

A study on the formation and structure of LTO head stains

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Abstract

Linear Tape Open (LTO) metal particles tapes with of identical formulation as Travan5 tape were cycled against LTO heads using the Linear Tape Open (LTO) system as the experimental platform. Atomic force microscopy (AFM) was used to analyse the surface topography of the heads while Auger electron spectroscopy (AES) and X-ray photoelectron spectroscopy (XPS) were employed to analyse the chemical changes on the surface of the worn heads and tapes. Ar⁺ etching was employed with XPS to analysis tape and stain on the worn heads. Optical Microscopy was used to observe the head surface changes.

The results were different to those observed in work done on earlier systems with higher contact pressures (for example Travan5). Since the tape formulation was essentially the same, the differences could be explained in terms of the lower head/tape contact pressures in the LTO system with the subsequent lower contact temperatures. Since the formation of stain is a chemical process, it is postulated that a certain threshold contact temperature is necessary for substantive stain formation. Assuming this to be true, the effects of ambient water vapour concentration are also explained.

The nature of the stain has been confirmed by surface analysis. This has shown the stain produced in this system consists of chemically unchanged passivated metal particles plus binder material, thus confirming our earlier model of stain formation.

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1. Introduction

Volumetric data densities of tape are high, but to remain competitive, areal densities of greater than 2 Gb/in.² must be attained in the next few years. In spite of many measures taken by the industry [1], physical spacing between head and tape remains a major factor in signal degradation and error growth and subsequently this effect limits attainable storage density. Thus, significant increase in densities can only be attained by minimising physical spacing between media and sensors (pole tips). The major causes of this spacing (and hence spacing losses) are Pole Tip Recession (PTR) and transferred materials from tapes to heads (stains). At current recording wavelengths, every 10 nm increase in d leads to 0.8 dB of output loss. This will significantly worsen as wavelengths decrease. For a 2 Gb/in.² capacity and above, the spacing must be reduced from its present value of

about 50 nm to a value approaching 10 nm. Proposed mechanisms responsible PTR and stains in other recording formats have been isolated by Sullivan and co-workers [2–7] and Bhushan [8,9]. Our latest work on PTR in LTO systems found the three-body particles are major from the ceramic of the head [10], but here we concentrate on the mechanism of production of stain in LTO systems.

In current systems, the formation of stain is known to depend on the amount of water vapour present in the vicinity of the contact and on the temperature of the contact. Considering water vapour first, in most previous studies relative humidity has been used as a measure of the amount of water present at the head/tape interface. We have shown, however, that it is actual water content in the vicinity of the contact that is the important factor [3]. The effects of this (termed normalised water content (NWC)) on the head/tape interface was reported by Wild et al. [3]. Secondly, it is well known that the interface flash temperature between the head and disk can be very high [11–13]. Bhushan [11] found that if the exposed magnetic particles or alumina particles contact the slider surface in head-disk system, the transient temperature rise could be more than 1000 °C. Sullivan [5]

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studied the contact temperatures and found that the mean maximum contact temperatures for a particular linear tape system were calculated to be over 130 °C.

Fe stain starts at nucleation sites and then grows into patches and possibly a continuous film. For MP tape the conventional stain consists mainly of iron particles transferred directly from media to head due to adhesive bonding and held in place by electron transfer interactions [5]. This type of Fe stain is only formed if water vapour is below some threshold value that does not allow surface bonds to be saturated. It is not formed in high relative humidity condition where water saturation of active sites on the head prevents the formation of adhesive bonds [5]. The common features of conventional Fe stain are; that thickness is constant and is related to the magnetic pigment size and corresponds to one particle thickness (in the range 20–30 nm, depending on tape type); the Fe stain forms a lumpy deposit in the initial stages and in general the areal coverage increased with number of passes. The stains formation is a dynamic process. There is a second form of stain (polymer stains) that may be produced for some tape formulations at high water content and high ambient temperature. This stain is wholly polymeric in nature, much thicker, more extensive and not nearly so adhesive.

In the LTO system the contact pressures are considerably lower than in many other systems [14]. Contact pressures will directly affect the contact temperatures and hence we would expect this in turn to affect conventional Fe based stain formation since this formation is a chemical process that probably depends on Arrhenius type growth. Thus we would expect stain production in LTO to be less than that produced in other systems with high contact pressure and hence contact temperatures are higher.

2. Experimental procedure

In the experiments generation one LTO Ultrium drives with single-reel cartridge design were used as an experimental platform. The heads were eight channel heads where the pole shared pole/shield and shield are each constructed from cobalt–zirconium–tantalum (CoZrTa) amorphous film and the insulator of low temperature sputtered amorphous Al₂O₃. The ceramic tape bearing surface (TBS) substrate is non-magnetic alumina titanium carbide (Al₂O₃–TiC). The Al₂O₃ is between 60 and 70% by weight, TiC 30–40% by weight with the grain size of TiC being limited to 1–1.5 μm.

Communication between the drives and computer was established using a macro language (Dexter). This allowed various tasks including cycling and error rate tests to be performed. The head position could also be set at any point across the width of the tape. To simulate the serpentine motion of a head across a tape the head was placed at four positions across the width of the tape during cycling. The tape speed during operation was 2.3 ms⁻¹.

Table 1
Breakdown of tape cycling experiments for one tape cartridge

| Tape position (m) | Number of passes | Total number of passes (km) endured by LTO head |
|-------------------|------------------|---|
| 400–600 | 100 passes | 100 passes (20 km) |
| 200–400 | 900 passes | 1000 passes (200 km) |
| 0–200 | 4000 passes | 5000 passes (1000 km) |

Heads were cycled for 5000 passes in custom built LTO drives located in a Votsch environment chamber. The tapes used in the heads cycling could be seen in Table 1, one LTO tape cartridge has 600 m length of tape was divided into three parts to be used to cycle against LTO heads, for each of the experimental conditions could be seen in Table 2. An unused head and cartridge was used for each experiment. Three drives were run at each series of environmental conditions to improve reproducibility of results.

Topographical information regarding the physical structure of the LTO heads was obtained using a ThermoMicroscope AFM operated in contact mode. Image enhancement was restricted to the use of shading and levelling algorithms. For time constraints, analysis of the heads was restricted to channels No4 and No7 of the left rail for every LTO head.

Auger electron spectroscopy (AES) was used to analyse the heads due to the small size of the areas being studied. AES enabled elemental compositions to be determined at different points on the surface of the LTO heads with sub micron resolution. For the ceramic or insulator region, AES was performed using an area of 10 μm² otherwise multi-point analysis was used. Chemical examination of the tape samples was conducted by means of X-ray photoelectron spectroscopy (XPS). Both analyses were conducted in a VG ESCALAB 200D electron spectrometer equipped with a hemispherical sector energy analyser. Mg K_α X-radiation was employed for the XPS examination, at source excitation energy of 15 keV and emission current of 20 mA. Analyser pass energy of 20 eV with step size of 0.1 eV and dwell time of 100 ms was used throughout. The base pressure within the spectrometer during examinations was always better than 5 × 10⁻⁹ mbar and this ensured that all signals recorded were from the sample surface. The area of tape analysis was chosen to be 2 mm × 3 mm for tape samples analysis. The stains XPS analysis was chosen 300 μm (diameter) area scale to analyse due to the small head structure.

Table 2
Environmental conditions used in this research experiments with normalised water content

| Environmental condition | 10 °C/ 10%RH | 15 °C/ 15%RH | 40 °C/ 15%RH | 22 °C/ 40%RH | 40 °C/ 80%RH |
|--------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Normalised water content (NWC) | 1.0 | 1.9 | 6.7 | 7.5 | 35.5 |

Normalised to 10 °C, 10%RH.

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