lack of an equal-potential (normally provided by a highly conductive contact), defining input/output. These are problems of a fundamental nature that need new approaches.
- Traditional superlattices based on heterojunctions should be broadened to embrace the new silicon/oxygen SL, having a single layer of oxygen between Si structures. This scheme ushers in the present push of putting a single layer of graphene between silicon (or others such as c-BN). This concept is in line with the broadening of molecular chemistry to systems involving polymers.
- The underlying concept of the Random Phase Approximation may serve as a figure of merit structures consisting of individual components of nanometer dimensions. A parameter of phase coherence may define everything from electronic materials to living cells such as hemoglobin and chlorophyll.

Nanoscience and technology cover nearly everything living and nonliving. Therefore, we shall see a rapid expansion of the role of nanoscience and technology into all phases of science and technology from electronics, robotics, to even construction engineering as well as biology and medicine.

Professor Raphael Tsu is a world leader in the areas of quantum properties of materials and device physics. An acknowledged authority in these subjects, he has published nearly two hundred scholarly papers in scientific journals; is an author of a monograph on quantum wells and superlattice materials and devices of which he is a co-inventor, and is holder of several patents for his discoveries and invention. The description of his research contributions while at the IBM T.J. Watson Research Center was presented to the White House by the US Army Research Office, The Superlattice Story, which played an important role in the 90's towards the US National Nanoscience Initiative (NNI).

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