NANOELECTRONICS


Recent advances in atomic force microscopy and its practical use in fabricating the component basis for micro- and nanoelectronics are reviewed. New designs of cantilevers and sensors (selectively sensitive devices) are considered. The advancements and trends and in atomic force microscopy-based nanolithography are discussed. (53 References).


In this paper we investigate the nonlinear dynamics of circuits made of single-electron tunneling junctions (SETJ) driven by a sinusoidal pump and biased by a DC voltage source. The mathematical model of an isolated SETJ circuit is a first-order nonautonomous impulsive differential equation. The tunneling effect of each SETJ can be realistically modeled by the impulsive effect of the junction voltage, which we choose to be the state variable of our circuit model. Based on this model we present theoretical results on the stability of the periodic and almost periodic solutions of driven SETJs. Our theoretical results show there are two phase states in each isolated SETJ circuit, which corresponds to two phase-shifted periodic solutions of our model. We present theoretical and numerical results of return maps of an isolated SETJ circuit. Our results also show that if the tunneling events are equipotentially almost periodic then the attractors generated by two-coupled SETJs will be confined to the vicinity of some periodic orbits. This result provides a foundation for implementing robust logic operations in nanoelectronics. (13 References).


The devices models created with the use of scanning probe microscopy (SPM) methods including planar models of nanodiodes are described. The devices are based on elements with nanometer dimensions (quasi-one-dimensional micro-contacts) that show nonlinear properties of conductance, including the phenomenon of resistance quantization at room temperature. (3 References).


A novel nanometer-scale electronic technology, called nanoelectronics is emerging. Nanoelectronic discrete devices, such as resonant tunneling diodes and transistors, single-electron transistors, bistable quantum-cells, quantum interference devices, etc. have been proposed and built. Technology and physics of the devices are reasonably well understood, but there exists a gap between device physics and nanoelectronic systems integration. In this paper it is shown that in case of local quantum coherence, i.e., if coherence is restricted to the internal dynamics of Coulomb-coupled devices, system dynamics can be described by a set of coupled ordinary nonlinear differential equations. In this case virtual charges, voltages and currents, obeying Kirchoff's equations, can be assigned to the dynamic variables of the state equations, thus circuit models can be introduced. We also show that edge-driven arrays performing ground state computing are locally passive systems if the Coulomb-coupled devices are excited by the input signals only. In order to perform signal processing or computing, external energy should be pumped into the array, and the pumped array should be locally active. Adiabatic pumping is one way of injecting energy to the signal path. (10 References).


Summary form only given, as follows. We investigate the use of nanoelectronic structures in cellular neural network (CNN) architectures, for future high-density and low-power CMOS-nanodevice hybrid circuits. We present simulation results for Single Electron Tunneling (SET) transistors configured as a voltage-to-current transducer for CNN cells. We also present an example of quantum-dot cellular arrays which may be used to realize binary CNN algorithms. Nanoelectronics offers the promise of ultra-low power and ultra-high integration density. Several device structures have been proposed and realized experimentally, yet the main challenge remains the organization of these devices in new circuit architectures. Here, we investigate the use of nanodevices in CNN architectures. Specifically, we focus on nanostructures based on SET devices and Coulomb-coupled quantum-dot arrays, the so-called Quantum-Dot Cellular Automata (QCA). CNN-type architectures for nanostructures are motivated by the following considerations: on the one hand, locally-interconnected architectures appear to be natural for nanodevices where some of the connectivity may be provided by direct physical device-device interactions. On the other hand, CNN arrays with sizes on the order of 1000-by-1000 (which are desirable for applications such as image processing) will require the use of nanostructures since such
integration densities are beyond what can be achieved by scaling conventional CMOS devices. (13 References).


We demonstrate Coulomb blockade oscillations in different single-electron devices in Silicon-On-Insulator (SOI) films up to temperatures of 300 K. The layer sequence in SOI allows the underetching of these devices in order to realize suspended, highly doped silicon nanostructures. Similar suspended silicon beams are fabricated to form novel nanomechanical resonators that can be excited at radio frequencies up to about 300 MHz. Controlling the vibration frequency by a side-gate voltage, these resonators allow charge detection with a sensitivity of 0.1 e/square root Hz, comparable to that of cryogenic single-electron devices. (9 References).


The ultra-high vacuum scanning tunneling microscope (UHVSTM) has been used to induce desorption of H from the Si(100)-2X1:H surface with atomic-level precision. The study of the desorption mechanism led to the discovery of a substantial isotope effect between H and D, which has recently been employed to minimize hot electron degradation at the Si/SiO/sub 2/ interface in conventional complementary metal-oxide-semiconductor (CMOS) circuits. This paper reveals secondary ion mass spectroscopy (SIMS) data that show a direct correlation between D incorporation at this interface and transistor lifetime. D incorporation can be enhanced via high-pressure processing, which has led to lifetime improvements in excess of 700* for Samsung's latest 0.18 mu m, 1.5 V CMOS technology. In addition to enhancing current integrated circuits, UHVSTM-induced hydrogen desorption has aided the development of nanoelectronics on the molecular-size scale. Feedback-controlled lithography (FCL) has refined the desorption process to the point where templates of individual dangling bonds can be generated in arbitrary geometries. The chemical contrast between dangling bonds and H-passivated Si is then utilized to isolate individual copper phthalocyanine (CuPc) and C/sub 60/ molecules on the Si(100) surface. Following isolation, STM spectroscopy has characterized the mechanical and electrical properties of these molecules with intra-molecular precision. (16 References).


Self-assembly ('building') approaches can provide well-controlled structures and assemblies at the nanometer scale, but typically do not provide the specific structures or functionalities required for robust nanoelectronic circuits. One approach to realize high-density nanoelectronic circuits is to combine self-assembly techniques with more conventional semiconductor device and circuit approaches ('chiseling') in order to provide suitable functionality and arbitrary circuit functions. An interesting challenge is to find approaches where these techniques can be combined to realize suitable device structures. This paper describes recent work which combines self-assembly techniques involving metal nanoclusters and conjugated organic molecules with semiconductor interface and device structures to form structures of interest for nanoelectronics. One key requirement for this approach is the availability of a chemically stable semiconductor surface layer, which can provide a low-resistance interface between the metallic nanostructure and the semiconductor device layers following room-temperature, ex situ processing. As an illustration of the structures which can be realized, we describe a nanometer-scale ohmic contact to n-type GaAs which utilizes low-temperature-grown GaAs as the chemically stable layer. Contact structures have been realized using both isolated (sparse) clusters and using close-packed arrays of clusters on the surface. The low-resistance contacts between the nanoclusters and the semiconductor device layers indicates that relatively low surface barriers and high doping densities have been achieved in these ex situ structures. The general conduction model for this contact structure is described in terms of the interface electrical properties and the contributions from the various components are discussed. (24 References).


This Account deals with the synthesis and characterization of monodisperse soluble oligothienylenevinylengenes with chain lengths up to 100 A. The chain length dependence of the electronic and electrochemical properties both in solution and in the solid state are analyzed and discussed in the context of the potential use of oligothienylenevinylene as molecular wires. Problems related to interchain interactions are illustrated by the analysis of the effects of structure on the reversible dimerization of cation radicals and by the synthesis of new series of end-substituted oligomers.


Summary form only given. Molecular beam epitaxy (MBE) is currently the most powerful and flexible growth
method available for the fabrication of advanced device structures for nanoelectronics. Sensor technology is now sufficiently mature to make real-time sensor feedback control of the major process parameters of MBE a realistic and practical possibility of fabricating resonant tunneling diodes (RTDs), and IR photodetectors. The design and operation of a system is described, beginning with a discussion of the individual sensors and the physical basis for their operation. Then, the system performance is illustrated through specific examples of real-time sensor-feedback control of substrate temperature and layer composition during the growth of InGaAs-InAlAs HBTs, and control of barrier layer thickness for AlAs-InGaAs RTDs, with quantitative results on the improved repeatability achieved through the use of sensor-based control. (0 References).

Xu, J. M. (2000). "Infrared conductivity mapping for nanoelectronics." Applied Physics Letters 77(24): 3980-2. With ever shrinking dimensions in microelectronics, the conductivity performance of charge carriers approaches physical limits and demands tighter control. We show that near-field microscopy carried out at sufficiently long infrared wavelengths-below the plasma frequency-selectively detects and characterizes subsurface mobile carriers with 30 nm resolution, timely for next generation chips as well as for fundamental research, e.g., on low-dimensional electron systems. (15 References).