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Parallel Fabrication and Electronic Characterization of Nanostructured and Nanoheterostructured Metal Surfaces  
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Original Objectives  
- generation of selectively nanostructured substrates  
- integration of nanostructures with silicon-based microelectronics  
- electronic properties of metal nanostructures  

Status of Effort  

Among the more notable accomplishments during the course of this contract we identify the following results:  

- **Formation of Ordered Nanocluster Arrays by Self-Assembly on Nanopatterned Si(100) Surfaces.**  
A precisely ordered and precisely located array of 5 nm diameter nanoclusters has been fabricated by first etching into the substrate an array of holes with diameters comparable to the size of nanoclusters sought and then depositing adatoms on the substrate. The severely restricted diffusion field defined by the holes dominates nucleation and growth to produce a single nanocluster in each etched hole. Using Low Energy Electron Enhanced Etching (LE4) in a DC hydrogen plasma, we transferred an hexagonal array of 18 nm diameter holes with a 22 nm lattice constant from a biologically derived mask into Si(100). After etching, the mask was removed, and the patterned surface was intentionally oxidized in an oxygen plasma. Deposition of 1.2 nm of Ti on the oxidized surface produced an ordered array of 5 nm diameter metal nanoclusters positioned at the etched hole sites. Our methods achieved massively parallel processing at the key fabrication steps of pattern generation, pattern transfer, and nanocluster formation. Therefore, our methods enable rapid fabrication of arrays for fundamental studies and provide a route to manufacturability of nanostructure arrays for technological purposes.
• Controlled Morphology of Biologically Derived Metal Nanopatterns
We reported the ability to control the morphology of nanometer thick Ti oxide films which were created via a parallel nanofabrication process using a two-dimensional protein crystal as a template. Atomic force microscopy was used to examine the evolution of these structures from a periodic array of nanometer-scale dots (nanodots) to a screen containing a periodic array of nanometer-scale holes (nanoscreen) as the film thickness was increased. A Monte Carlo solid-on-solid simulation was then developed to explain the thickness dependence of the morphology as the metal film self-organizes into these nanopatterns.

• Creation of Nanometer Scale Patterns with Selected Metal Films
The goal of these experiments was three-fold: (1) to determine if some of the metals near Ti in the periodic table might have pattern forming properties similar to that of titanium, (2) to gain the ability to predict which additional metals might form nanodots and (3) to understand why some metals produce patterns, but not others. We reported the creation of large arrays of nanometer-scale dots (nanodot arrays) with several of these of these transition metals. The correlation between nanodot array formation and the interaction energies between metal atoms, other metals atoms and the surface of the sample was explored. The behavior of the metal films was then investigated with the aid of a Monte Carlo solid-on-solid simulation.

• Numerical Simulation of the Evolution of Nanometer-Scale Surface Topography Generated by Ion Milling
Using the theory of ripple topography proposed by Bradley and Harper, a computer simulation of nanoscale hole formation based on curvature dependent sputtering and surface self-diffusion was formulated. To determine the validity of this model as applied to the patterning process, profiles of actual nanoscale etch pits were obtained using atomic force microscopy, and the simulation has been used to evolve these profiles in time. Even with a number of simplifying assumptions in place, the model simulates the experimental data quite well.

Personnel Supported During this Contract:

Faculty: Dr. Kenneth Douglas; Dr. John Price
Post-Docs: Dr. Patrick Sullivan; Dr. Thomas A. Winningham
Graduate Students: Thomas A. Winningham, awarded Ph.D. in May, 1997; Jon T. Moore, awarded Ph.D. in December, 1997
Other: None
Publications

Accepted


Interactions/Transitions

participation/presentations at meetings, conferences, seminars, etc.

"Fused-Salt Electrodeposition of Thin-Layer Silicon," 26th IEEE Photovoltaic Specialists Conference, Anaheim,CA (September, 1997).
"Nanopattern Transfer Using Protein Crystal Masks: A Numerical Simulation of Experimental Results ", American Vacuum Society's 44th National Symposium, San Jose, CA (October, 1997)


"Ordered Nanocluster Array Formation on Si(100) Surfaces Patterned by Low Energy Electron Enhanced Etching through Biological Masks," Optical Society of America Topical Meeting on Chemistry and Physics of Small Structures, Santa Fe, NM, (February, 1997).


consultative and advisory functions to other laboratories and agencies
None

transitions
None

New Discoveries, Inventions, or Patent Disclosures


Honors/Awards

Faculty Sponsor:

American Western University Fellowship