Thin Films Division
Room 310 - Session TF-TuM
Thin Films for Sensing and Data Storage

Moderator: S. Semancik, National Institute of Standards and Technology

8:20am **TF-TuM1 Thin Film Media Requirements in Ultrahigh Density Magnetic Recording**, ***D. Weller***, *A. Moser,* IBM Almaden Research Center **INVITED**

Rapidly increasing areal densities and data rates in hard disk magnetic recording impose stringent requirements on media and head materials. An imminent problem is media instability, which results from superparamagnetic effects. These effects become measurable in thin film granular magnetic recording media in the thickness range of about 10 nm and below. They lead to sizeable magnetic viscosity (logarithmic magnetization decay as function of measurement time) and to a write pulse width dependent coercivity. Examples of the latter measurements over 10 magnitudes in time (5 ns to 50 s) will be presented for typical CoPtCr magnetic recording media of variable thickness and at variable temperatures. The results will be discussed in the context of Neel-Arrhennius based decay models and recent micromagnetic modeling calculations. The thermal stability problem has led to a surge in interest in novel materials and media schemes. These include conventional but higher anisotropy media, perpendicular media, self assembled particle arrays and patterned media. We will discuss these various approaches in the context of ultimately achievable areal densities.

9:00am **TF-TuM3 Molecular Dynamics Analysis of Energy Modulated Deposition of Model GMR Materials**, ***H.N.G. Wadley***, *X.W. Zhou,* University of Virginia

Vapor deposited multilayers consisting of low electrical resistivity conductors sandwiched between ferromagnetic metals exhibit giant magnetoresistance (GMR). The best GMR properties are obtained from materials with flat interfaces and low intermixing between adjacent layers. Interfacial roughness and intermixing are sensitive to the deposition method and process conditions. A three dimensional molecular dynamics model has been developed and used to establish the relationship between the multilayer nanostructure and vapor deposition conditions, including incident atom angle, incident atom energy and substrate rotation. The results indicate that at low incident energies (e.g., 1 eV or below), an increase in the incident angle leads to a significant increase in the interfacial roughness (and even to void formation) due to a shadowing effect. The development of interfacial roughness was also found to be accompanied by an increase in intermixing. The high interfacial roughness formed during oblique, low energy deposition can be significantly reduced by substrate rotation. High incident atom energies were found to result in a lower interfacial roughness, but at the expense of increased intermixing caused by an atomic exchange mechanism. Under normal incidence conditions, an intermediate incident energy of between 1 and 2 eV resulted both in a low interfacial roughness and intermixing. The simulation methodology was used to explore the benefits of modulated incident energy deposition strategies. When thermal energy adatoms were used to deposit the first few monolayers of each new metal layer, intermixing by the exchange mechanism during subsequent hyperthermal energy deposition could be eliminated, and films with almost no interfacial roughness or intermixing could be grown over a wide incident angle range.

9:20am **TF-TuM4 Obtaining Optical Constants of Thin Ge@sub x@Sb@sub y@Te@sub z@ Films from Measurements of Reflectance and Transmittance**, ***D.V. Tsu,*** Energy Conversion Devices

Chalcogenide thin films are currently used in Phase Change Rewritable Optical Recording media such as CD-RW and PD. These media have storage capacities 650 Mbytes, and can be rewritten over 1000 and over 100,000 times respectively. The second generation of Phase Change Rewritable media, using the DVD format, will extend that capacity to 4.7 GBytes/side. At the heart of this technology is the Chalcogenide layer, which undergoes a reversible change between amorphous and crystalline structures upon absorption of appropriate laser energy. The accompanying change in the optical constants [n,k] of the chalcogenide layer results in large reflectivity differences of the multi-layer media. Design of Phase Change optical media requires precise determination of [n,k] for both structures of the alloy over a wide spectral range. We have accomplished this task from measurements of [R,T] using the [air/film/substrate/air] configuration for films < 50 nm thick. The film's [n,k] are obtained by direct numerical inversion of the appropriate [a/f/s/a] expressions relating [n,k] to the measured [R,T]. Since R and T are highly non-linear in [n,k], calculating [n,k] provides multiple solutions at each wave length including the physical solution and also other mathematically relevant solutions. The other solutions can be used to determine the film's average thickness to an accuracy of ~ 1% or better. Using this technique we show that when as-deposited amorphous Chalcogenide films crystallize upon annealing they typically undergo a reduction in thickness of ~ 10%. We have developed software which can calculate [n,k] at 1800 wavelength points in less than 30 seconds. Attaining the correct film thickness requires only a few iterations. The calculation methodology does not include any assumption regarding the dispersion relation of the unknown film. This is critically important when multi-layered media structures are developed using new alloys.

9:40am **TF-TuM5 Process Monitoring of Hemispherical-Grained Polysilicon Thin Films for DRAM Applications**, *C. Hayzelden,* ***A. Bivas***, *C.L. Ygartua, K.C. Chan,* KLA-Tencor Corporation

The fabrication of hemispherical-grained (HSG) polycrystalline silicon was developed to increase the surface area (and storage capacitance) of Dynamic Random Access Memory (DRAM) devices. The increase in surface area (typically 2.4 x) is extremely sensitive to processing conditions. Therefore, to obtain high yields, process monitoring is of great importance. The use of spectroreflectometry and spectroscopic ellipsometry, described in this paper, provides a non-destructive method to monitor film fabrication. Using these two measurement technologies, the intensity and polarization state of the light reflected from the wafer surface is measured and analyzed over the wavelength range 220 to 800 nm. In the measurement analysis, a polysilicon layer is frequently modeled as a mixture of several materials, using the Effective Medium Approximation (EMA). Using the EMA model, with a composition of crystalline silicon, amorphous silicon, and a percentage of "voids", the analysis of measurement data yields values of the optical parameters (refractive index, extinction coefficient) and effective thickness of the HSG layer. In this paper, we present capacitance data from a series of HSG-processed wafers and report the observed correlation with the measured variables: percentage of "voids", effective thickness and optical parameters. The most appropriate variables to report for accurate process control will be discussed.

10:00am **TF-TuM6 Atomistic Scale Modeling of Ion Assisted Deposition of GMR Multilayers**, ***X.W. Zhou***, *H.N.G. Wadley,* University of Virginia

Giant magnetoresistance (GMR) is found in many ferromagnetic metal multilayers separated by thin copper films. Low interfacial roughness and intermixing are critical for obtaining the high giant magnetoresistance ratio needed for magnetic random access memories. A three dimensional molecular dynamics physical vapor deposition model has been developed and used to explore the effects of Ar- and Xe- ion assisted deposition of model Ni/Cu/Ni multilayers. The results indicate that the interfaces can be significantly flattened by ion assisted deposition provided the ratio of ion to metal atoms exceeds about 2.0. However, we found that as the assisting ion energy is increased, interfacial roughness decreases, but intermixing of the layers increases. A modulated ion energy / flux strategy for ion assisted deposition has then been investigated in which the ion beam energy / current was reduced while depositing the first few monolayers of each new metal layer. This strategy was found to successfully reduce both interfacial roughness and intermixing. The optimal ion to metal atom ratio and ion incident energy were identified.

10:20am **TF-TuM7 Thin Film Gas Sensors Based on Metal Oxides**, ***H. Meixner***, *M. Fleischer,* Siemens AG, Germany **INVITED**

Recently, research into the characteristics of semiconductor metal oxides that are stable at high temperatures with a view to providing reproducible detection of oxygen and reducing gases has intensified. First of all, there is a discussion of the specifics relating to these materials, for example the reduction of the effects of grain boundary barriers on the conduction mechanism, the reduction of the humidity cross sensitivities and also on the various reaction mechanisms. Then, the technology for constructing gas sensors of this kind will be described. Examples that have already been implemented, say, @gamma@ detection, O@sub 2@ measurements in the exhaust gases from incinerators, methane alarms, and air quality control as well as certain trends in development are discussed. Keywords: Metal Oxides, Thin Films, High Temperatures, Conduction Mechanisms, Gas Sensors

Tuesday Morning, November 3, 1998

11:00am **TF-TuM9 A Study of Thermally-Defined Gas Sensing Films on Micromachined Arrays***, **R.W. Walton**, R.E. Cavicchi, J.D. Allen, S. Semancik,* National Institute of Standards and Technology

Film microstructure and interfacial composition of sensing materials can have a profound effect on the performance of solid state gas sensors. We report on an efficient, array-based study of property/performance relationships for conductometric gas sensing films done on micromachined devices called microhotplates. Four-element arrays were used primarily in this study. Two types of lithographic processes were employed to deposit the catalytic metal/semiconducting oxide sensing films; each method utilizes the localized heating and temperature control available for the individual elements of the microhotplate array. A CVD process uses the heater to activate surface reactions for selected-area film deposition. We also introduce a new lithographic process that involves coating the entire array with nitrocellulose and exposing chosen elements by eliminating their coatings with a high temperature pulse. Following deposition (by evaporation, sputtering), lift-off of the nitrocellulose removes unwanted material. In situ monitoring of both deposition processes makes use of built-in electrical contacts for measuring conductance. We demonstrate the power of this array approach for studying film deposition, thermal treatments (sintering), and sensor testing. CVD films of SnO@sub 2@ films were prepared by heating each 50µmx50µm hotplate to 500° C in a flow of tetramethyltin and O@sub @ in Ar. We correlate the effects of catalyst thickness (0-200 Å), annealing (to 700° C), and composition (evaporated Pd and Pt) with gas sensing response from 100° C to 500° C. SEM images show anneal treatments as low as 500° C change the morphology of the catalysts on the oxide grains to produce islands or porous structures that enhance sensitivity to reducing gases.

11:20am **TF-TuM10 Germanium Films and Their Application in Cryogenic Temperature Sensors***, N.S. Boltovets,* State Research Institute "Orion", Ukraine*; J.P. McFarland, G.G. Ihas,* University of Florida*; R.V. Konakova, **V.F. Mitin**,* Microsensor Co. Ltd., Ukraine

The principal objectives of our work were: (i) to prepare Ge films on GaAs suitable to develop temperature sensors; (ii) to study the structure and electrical properties of Ge films; (iii) to develop and design miniature wide-range thermometers capable of operating in the 30 mK to 300 K temperature range; and (iv) to investigate sensors at low temperatures and in high magnetic fields. The films have been prepared by Ge thermal evaporation in a vacuum on semi-insulating GaAs substrates. The electrical properties of the films obtained depended on the details of their fabrication. To fabricate a resistance temperature sensor capable of operating over a wide temperature range, several different conduction mechanisms are to be realized in the Ge film, each of which providing thermo-sensitivity in its own temperature range. This may be achieved through multi-component doping and compensation of the Ge film. At least three main sources of extra charge carriers exist in the Ge films on the GaAs substrates; namely, Ga and As atoms and structural defects. A relationship between them is determined by the film growth conditions. By varying the conditions during the film fabrication, one can prepare Ge films having different doping levels and degrees of compensation, i.e., different thermo-sensitivities. In this way, temperature sensors having different thermometric characteristics and capable of operating over different temperature ranges can be produced. Films with a monotonic temperature dependent resistance in the 30 mK to 300 K range have been fabricated. We present the miniature temperature sensor design based on Ge films, and results of sensor investigation in this temperature range and in magnetic field up to 6 Tesla. We also discuss the mechanism of conductivity in the films responsible for magneto- and thermo-sensitivity.

11:40am **TF-TuM11 Characterization of Sol-Gel Prepared WO@sub 3@ Thin Films as a Gas Sensor***, **M.Z. Atashbar**, Y. Li, M.K. Ghantasala, W. Wlodarski,* RMIT University, Australia

Increasing awareness of well human being to environmental issues has attracted many scientific researches in the field of gas sensing. Tungsten trioxide (WO@sub 3@) thin films have promising electrical and optical properties for different applications, such as electrochromic displays, photolysises and gas sensing. The change of its conductivity due to the gas exposure has made itself a excellent candidate for nitrogen oxide (NO@sub x@) and ozone (O@sub 3@) sensing applications. In this study, the effect of the structure, micro-morphologies and composition of the WO@sub 3@ film on NO@sub x@ and O@sub 3@ sensing properties has been investigated. WO@sub 3@ thin films were prepared from starting precursors via sol-gel route in dry nitrogen atmosphere (@<=@10%RH). The used precursors was tungsten ethoxide (W(OC@sub 2@H@sub 5@)@sub 3@) with an analytic purity, which was dissolved in different analytical solvents. After ultrasonic mixing at room temperature for 1 hour the precursor solution was dropped on substrates and spin-coated at different speeds. The film thickness (20 to 200 nm) was controlled by changing the solution concentrations and spinning speed. After annealing at temperature of 400°C to 700°C crack-free WO@sub 3@ thin films were obtained. The morphology, microstructure, crystalline structure and composition of the deposited films were analyzed by SEM, XRD and RBS. The SEM analysis showed that that film is porous and the grain size is the rang of 20nm to 100nm. The RBS results indicated that the film is sub-stoichiometric. XRD analysis showed that the films are polycrystalline in nature. A detailed analysis of these results on the O@sub 3@ and NO@sub x@ sensitivity of the film has been discussed. The electrical resistance of the film has been examined for the detection of ozone in ppb level and NO@sub x@ ppm level.

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