Electronics
Room 312 - Session EL+NS-TuA
Nanoelectronics

Moderator: R.S. Goldman, University of Michigan

2:00pm **EL+NS-TuA1 Nano-switches Using Vacuum Nano-electronics and Superconducting Weak Links***, **D.G. Hasko,*** Cambridge University, UK **INVITED**

New physical principles influence device operation when size is reduced to the nanometre range Recent research has lead to two types of switching devices; vacuum nanoelectronic (VNE) and superconducting switches have been described and are reviewed in this paper. Conventional vacuum microelectronics exploits cold field emission of electrons in devices made by microcircuit fabrication techniques but requires UHV vacuum operating conditions. By reducing the field emission tip radius and the tip-extractor electrode spacing a new class of VNE devices may be operated at lower voltages and with improved stability. Tips of nanometre size also show much smaller angular spreads and reduced energy spread. Diode and triode devices, with electron transport path length of ~100nm (shorter than the mean free path in air) were fabricated and their electrical characteristics reported. Hot phonon injection from an electrically isolated heater has demonstrated effective switching behaviour in Nb weak link junctions and is of great interest for high speed and quantum effect circuit functions. This method isolates the control circuit from the weak link and has demonstrated significant device gain in contrast to previous device structures.

2:40pm **EL+NS-TuA3 Persistent-current Qubits for Quantum Computation***, **E.L. Mooij,*** DIMES Institute, The Netherlands **INVITED**

In a collaboration between MIT and Delft University we have designed a quantum bit (qubit) for quantum computation that consists of a superconducting loop with three small Josephson junctions in series.@footnote 1@ When the flux through the loop is close to half a superconducting flux quantum, the qubit has two stable macroscopic quantum states with persistent currents in opposite directions. Quantum transitions between the two states are possible if the capacitance of the junctions is small. Samples are fabricated from aluminum and measurements are performed at very low temperatures to reduce decoherence effects. First measurement results have been obtained that demonstrate the quantum superposition of the states. Next experiments will focus on time-dependent response. With these qubits in principle a scalable quantum computer can be constructed if the decoherence time is long enough. A quantum computer of sufficient size can perform calculations beyond the power of a conventional computer. However, many challenges will have to be faced before a quantum computer is realized. @FootnoteText@ @footnote 1@J.E. Mooij, T.P. Orlando, L.Levitov, Lin Tian, Caspar H. van der Wal and Seth Lloyd, Science 285, 1036 (1999)

3:20pm **EL+NS-TuA5 Coulomb Blockade Devices Fabricated by AFM-manipulation of Nanoparticles***, S. Carlsson, T. Junno, H. Xu, **L. Samuelson,*** Lund University, Sweden

We report successful fabrication of Coulomb blockade devices obtained by manipulation of pre-fabricated nanoparticles, using an atomic force microscope (AFM) as a nano-engineering tool. This approach, together with in-situ electrical measurements during manipulation, allows the formation of tunnel gaps with accuracy on the Ångstrom scale. Three-terminal single-electron transistors (SETs) with ideal electrical characteristics are obtained, demonstrating Coulomb blockade as well as Coulomb staircase in the I-V characteristics, and with hundreds of current oscillations as function of gate voltage. Furthermore, we have built double-island structures with three gaps trimmed to tunneling dimensions and with two addressing gates, allowing control of the charge distribution, or polarization, of these two-atom artificial molecule objects.

3:40pm **EL+NS-TuA6 A Novel Scheme for the Fabrication of Ultra-short Metal-oxide-semiconductor Field-effect Transistors***, **R. Martel,*** IBM T.J. Watson Research Center*; J. Appenzeller, J. Knoch,* Physikalisches Institut, RWTH Aachen, Germany*; K. Chan,* IBM T.J. Watson Research Center*; M. Tanner, S. Thomas, K.L. Wang,* University of California, Los Angeles*; Ph. Avouris,* IBM T.J. Watson Research Center*; J.A. del Alamo,* Massachusetts Institute of Technology*; P. Solomon,* IBM T.J. Watson Research Center

We present a novel scheme for the fabrication of ultra-short channel length metal-oxide-semiconductor field-effect transistors (MOSFETs) involving nanolithography (proximal probe or e-beam) and molecular beam epitaxy (MBE). The active channel is undoped and is defined by a combination of nanometer-scale patterning and anisotropic etching of a n@super ++@-layer grown on a silicon on insulator (SOI) wafer. The method is self-limiting and can produce MOSFET devices with channel lengths of less than 10nm. Measurements on the first batches of n-MOSFET devices fabricated with this new approach will be presented. They show very good output characteristics and good control of the short channel effects. The combination of highly doped contact areas (n@super ++@ 1x10@super 20@cm@super -3@) with a nominally undoped channel region (p@super -@ 5x10@super 14@cm@super -3@) is now being explored further to keep the parasitic resistances low and possibly achieve ballistic transport at room temperature.

4:00pm **EL+NS-TuA7 Quantitative Analysis of Charge Injection and Discharging of Si Nanocrystals and Arrays by Electrostatic Force Microscopy***, **L.D. Bell,*** Jet Propulsion Laboratory, Caltech*; E. Boer, M. Ostraat,* Caltech*; M.L. Brongersma,* Caltech, US*; R.C. Flagan, H.A. Atwater,* Caltech

Charge injection and storage in dense arrays of silicon nanocrystals in SiO@sub 2@ is a critical aspect of the performance of potential nanocrystal flash memory structures. We have performed charging experiments on Si nanocrystals both embedded within and deposited on SiO@sub 2@ using conducting-tip atomic force microscopy (AFM). In the case of both isolated aerosol-deposited nanocrystals and those formed by ion implantation and annealing of SiO@sub 2@ films, charging has been accomplished by moving a conducting AFM tip close enough to the nanocrystal to transfer charge. This charging and subsequent discharging were characterized by monitoring the apparent change in nanocrystal height detected by AFM. The trapped charge produces an electrostatic force component that changes the response of the AFM tip, causing a change in the apparent height of the nanocrystal. This mode of electrostatic force microscopy (EFM) together with electrostatic modeling enables quantitative measurement of the trapped charge and discharging dynamics. Simulation enables the EFM sensitivity to be estimated systematically as functions of tip radius and height. Forces due to interaction with this charge and the induced charge on the tip can be determined, and AFM response to these forces can be calculated. Constant-force-gradient contours have been calculated that agree well with measured profiles, and we can determine the amount and location of the injected charge as well as some details of the discharge mechanism. Trapped charge as small 7e is detected in isolated small nanocrystals, and charge in the range 100e - 1000e is observed in larger isolated nanocrystals or embedded nanocrystal ensembles. The combination of EFM imaging and simulations can be used to estimate the homogeneity of the charge density and to probe for high conductance paths within a nanocrystal floating gate. Modeling indicates a discharge mechanism consistent with tunneling through a field-lowered barrier.

4:20pm **EL+NS-TuA8 Quantized Conductance in AuPd Alloy Nanocontacts***, **A. Sakai**, A. Enomoto, J. Sasaki, S. Kurokawa,* Kyoto University, Japan

Quantization of conductance can be observed most beautifully in Au nanocontacts but much less clearly in transition metals such as Pd. Then, an interesting problem is how the quantized conductance changes by alloying Au with Pd. Do all quantized peaks in the conductance histogram of Au disappear by a small amount of Pd, or do they survive even for Pd-rich nanocontacts? To answer this problem, we have carried out conductance measurements on AuPd nanocontacts in air at room temperature. We prepared Au@sub 1-x@Pd@sub x@ alloy wires with x = 20, 40, 50, 80, and 95 wt%, and measured the transient conductance at the break of two contacting wires. We find that the transition from the conductance behavior of Au to that of Pd takes place gradually with increasing the Pd concentration: sharp peaks in the histogram of Au are suppressed and replaced by a broad and featureless distribution observed in the histogram of Pd. At x = 40 and 50 wt%, both quantized peaks of Au and broad background of Pd coexist in a conductance histogram. This result implies that the conductance of AuPd nanocontacts becomes that of Au or Pd depending on which one of two constituent atoms occupies the narrowest constriction of the contact.

4:40pm **EL+NS-TuA9 Bistability in Conductance of Point Contact formed between a Metal Tip and Ga-terminated Si(111)***, **S.L. Pryadkin**, D. Chen,* Rowland Institute for Science

Recently, it has been found that voltage-current dependence of a tunnel junction formed by an STM tip and a Ga terminated Si(111) surface exhibits large hysteresis at 77K, similar to that of a double barrier structure.@footnote 1@ This new finding raises the possibility of creating nanoscale storage and switching devices, compatible with silicon technology. To further explore this potential, we have studied the effects of temperature and dopping. It is found that the hystersis exists in a wide range of temperature. Moreover, when the tip is brought to a point contact with the surface, it still gives rise to the bistable transport. This allows us to simplify the junction structure even further and to determine the timing characteristics of this new nanoscale switching/storage device. @FootnoteText@ @footnote 1@ I.B.Altfeder, D.M.Chen Phys.Rev.Lett. 84, p.1284(2000).

5:00pm **EL+NS-TuA10 Analysis of Non-linear Behaviour in Gold Nanowires***, **A. Wlasenko**, P. Gruetter,* McGill University, Canada

In the presented experiment, a gold nanowire is formed with a mechanical break junction. A voltage bias is applied in the form of a triangle wave (typically 0.1 Hz, 2V@sub pp@) plus a small sine wave (typically 10kHz, 10mV@sub rms@) across the nanowire in series with a load resistor. A current pre-amp measures I(V), while a lock-in amplifier measures its partial derivative with respect to voltage. While others have made I(V) measurements of nanowires (Costa-Kramer et al., PRB 55, 5416 (1997) and Costa-Kramer et al., Nanoscale Science and Technology pp. 1-10 (1998) Kluwer Acedemic), the simultaneous measurement of the derivative allows powerful analysis without choosing a physical model or using mathematical fits. In general, the current is not just a function of voltage [I(X,V)=g(X)f(X,V)]. For instance, the geometry of the nanowire or presence of scatterers should have an effect on the current. The analysis indicates how changes in these non-voltage factors [X] are changing the current [@DELTA@I(@DELTA@X,V)] without having to know explicitly what these are factors are or how they are changing. It is also possible to determine how the form of current f(X,V) is changing with respect to the voltage without knowing g(X). Several individual sets of data shall be investigated that illustrate particular features of both typical and atypical nanowire behaviour. A discussion is presented of the possible physical arguments concerning these features and general trends.

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