Processing at the Nanoscale
Room 308 - Session NS+MI-TuA

Nanoscale Patterning and Lithography

Moderator: B.D. Terris, IBM Almaden Research Center

2:00pm **NS+MI-TuA1 Patterning Magnetic Recording Media by Imprinting***, **G.M. McClelland**, M.W. Hart,* IBM Almaden Research Center*; M.E. Best,* Hitachi San Jose Research Center*; C.T. Rettner, K.R. Carter,* IBM Almaden Research Center*; G. Hu, B.D. Terris, M. Albrecht,* Hitachi San Jose Research Center **INVITED**

Patterning magnetic media is a promising strategy for increasing magnetic recording density beyond the current value of 15 Gbit/sq. cm. As proposed by Chou, imprinting is an attractive means for generating the small structures required. This application is not affected by some difficult aspects of imprinting: overlay is not required, long range distortion is accommodated by positioning of the recording head, and defects can be corrected by error correction during read out. We have developed a complete, cost effective process for patterning of 30-nm-dia. single-domain magnetic islands over a 65 mm disk. The process steps are: forming a flexible stamp from a master, imprinting a replica in resist, reactive ion etching SiO2 pillars into the substrate, and depositing a magnetic film by evaporation. To accommodate the roughness and curvature of the substrate, a 10-micon-thick polymer stamp on an acrylic backing plate is used. The stamp is formed by photocuring an acrylate mixture in contact with an SiO2 master made by e-beam lithography. The resist is formed from a 15-nm-thick prepolymer liquid acrylate film spun onto the glass substrate. The film is viscous, so that non-flatness in the substrate is accommodate by stamp deformation, rather than by flow of the resist. After UV exposure, the stamp is removed to leave 30-nm-high resist pillars on a 10-nm-thick base layer. A dozen repeated imprints show a defect rate of about 1 in 10,000 pillars. A CF4/CH4 etch transfers the resist pattern into 30-nm-high, 30-nm-dia. SiO2 pillars with a period of 60 nm. To form a magnetic film, a 10-nm CoPt multilayer is deposited by e-beam evaporation at 300 K. This method shows promise for large-scale manufacturing, because the stamp-making process can be repeated indefinitely from a single master, and many replicas can be formed from each stamp.

2:40pm **NS+MI-TuA3 Buffer Layer Assisted Laser Patterning of Metals at the Nanometer Scale***, **G. Kerner**, M. Asscher,* The Hebrew University of Jerusalem, Israel

Spatial patterning of thin films on surfaces is of great importance for basic physical sciences and technology. An innovative method is presented for a single pulse, macroscopic scale laser patterning of metallic thin film to form nanometer range variable width conducting wires. Employing laser induced thermal desorption (LITD) via interfering split low power beams- metallic gold and potassium coverage grating on top of multilayer Xe is formed over Ru and Si at 20K as a demonstration. Upon annealing to 80K, the Xe layer desorbs and the metallic pattern softly lands and strongly attaches to the substrate. This is a highly versatile patterning technique that can be employed with practically any element and chemical species. It may readily be utilized to prepare millimeters long, 30nm wide conducting wires using current laser technology. The structure and thermal stability of the metallic pattern has been studied by means of AFM, STM, optical second harmonic and linear diffraction. The metallic structures are composed of nanometer size clusters, their size and distribution depend on the buffer layer thickness. The technique presented here is potentially an attractive alternative method for the deposition of periodic and more complex spatial patterns of conducting wires at widths well below the current limits.

3:00pm **NS+MI-TuA4 Low-Temperature Nanolithography using Energetic Neutral Atoms***, **E.A. Akhadov**, A.H. Mueller, M.A. Hoffbauer,* Los Alamos National Laboratory

Neutral atomic beams with kinetic energies of a few eV are exploited for etching of nanoscale features in polymeric materials and for epitaxial thin film growth on substrates held near ambient temperature. A unique low temperature etching and thin film growth technique, called Energetic Neutral Atom Beam Lithography (ENABL), has been recently developed at LANL. Using a collimated atomic beam with a small de Broglie wavelength permits the fabrication of high-aspect-ratio (>25:1) nanoscale features in polymeric substrates without undesirable defects (undercutting, tapering etc.) common to conventional etching. The high flux (~10@super17@ atoms/cm@super2@sec) and high kinetic energies (1 to 5 eV) of reactive atomic species (O and N) allow etching of sub-100nm features at high rates and the growth of high-quality oxide films at ambient temperatures. The use of ENABL for etching and film growth opens new frontiers for materials synthesis and processing at the nanoscale at ambient temperatures. Future prospects and challenges for low-temperature ENABL-based nanoscale fabrication will also be addressed.

3:20pm **NS+MI-TuA5 Self-Assembling Circuits?***, **K.W. Guarini**, C.T. Black,* IBM **INVITED**

The aggressive dimensional and performance targets for future technology generations place severe demands on lithography, not only for feature size scaling but also pattern integrity, density, line edge roughness, and process control. Already today many process "tricks" are routinely employed to shrink the dimensions of lithographically-defined features, such as resist trim and sidewall image transfer, but there are limitations on the extendibility of such approaches. While the great potential of various so-called "next generation" lithography techniques has been well touted, these solutions are inherently complex, require new tooling infrastructure, and present throughput challenges. Self organizing materials offer an exciting prospect for overcoming many of these hurdles. The simplicity, reproducibility, and dimensional control inherent in self-assembling materials make them attractive for silicon nanofabrication. In the grandest vision, we might imagine integrated circuits that one day "organize themselves"-yielding the ultimate sizing and positional control, but this vision is still in the realm of science fiction. However, already today we can implement self-organizing materials for selective unit processes to complement or enhance conventional semiconductor processing. For instance, self-assembling polymer films provide an appealing alternative to photoresists for certain types of patterning at nanometer-scale dimensions. In particular, diblock copolymer thin films self assemble into uniform, densely-spaced nanometer-scale features over wafer-scale areas. These films are compatible with standard semiconductor fabrication processes, enabling their integration into device and circuit fabrication. Such self-organizing materials provide novel nanofabrication capabilities and may enable solutions to some challenges confronting integrated circuit fabrication.

4:00pm **NS+MI-TuA7 Fabrication and Electrical Characterization of 2D Dopant Nanostructures in Si***, **J.S. Kline**, J.C. Kim, S.J. Robinson, K.-F. Chen, R. Chan, M. Feng, J.R. Tucker,* University of Illinois at Urbana-Champaign*; J.-Y. Ji, T.-C. Shen,* Utah State University*; C. Yang, R.-R. Du,* University of Utah

Lithography and contact with external leads are the two major challenges in nanoscale electronic device fabrication. We attempt to address both of these issues by using an integrated approach. STM lithography on H-terminated Si surfaces routinely achieves 1nm resolution. P donors can be selectively deposited onto the H-desorption area by dosing phosphine gas onto the STM patterned device template. Subsequent Si low-temperature deposition and annealing allows epitaxial overgrowth and the dopant atoms are completely activated. The sheet resistance of the P-delta layer is in the range of 1-4k@Omega@/square and can be controlled by phosphine surface coverage. External contacts to the device are fabricated by As ion implantation. We present a method whereby differences in surface features and tunneling spectroscopy between the contact and device region allow the registration of the STM. Low temperature electrical measurements of nanowires and other more complex structures are currently in progress and will also be reported. This work is supported by NSF, ARO, and DARPA.

4:20pm **NS+MI-TuA8 Polymer Patterning using a Soft Inkpad***, **Y.P. Kong**,* Institute of Materials Research and Engineering, Singapore*; L. Tan, L.-R. Bao,* University of Michigan, Ann Arbor*; X.D. Huang,* Institute of Materials Research and Engineering, Singapore*; S.W. Pang,* University of Michigan, Ann Arbor*; A.F. Yee,* Institute of Materials Research and Engineering, Singapore

We present a method of producing micrometer and submicrometer patterns of polymer on substrates. A patterned hard mold is pressed onto an 'inkpad' coated by a polymer. The inkpad consists of a polydimethylsiloxane (PDMS) layer backed by a hard substrate. The function of the PDMS layer is twofold. Oxygen plasma treatment of the PDMS layer allows a polar polymer solution to be spun coated on it. The hydrophobic recovery of the PDMS layer then lowers its surface energy and this allows the transfer of the polymer to the hard mold that has a higher surface energy. Secondly, the deformation of the PDMS layer during the pressing induces a large stress field gradient at the edges of the mold protrusions. It is this stress that leads to a localized rupture of the polymer layer. The pressing is carried out at temperatures close to the glass transition temperature of the polymer and under relatively low pressures to transfer the polymer onto the protrusions of the hard mold. After the hard mold is separated from the inkpad, it is brought into contact with a substrate under a suitable temperature and pressure to produce a positive replica of the mold. At the same time, a negative image of the mold is left on the inkpad and this negative pattern can be transferred to a substrate. With a 700 nm period silicon grating mold, we are able to produce both positive and negative polymeric gratings. We also demonstrate the transfer of multiple layers of polymer onto the protrusions of the mold thereby increasing the aspect ratio of the patterns. Transferring of different polymer layers leads to the possibility of making high-resolution polymer light emitting displays and organic circuits. The advantages of our patterning method over nanoimprint lithography are: lower process temperatures and pressures, no material transport related problems, absence of a residual layer that needs removal, and the possibility to create both negative and positive replicas of the mold.

4:40pm **NS+MI-TuA9 Influence of Stoichiometry and Structure on the Local Oxidation of Metal Films**, ***N. Farkas***, *G. Zhang, K.M. Donnelly, E.A. Evans, R.D. Ramsier,* The University of Akron; *J.A. Dagata,* National Institute of Standards and Technology

Oxidation growth kinetics of sputter-deposited Zr and ZrN thin-films are studied on the local scale by atomic force microscope (AFM) -assisted lithography. The growth kinetics are found to depend strongly upon the nitrogen content of the deposition plasma. Mass transport of subsurface O, H, and N species also plays an important role in the growth of nanometer-scale oxide structures, producing feature heights up to an order of magnitude greater than those observed in other material systems such as silicon and titanium. The stoichiometric and structural differences in the films are investigated by X-ray photoelectron spectroscopy (XPS), secondary ion mass spectrometry (SIMS) and X-ray diffraction (XRD) techniques to account for solid-state reaction and transport mechanisms involved in oxidation driven by a highly localized electric field. These results demonstrate the potential of AFM lithographic techniques for characterizing oxidation kinetics in the presence of the rich chemical behavior exhibited by reactive metal films.

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