Nanotribology

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The effectiveness of the lubricant and the diamond-like carbon overcoat to protect the magnetic hard disks from wear is key to higher data storage density and data transfer rate. Working with the National Storage Industry Consortium Tribology Working Group, we address the measurement needs of friction, stiction, and wear and means of controlling wear at the nanometer scale. We also explore the fundamental concept of designing and organizing novel molecular assemblies to achieve better wear protection for the disks in conjunction with our CRADA partner Pennzoil-Quaker State Company.

Head disk interface study

Current magnetic hard disks are protected by one nanometer thick perfluoropolyethers (PFPE) and 7.5 nm thick carbon overcoat. In order to increase the areal density, the magnetic spacing (the distance of the sensor to the middle of the magnetic layer) needs to be decreased from 30 nm, the current distance, to 10 nm. This results in a flight height of about 5 nm. At this flight height, occasional collisions between the head and disk may be unavoidable since manufacturing technology cannot produce such flatness and smoothness. In addition, with the increase of areal density, it is desirable to increase the data transfer rate to take advantage of the sensor capability. Higher data transfer rate means the linear velocity of the head will be increased from the current 10 m/s towards 40 m/s. As the speed is increased, potential high speed impacts due to the waviness of the disk, rotation wobbles, and roughness of the surface increase significantly. We have initiated an effort to develop a one-pass high-speed impact test to quantify the resulting damage.

Monolayer film design and organization

With the decrease in flight height and increase in speed, the need to protect the integrity of the magnetic layer becomes more critical. The decrease of the diamond-like carbon overcoat thickness to allow higher areal density makes the effectiveness of the lubricant layer critical.

Current lubricant Z-Dol (a PFPE with two alcohol functional groups) works by diffusing into the contact area after the head passes over, thus creating a “self-repairing” property. However, the lack of bonding with the surface makes it relatively weak in resisting high shear impacts. We have proposed to organize a monolayer molecular assembly with different molecular species. Some species will bond strongly with the surface providing high shear resistance, some species will be mobile to provide “self-repairability”, and some species will cross-link under certain temperature and shear conditions (typical of the contact conditions under high speed sliding contacts). Such a molecular assembly, if successful, will provide a much higher degree of protection of the magnetic sub-layer. There are potential applications of such a concept to microelectromechanical (MEM) and other microsystems.

Research on Self-Assembled Monolayers (SAM) suggested poor durability in a hard disk system. Subsequent research suggested that a minimum molecular weight of 1,000 is needed to control friction and wear. Different custom-synthesized molecules with various functional groups and different molecular weights are required to validate this theory. Thus, we signed a CRADA with Pennzoil-Quaker Co. to test the validity and viability of implementing such molecular assemblies for wear control.

Using dip-coating (single and successive dipping) and vapor phase deposition (single and successive coating), we were able to deposit 3 to 4 components onto a hard disk surface with an overall thickness of about one nanometer. Durability test results suggested much improved resistance to shear.

Monolayer film characterization

While we can successfully deposit 3 or 4 molecules on an engineering surface such as a magnetic hard disk, the spatial distribution of different species and their stacking characteristics are of profound significance. Ultra-soft X-ray near edge fine structure spectroscopy at the Brookhaven Synchrotron Radiation Facility has been used and has been successful in determining the relative concentration of each species and the nature of interactions between the monolayers with a disk surface. Collaboration with Wayne State University on high resolution modulated AFM provides additional insight of where the molecules are on a typical surface.

We are now initiating an effort to study the chemical nature of the diamond-like carbon overcoats using Nuclear Magnetic Resonance (NMR) and Electron Spin Resonance (ESR). Disks of different chemistries (CHx, CNx, and ChxNy) from the National Storage Industry Consortium (NSIC) will be characterized in terms of the surface energy, bonding characteristics, and interaction pattern with monolayers.

Contributors and Collaborators

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