ABSTRACT

In HAMR, the media surface will be heated to above 400 °C by laser irradiation. The state-of-the-art media lubricants cannot survive this temperature and the novel high temperature lubricants need to be developed. In the current proposal, a comprehensive 3-year research plan has been made to fulfill this challenge. In the first year, we plan to study three groups of promising material candidates to understand how chemical structure affects the thermal stability and design the HAMR lubricant candidates. In the second year, we will evaluate the thin-film samples and optimize the design. In the third year, we will conduct component and drive testing and finalize the HAMR lubricant design.
PROJECT DESCRIPTION

1. INTRODUCTION

To maintain high growth rate in the areal density of hard disk drives (HDDs), HAMR has been proposed to deliver 1 Tbps or above data density.¹ In HAMR, the media surface will be heated to or above the Curie temperature ($T_C$) by Laser irradiation and the estimated $T_C$ could be above 400 °C, which makes the thermal stability of the media lubricant a big concern.¹ The state-of-the-art media lubricant, such as Fomblin Zdol and Ztetraol, starts evaporating around 250 °C and will not survive the HAMR heating.² Therefore, novel lubricants with much higher thermal stability need to be developed.

2. OBJECTIVES AND APPROACH

The proposed research aims to understand the structure-property relationships of lubricant materials and develop novel high temperature lubricants for HAMR. The target temperature is between 400 °C and 550 °C and the target lubricant thickness is below 2 nm. Moreover, the lubricant candidates must be compatible to HAMR overcoat candidates. To achieve the objectives, a comprehensive 3-year research plan has been made as shown below:

- Understand how the chemical structure of lubricants affects the thermal stability.
- Investigate the compatibility between HAMR lubricant and overcoat candidates.
- Design/develop novel lubricant candidates for HAMR.
- Fabricate the thin film samples and evaluate thermal stability, tribological properties and corrosion protection.
- Evaluate the HAMR lubricant candidate(s) at both component-level and drive-level, collaborating with ASTC sponsor companies.

3. RESEARCH PLAN: FIRST YEAR

Our first year’s focus will be on understanding the structure-property relationship and designing HAMR lubricant candidates. TGA will be utilized to study the thermal stability of the bulk material while the thickness change before and after oven heating will provide the information on the thermal stability of nanometer-thick films if needed. HAMR lubricant/overcoat compatibility will also be studied if the overcoat candidate materials, such as graphene, are available.

3.1 Understand the structure-property relationship

To fully understand how the chemical structure affects the thermal stability, three groups of materials will be studied. The first one is Perfluoropolyethers (PFPEs). Z-type PFPEs with hydroxyl end-groups have been the media lubricants in HDD for decades. Previous research² showed that the intrinsic thermal stability, which defines the upper limit of the application temperature, of this material is 350 °C. The unanswered question is how the backbone structure will impact the intrinsic thermal

![Fig. 1 Chemical Structure of a SAMs (top) and an ionic liquid (bottom)]
stability. In the proposed research, the thermal stability of various PFPEs with different backbones will be studied and the structure-property relationship will be established. Self-assembled monolayers (SAMs) are organic molecules that can form nanometer-thick layers on a solid substrate with low surface energy, low friction and good thermal stability. It has been reported that some SAMs, e.g. FDTS as shown in Fig. 1, can survive 400 °C for as long as 90 minutes. Different SAMs will be evaluated in the current research and the thermal stability will be investigated. Room temperature ionic liquids (RTILs), synthetic molten salts with the melting temperature below room temperature, are another class of promising lubricant candidates for HAMR because of their negligible vapor pressures, non-flammability, high thermal stability and broad liquid range. Some of the ionic liquids, such as BMIM-TFSI shown in Fig. 1, have been reported to be thermally stable up to 459 °C. In the proposed research, we will investigate thermal stability of different RTILs. We want to point out that thermal stability is NOT the only requirement for HAMR lubricant. Tribology, corrosion, lube-carbon compatibility and many other properties are also important. However, since thermal stability is the most critical design parameter for HAMR, we will first identify the candidates based on thermal stability and then study other properties to finalize the HAMR lubricant design. This approach is much more efficient than studying all the properties of all the lubricant materials simultaneously.

3.2 Evaluate the compatibility between HAMR lubricant and overcoat materials

To understand the compatibility between HAMR lubricant and overcoat materials, we will collaborate closely with the overcoat researcher. First, the possible effect of the overcoat materials on the thermal stability of the lubricant will be investigated. Second, the wetting and the bonding of the lubricant on the novel overcoat films will be studied. Third, the friction and wear performance of lubricant/overcoat system will be evaluated with a CSM NTR2 nanotribometer.

3.3 Design/develop HAMR lubricant candidates

Based on our learning on the structure-property relationship, HAMR lubricant candidates will be identified. If synthesis is needed, we will start chemical synthesis near the end of the first year.

4. EXPECTED RESULTS AND TIMELINE

In the first year, we expect to study three types of materials, including PFPEs, SAMs and RTILs, to understand the structure-property relationship. Based on this, HAMR lubricant candidates will be identified near the end of the first year. In the second and third year, we will continue to evaluate the thin-film samples and conduct component and drive testing to finalize the design.

References:

BUDGET

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HOME INSTITUTIONS & RESOURCES

Office:
Dr. Li’s office is located on the 12th floor of the Benedum Hall, equipped with a computer, a telephone, and a color inkjet all-in-one printer and Internet access.

Laboratory:
Dr. Li’s labs are located on the 12th floor of the Benedum Hall. There is one chemical hood and two wet benches in the lab. Central air, vacuum, gas and water are provided to each hood and bench.

Computers:
Five computers, including two laptops and three desktops are associated with instruments.

Major equipment in Dr. Li’s laboratory:
- CSM NTR<sup>2</sup> nanotribometer
- RT Instruments 320U TGA/DTA
- VCA Optima XE contact angle tester
- KSV DC-2X dip-coater w/ anti-vibration platform

Major equipment available (w/ charged access) at the University of Pittsburgh
- HORIBA JOBIN YVON UVISEL Spectroscopic Phase Modulated Ellipsometer
- Veeco ‘Multimode V’ & ‘Dimension V’ Combination Scanning Probe Microscope (SPM)
- Philip XL30 Scanning Electron Microscope (SEM)
- JEOL 'JEM-2100F' Transmission Electron Microscope (TEM)
- Bruker AXS 'D8 Discover' X-ray Diffractometer (XRD)
- Bruker Vertex-70LS FTIR w/ Hyperion 2000 FTIR Microscope

Other:
- All of the libraries at the University of Pittsburgh are available for this research.
BIOGRAPHICAL SKETCH

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EDUCATION

<table>
<thead>
<tr>
<th>University of Michigan, Ann Arbor, MI</th>
<th>Ph.D.</th>
<th>2001</th>
<th>Macromolecular Sci. &amp; Engr.</th>
</tr>
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<tr>
<td>Tsinghua University, Beijing, China</td>
<td>M.S.</td>
<td>1997</td>
<td>Polymer Materials</td>
</tr>
<tr>
<td>Tsinghua University, Beijing, China</td>
<td>B.E.</td>
<td>1994</td>
<td>Polymer &amp; Chem. Engr.</td>
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WORKING EXPERIENCE

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<th>Assistant Professor</th>
<th>Sep. 2011-</th>
<th>University of Pittsburgh</th>
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<tr>
<td>Visiting Research Assistant Professor</td>
<td>Feb. 2010 - Present</td>
<td>University of Pittsburgh</td>
</tr>
<tr>
<td>Research Staff Member</td>
<td>May. 2003-Jan. 2008</td>
<td>Seagate Technology LLC</td>
</tr>
<tr>
<td>Postdoctoral Researcher</td>
<td>Nov. 2001-May. 2003</td>
<td>Seagate Technology LLC</td>
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PUBLICATIONS

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