The Science of Micro-Electro-Mechanical Systems Topical Conference
Room 610 - Session AS+MI+VM-MoM
Magnetic Recording: Chemical Integration and Tribology
Moderator: R.L. Opila, Bell Labs, Lucent Technologies

8:20am **AS+MI+VM-MoM1 Disk Drive Chemical Integration: Influence of Outgassing on Stiction***, **D.E. Fowler**, R.H. Geiss, E. Ghelichkhani,* Maxtor Corporation **INVITED**

Beyond optimizing the magnetic read/write sensor and the magnetic storage media, the successful introduction of a new disk drive product requires the integration of the best electronics and a great mechanical design to surround this magnetic interface. However, all of this effort will be for naught, if the disk drive cannot spin-up because the interface is stuck together or if contamination at the interface causes the sensor-to-media spacing to be a few nanometers greater than the designed fly height. Failure to spin-up can be the result of stiction and, in some cases, a phenomenon called fly stiction. We briefly discuss the distinguishing physical features of stiction induced by the disk lubricant as compared to stiction induced by in-drive outgassing, before focussing on outgassing-induced fly stiction. Various analytical methods have been used to identify the important outgassing sources and materials within the drive. The formation of liquid droplets on the read/write sensor during drive operation has been documented as an important contributor to increased stiction of the sensor-to-media interface following a period of nonoperation. We describe a real time visualization setup which monitors these processes in experimental, but fully functioning disk drives. This offers the opportunity to study the phenomenon and the mechanisms of fly stiction in a realistic drive environment. Results of these visualization experiments are presented. The goal of these studies is to develop a low-stiction interface through the optimization of the chemical integration of the drive. This allows the high-performance magnetic interface to function according to its design.

9:00am **AS+MI+VM-MoM3 The Evolution of the Corrosion Process on Thin-Film Media***, **J. Ying**, T. Anoikin, C. Martner,* MMC Technology Inc.

Thin-film hard disks have been exposed to elevated temperature/humidity, and dilute acidic vapor environment. These tests are designed to simulate possible galvanic corrosion, which, for the thin-film media, is characterized by the formation of Co and Ni containing corrosion nodules. The evolution of the corrosion process was elucidated by inducing different degrees of corrosion on the media, and these distinct corrosion stages were characterized morphologically by SEM and chemically by AES compositional analysis. In addition, an XPS chemical state study on the reactivity of Co, Cr, and Ni to ambient and chlorinated environments was conducted. A probable galvanic corrosion mechanism is proposed to understand the chemistry observed during the evolution of the corrosion process. In particular, the effects of ionic contaminants as corrosion accelerators and the role of the Cr underlayer as a corrosion-preventing barrier layer are discussed.

9:20am **AS+MI+VM-MoM4 Tribochemistry of Monodispersed ZDOL with Hydrogenated Carbon Overcoats***, **C.-Y. Chen**, W. Fong,* University of California, Berkeley*; D.B. Bogy,* University of California, Berkeley, U.S.

Tribo-chemical studies of the lubricant molecular weight effect on the tribology of the head/disk interface (HDI) were conducted using hydrogenated (CHx) carbon disks coated with ZDOL lubricant. The studies involved drag tests with uncoated and carbon-coated Al2O3-TiC sliders and thermal desorption experiments in an ultra-high vacuum (UHV) tribochamber. The studies showed that the lubricant interaction with the carbon overcoat varies as a function of lubricant molecular weight. The friction coefficient increases as the molecular weight increases. The higher friction is due to the higher viscosity. The friction and catalytic decomposition mechanisms of ZDOL are described. In general, the PFPE polymers are decomposed by chain scission involving the breakage of the backbone bonds to yield free-radical segments. Chain scission can occur by three mechanisms: (1) random degradation, (2) depolymerization, and (3) weak-link degradation. Our studies further support previous observations that catalytic reactions occurred at the endgroup functionals. The lower number of endgroup functionals for ZDOL with higher molecular weight reduces the possibility of the occurrence of catalytic reactions. Moreover, the ZDOL desorbed peak temperatures shifted to lower temperatures with increasing molecular weight in thermal desorption tests. The spreading diffusion coefficient of ZDOL decreases with increasing molecular weight. As the mobility of the lubricant chain decreases, the desorption energy needed to break the lubricants increases, resulting in higher desorption peak temperatures. In addition, the longer chain length of the higher molecular weight ZDOL causes higher degrees of crosslinking. The crosslinking restricts chain mobility and causes an increase in the desorption peak temperatures.

9:40am **AS+MI+VM-MoM5 Thermal Effects on Magnetic Head/Disk Interface Materials***, **R. Koka**,* Read-Rite Corp.*; L. Zhang,* Seagate Technology, Singapore **INVITED**

The materials interacting at the head/disk interface of a rigid disk drive are primarily the disk carbon overcoat, lubricant on the disk, and the head ceramic,Al2O3.TiC. The interface materials can be subjected to high, localized temperatures when the head is flying or sliding on the disk or when wear debris is trapped in the interface. The head or disk by itself can be exposed to high temperatures during the manufacturing process. This presentation addresses some of the changes that occur in the interface materials when they are individually subjected to high temperatures. Raman spectroscopy of thermally annealed disks will be presented to show that the carbon overcoat tends to become slightly graphitic. At 350C in air, the overcoat oxidizes rapidly and completely disappears. The widely used PFPE lubricants (ZDOL & AM) used on disks, degrade at high temperatures (~350C). In the presence of Lewis acids, the degradation process occurs at lower temperatures (~200C) and the rate of degradation is very high. The products of thermal degradation are different for the two lubricants because of the functional end groups. With respect to tribology, a head made of a passive ceramic such as SiC tends to perform relatively better than a material such as Al2O3.TiC, which is known to be an aggressive catalyst for lube degradation. Annealing of the Al2O3.TiC head ceramic shows that around 350C, carbon diffuses from the TiC grains and titanium oxides are formed. The diffused carbon is amorphous with a mixture of sp2 and sp3 bonds and it becomes nanocrystalline graphite above 600C. Thin, diamond-like, carbon coatings (60A thick) on the surface of the head effectively protect the Al2O3.TiC from oxidation and carbon diffusion at temperatures below 500C. A few examples of disk wear and smear formations on heads and disks will be presented. Some similarities between the Raman spectra of smears on heads and annealed disk overcoats and degraded lubricant will be discussed.

10:20am **AS+MI+VM-MoM7 The Process Induced Changes on the Co-alloy Films and the Tribological Effects on Magnetic Recording Heads***, **Y.S. Chaug**, R. Adams,* Storage Technology Corporation

The ferromagnetic alloys of Co-metal systems are soft magnetic materials having large saturation magnetization and low coercive force. Sputter deposited Co@sub 1-x@(Zr,Ta)@sub x@ (0.05<x<0.16) amorphous films have been used as magnetic pole material in magnetic inductive heads for its zero magnetostriction. In the wafer process, the Co@sub 1-x@(Zr,Ta)@sub x@(CZT) films were patterned through the photolithography process and then treated with an oxygen plasma for cleaning. The surface changes on the processed CZT surface were studied using x-ray photoelectron spectroscopy. The migration of Co ions to the CZT surface was found after the oxygen plasma treatment. Atomic force microscope, scanning electron microscope and Nano-Triboscope were used to examine the changes of the Co rich CZT surface in a high humid environment. The process induced changes on the CZT surface which impacted the ABS (air bearing surface) lapping process in manufacturing the magnetic inductive heads. The tribology of the magnetic recording heads using CZT as magnetic pole will be discussed.

10:40am **AS+MI+VM-MoM8 Study of Tribochemical Processes at the Head-disk Interface Using Photoemission Electron Microscopy**, ***S. Anders**, A. Scholl, F. Nolting,* Lawrence Berkeley National Laboratory*; W. Fong, C.-Y. Chen,* University of California, Berkeley*; D.B. Bogy,* University of California, Berkeley, U.S.*; C.S. Bhatia,* SSD/IBM*; J. Stohr,* IBM Almaden Research Center

Photoemission electron microscopy (PEEM) has been applied to study the tribochemical processes at the head-disk interface of magnetic storage devices. High resolution PEEM imaging is based on several contrast mechanisms (topographical, elemental, chemical, and various forms of polarization contrast) which makes it a unique tool for the study of tribochemical processes. We have studied surfaces of hard disks and sliders after various kinds of wear tests performed in ambient atmosphere and UHV. It was observed that the disk surface in the wear tracks is chemically modified if visible wear occurred and if a lubricant was present. In the case of unlubricated disks no chemical modifications were observed but a reduction in the hard carbon overcoat thickness. The chemical modifications consist of lubricant oxidation and fluorine removal. The lubricant oxidation and fluorine removal is enhanced with enhanced wear. It was found that degraded lubricant is transferred to the sliders and accumulated in scratches of the slider surfaces. The hard carbon overcoat on sliders was found to be reduced in thickness after the wear tests, but not chemically altered.

11:00am **AS+MI+VM-MoM9 Tribo-Chemistry of the Head-Disk Interface in Hard Disk Drives***, **D.B. Bogy**,* University of California, Berkeley, U.S.*; C.S. Bhatia,* IBM SSD*; C.-Y. Chen, W. Fong,* University of California, Berkeley **INVITED**

Tribo-chemical studies of the lubricant thickness effect on the tribology of the head/disk interface (HDI) were conducted using hydrogenated (CHx) carbon disk samples coated with perfluoropolyether ZDOL lubricant. The studies involved drag tests with uncoated and carbon-coated Al@sub 2@O@sub 3@-TiC sliders and thermal desorption experiments in an ultra-high vacuum (UHV) tribochamber. The studies showed that the lubricant interaction with the carbon overcoat varies as a function of lubricant thickness. Wear durability improves considerably for thicknesses greater than a monolayer. However, in the sub-monolayer thickness regime, the adhesion of the lubricant to the carbon overcoat is much stronger, as indicated by the fact that a much higher temperature is required to desorb the lubricant. When the lubricant thickness is around or above a monolayer, cohesion among the lubricant molecules plays a greater role and a much lower temperature is needed for lubricant desorption. In addition, we observed that hydrogen evolution from CHx overcoat initiates lubricant catalytic decomposition, forming CF3 and C2F5. The generation of HF during the thermal desorption experiments provides the formation mechanism of HF, which is the necessary component for catalytic reaction.

11:40am **AS+MI+VM-MoM11 Phase Transitions in Two-dimensional Ferroelectric Films***, **C.N. Borca**, J. Choi, S. Adenwalla, P.A. Dowben, M. Poulsen,* University of Nebraska, Lincoln*; J.L. Robertson,* Oak Ridge National Laboratory*; V.M. Fridkin, S.P. Palto, N. Petukhova, S.G. Yudin,* Russian Academy of Science*; S. Ducharme,* University of Nebraska, Lincoln

We studied ferroelctric copolymer films of vinylidene fluor ide with trifluoroethylene, P(VDF-TrFE) 70:30. The films exibit ferroelectric switching properties and can be used in a variety of piezoelectric devices. In addition to the first order ferroelectric to paraelectric bulk transition at 80 degrees C, we report two other phase transitions. One appears at 20 degrees C and is related entirely to a surface ferroelectric transition.@footnote 1@ The third transition around 150 degrees K is due to a stiffening of the lattice and a change in the bulk electronic structure. For P(VDF-TrFE), there is a negligible density of states at the Fermi level making this phonon related transition very unusual. This last transition was observed using neutron diffraction, @footnote 2@ X-ray diffraction, photoemission spectroscopy and EELS. The effective Debye temperature decreases from a value of about 250 K to 50 K with increasing temperature across the 150 K lattice stiffening transition. @FootnoteText@ @footnote 1@J. Choi, P.A. Dowben, S. Pebley, A.V. Bune, S. Ducharme, V.M. Fridkin, S.P. Palto, N. Petukhova, Phys. Rev. Lett. 80, 1328 (1998) @footnote 2@C.N. Borca, J. Choi, S. Adenwalla, Stephen Ducharme, P.A. Dowben, Lee Robertson, V.M. Fridkin, S.P. Palto, and N. Petukhova, Appl. Phys. Lett. 74, 347 (1999).

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