SYMPOSIUM X

Frontiers of Materials Research

April 13 - 15, 2004

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* Invited paper

This symposium is the Society's principal vehicle to maintain the interdisciplinary and integrative nature of its mission within the materials community with invited reviews presented over the lunch hour. Leaders in various specialties represented by the topical symposia present reviews designed for materials researchers who are **NOT** specialists in the reviewed field.

SESSION X1
Chairs: Israel J. Baumvol, James J. De Yoreo, Siegfried Mantl and Thomas X. Neenan
Tuesday Afternoon, April 13, 2004
Room 2010/2012 (Moscone West)

12:05 PM *X1.1
Sub-45 nm CMOS: A Grand Old Lady with New Clothes. Wilfried Vandervorst, M. Caymax and T. Schram; MCA Department, IMEC, Leuven, Belgium.

Si-based CMOS technology has been our standard solution for decades as building block for microelectronic circuits, memories and systems. The materials used in the original concept of the CMOS transistor were (primarily) Si, SiO_2 and Al. Transistor performance was continuously improved merely by downscaling of the devices. The accompanying lower resistance which was required, was pursued by introducing new materials such as silicides for contacts and Cu as metallization sytems. However for a long time the heart of the transistor remained unchanged i.e. SiO_2 as gate dielectric and poly-silicon as gate material. Recently, this has changed dramatically and for instance the gate material has progressed from SiO_2 over medium k towards high k materials moving away from the "natural" silicon based oxides towards complex material systems requiring detailed process engineering. Limitations in scaling due to poly Si depletion effects are counteracted by the introduction of metal gates and low k materials are introduced to reduce excessive RC-coupling. Finally, with shrinking dimensions and reducing junction depths, series resistances of the source/drain regions are increasing, necessitating the use of even higher active dopant levels. Coupled with the need for lower temperatures and reduced thermal budgets, this leads to processing steps providing high (but metastable) dopant concentrations. Enhanced performance for very small devices is further obtained by increased carrier mobilities resulting from stressed Si layers and/or alternative material (for example SiGe) in the channel region. The ultimate step will be to replace even the backbone of the CMOS transistor and to use Ge instead of Si as substrate material. This evolution from a simple three materials system (Si,SiO2, Al) towards a very complex materials stack has been facilitated by rigorous engineering of the different materials and even more importantly of the various material interactions during processing. Notwithstanding the increased processing complexity, this has given CMOS the ability to maintain its scaling properties for more than 20 years and provides still a very bright future for this old lady dressed in new clothes.

12:45 PM *X1.2
Materials Science for the Repair of Humans. Samuel I. Stupp, Materials Science & Engineering, Northwestern University, Evanston, Illinois.

Abstract Not Available

SESSION X2
Chairs: Israel J. Baumvol, James J. De Yoreo, Siegfried Mantl and Thomas X. Neenan
Wednesday Afternoon, April 14, 2004
Room 2010/2012 (Moscone West)

12:05 PM *X2.1
Light and Life: Biophysics, One Molecule at a Time. Steven Block, Department of Biological Sciences and Department of Applied Sciences, Stanford University, Stanford, California.

Optical tweezers (optical traps) represent the closest we've come to realizing the "tractor beam" familiar from science fiction. Optical tweezers derive their trapping ability from radiation pressure generated by infrared laser light focused through a strong lens. They can grasp and manipulate microscopic particles in the size range of nanometers to micrometers, and can apply piconewton-scale forces with exquisite control. With a judicious choice of laser power and wavelength, optical tweezers are non-damaging to trapped objects, even to living specimens such as cells or bacteria. Optical tweezers have found their greatest utility thus far *invitro*, in the new research area of **singlemoleculebiophysics**, where they're being used to study the nanomechanical properties of individual biomolecules. This talk will highlight recent experimental progress using optical tweezers in studies of the motor protein *kinesin*, which transports cellular cargo along microtubules, and in studies of transcriptional elongation by *RNApolymerase*, the enzyme that transcribes mRNA molecules from DNA with great fidelity.

12:45 PM *X2.2

OUTSTANDING YOUNG INVESTIGATOR ORAL PRESENTATION

Chemistry and Physics of Semiconductor Nanowires. Peidong Yang, Department of Chemistry, University of California-Berkeley, Berkeley, California.

One-dimensional nanostructures are of both fundamental and technological interest. They not only exhibit interesting electronic & optical properties intrinsically associated with their low dimensionality and the quantum confinement effect, but also represent the critical components in the potential nanoscale device applications. In this talk, the vapor-liquid-solid crystal growth mechanism will be briefly introduced for the general synthesis of nanowires of different compositions, sizes, and orientation. Unique properties including light emission and thermoelectrics will be discussed. In addition to the recent extensive studies on "single-component" nanowires, of increasing importance is the capability of incorporating different interfaces, heterojunctions as well as controlling doping profiles within individual single crystalline nanowires. Epitaxial growth plays a significant role in making such nanowire heterostructures and their arrays. I will present our recent research efforts towards superlattice nanowires and other nanostructures with horizontal junctions. The implication of these heterojunctioned nanowires in light emission and energy conversion (thermoelectrics and photovoltaics) will be discussed. Lastly, ways to assemble these one-dimensional nanostructures will be presented.

SESSION X3
Chairs: Israel J. Baumvol, James J. De Yoreo, Siegfried Mantl and Thomas X. Neenan
Thursday Afternoon, April 15, 2004
Room 2010/2012 (Moscone West)

12:05 PM *X3.1
Silicon Based Quantum Computing. Bruce Kane, Lab for Physical Sciences, University of Maryland, College Park, Maryland.

Silicon - the semiconductor that is the mainstay of the contemporary computer industry - also has many attractive properties for future quantum logical devices. Specifically, both electron and nuclear spins situated in Si can have extremely long lifetimes, and are consequently ideal qubits for quantum computation. After a brief introduction to quantum computers and the motivation for building these machines, I will describe a variety of devices being developed to perform quantum logic and measurement on single spins in Si. While is likely that these types of devices will be developed in the near future, the prospects for large scale quantum computation (say > 103 qubits) is much less certain. I will argue that large scale quantum computing will demand that devices be precisely engineered at the atomic level, a prospect that - while daunting - also opens new vistas for materials research at the endpoint of Moore's Law scaling in silicon.

12:45 PM *X3.2
Science in Sport. Jan-Anders Manson, Institut des Maxteriaux (IMX), EPFL, Lausanne, Switzerland.

Exceptional skill and physical ability is the criterion for success in sport. For this an athlete seeks the ultimate performance out of his own body, his equipment and his outfit. His equipment and outfit does not just need to be made of materials with the most extreme physical properties but it must also allow to transmit the "right" feeling and touch between himself and his equipment. Thus, in most cases the material has to possess a unique combination of structural and functional capabilities. Today these unique structural performances and functions are widely integrated in many sport equipments. For examples the latest tennis rackets and skies integrates these novel materials to reach the otherwise impossible combination of high stiffness, low weight and extreme damping performance. There are no doubts that the sports industry plays an important role during the implementation of a new material to the market. In comparison to other industrial branches such as aerospace and automotive the speed of the market changes in sport equipments and outfits are very high. This puts enormous time constrains on technology adaptation and market implementation. It is well known you cannot win America's Cup or Formula 1 with the latest years technology. Thus, it is not surprising that sport during last decade has increasingly position itself as a driver in materials research. However, it is vital to seek synergies in research and implementation strategies in order to gain maximum experience from each other's unique experience about design, material performance, durability and manufacturing concepts. Finally, it is clearly demonstrated in recent years that sport does not just take increased use of advanced technologies it also shows an increased importance for the public economy.