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Study of Current Density Phenomenon on Scratched Media Magnetic Disk

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Abstract: In hard-disk drive industry, a media disk is one important part. It contains multilayer of various materials, i.e. magnetic, nonmagnetic, DLC etc [1]. In the production line, during a test performed, contamination or nano-particles can cause scratching on media disk. The size of scratch can be in a range of nanometer-millimeter. In this paper, a technique of current density applied to media disk is proposed in association with thermal observation. A constant current is applied to media disk and then a current density on detecting point is measured. A variation of bias current, detecting point and scratch depth is studied.

Keywords: current density, scratch media, magnetic disk

1. Introduction

In the magnetic disk, the demand for increasing data capacity in the last decade has required several technological implementations. From the head disk interface the reduction of the distance between head and disk surface has been a main choice to achieve higher data density on the hard disk drive. In order to minimize the fly high between a head and disk, the surface roughness of the disk need to be low enough. The number of surface defects, such as scratches and particles must be smaller than nanometer [2]. Demands for higher storage densities have resulted in a continuous decrease of both the carbon overcoat thickness and the distance between the magnetic head and the disk surface. However, there is the possibility of head scratch in high-density magnetic systems. It has been reported that for ultra-high recording density (e.g. 500 Gbit/in.^{2}), the magnetic spacing should be about 6.5 nm and the corresponding thickness of the disk overcoat would be in the sub-2 nm range [3]. Consequently, nano- and micro- scale tribology plays an important role in high-density magnetic recording and microelectromechanical systems. Because of the small size and mass of the elements comprising microsystems, the dynamic performance of micro devices greatly depends on the surface properties [2].

Main point of investigation focus on overcoat layer is on Diamond-Like Carbon (DLC). The DLC layer is important to protect magnetic layer or data layer. The friction and wear behaviors of DLC coating depend on the deposition method, processing parameters, and operating conditions etc [5]. The friction coefficients of DLC coating usually span a range of 0.1–0.4 in ambient air, and are strongly governed by tribochemical effects [4]. Additionally, the coating also demonstrates high wear resistance and protects the rubbing surface of counterpart from extensive wear. Up to now, various theoretical mechanisms have been proposed to explain the tribological performance of DLC coating [5]. DLC are characterized by a relatively high hardness and good tribological properties.

Furthermore, it is interested in tribological properties, high thermal conductivity and low dielectric constant. Consequently, factors affecting the tribological properties of thin carbon overcoat are of great importance to magnetic storage.

In this study, a scratch testing on the carbon overcoat surface with several bias current, detecting point, scratch and thermal observation are examined.

2. Experimental setup

The layers of magnetic disk consist of carbon overcoat, magnetic layer, NiP layer and substrate. The overcoat layer is used to protect a scratch effect from contamination between head and disk interface by using Diamond-Like Carbon (DLC). The properties of DLC films have been studied extensively by numerous authors and a number of analytical techniques have been used to characterize the microstructure including Raman spectroscopy, electron energy loss spectroscopy (EELS), Rutherford backscattering spectroscopy (RBS), X-ray photoelectron spectroscopy (XPS), Auger electron spectroscopy (AES), atomic force microscopy (AFM), transmission electron microscopy (TEM), scanning electron microscopy (SEM) and other techniques [6]. In this study, the DLC characteristics are 30% hydrogen measured by Rutherford Backscattering Spectrometry, $1\times10^{11}\ \Omega\cdot m$ electrical resistivity, 10 nm thickness and 246 GPa composite young modulus measured by indentation test using triangular diamond pyramid [7]. For a 30% hydrogen DLC coating, the specific heat capacity value is 0.97 J g^{-1} K^{-1} [8].

A bias current is applied to the center of magnetic disk and the rim of disk is grounded. The bias current is distributed on the DLC surface and then, the surface thermal is observed. The geometry of bias current on the surface is shown in Fig.1 [9].

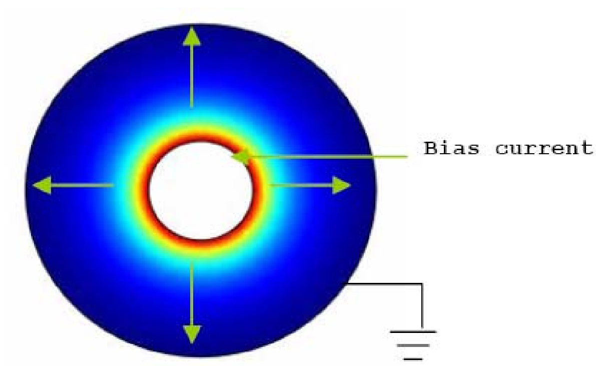

Fig. 1 The geometry of bias current on the surface.

In this study, heat is generated by passing a current through a DLC. The thermal effect, using Joule heating method, can be calculated by current density. When an object is heated, the transferring energy (Q) results in an increase of the object temperature (ΔT) as shown in Eq. (1) .

$$Q = mc\Delta T \qquad (1)$$

where m is mass of DLC and
c is specific heat of the DLC.

Mass of the DLC can be calculated by

$$m = \rho V \qquad (2)$$

where ρ is density of DLC and
V is volume of DLC.

When a current passes through the DLC layer, it results in generated heat (Joule's heating).The rate of DLC energy dissipating (P) is

$$P = i^2R \qquad (3)$$

where i is the current passing DLC and
R is the resistance of DLC.

DLC resistance can be calculated by

$$R = \rho l/A \qquad (4)$$

where ρ is resistivity
L is length and
A is contact area.

For the total time of dissipation (t), the dissipation energy (W) in DLC layer is

$$W = Pt = i^2Rt \qquad (5)$$

An equivalent between energy (W) and heat into DLC (Q) for thermally isolated system is

$$Q = W \qquad (6)$$

Equation (6) is known as the mechanical equivalent of heat. It can be translated into a relationship between the SI unit of work, the joule, and the unit of heat flow as 1 calorie is equal to

$$1\ cal = 4.185\ J. \qquad (7)$$

Nowadays, the numerical definition of the calorie is taken to be Eq. (7).

In the finally relationship between temperature (ΔT) and another parameter it is shown in the Eq. (8)

$$\Delta T = i^2Rt/\ mc \qquad (8)$$

3. Results and discussion

3.1 Current flowing on a center-to-rim disk

Although a scratch is not sufficiently deep enough to damage data layer or magnetic layer but the depth scratch directly affects read/write data. This consequence causes disk degradation.

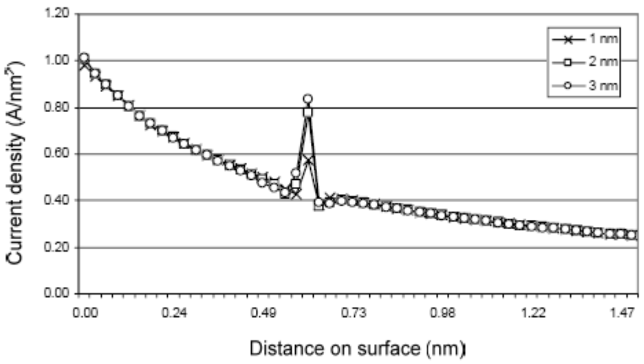

Fig. 2 Current density results on various depth scratches.

The scratches are made at a distance on surface of about 0.5 nm with 3 scratch depth (1 nm, 2 nm and 3 nm). A current density is measured from the center of the disk (from the center is 0 nm to ~ 1.47 nm). From Fig 2, it is found that the current density is dramatically decreased when a distance increases. At the scratch position, it is seen that a vast current density is occur. It is also found that when the scratch depth increases the current density is also increased.

When a bias current is applied to the center of magnetic disk, the phenomenon of current at different scratch positions is evaluated.

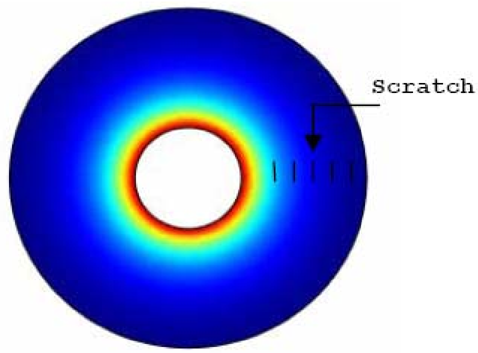

Fig. 3 Geometry of scratch position..

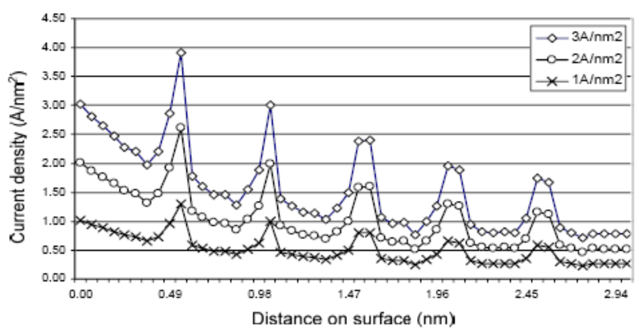

Fig. 4 Current density results on various scratch positions.

In Fig.3, it is shown the geometry of scratch positions on the surface with the same depth. The 5 scratch positions are made at 0.5 nm, 1 nm, 1.5 nm, 2 nm and 2.5 nm. Bias current densities of 1 A/nm^2, 2 A/nm^2 and 3 A/nm^2 are applied to the center of disk. All scratches are 5 nm deep.

It is seen from Fig.4 that the current density is decreased when the distance on surface increases. It is also seen that a jump of current density exhibits at each scratch position. It is seen Fig.2 and Fig.4 that current density depends on scratch depth, bias current density and distance on surface. The current density is large at a deep scratch and at a small radius. In contrast, a low current density will be occurred at a shallow scratch and a large radius.

3.2 Current flowing on a rim-to-center disk

A bias current is applied at the rim of the media and the center is grounded (from the rim is 0 nm to the center about 2.8 nm). The scratches are made at 0.5 nm, 1 nm, 1.5 nm, 2 nm and 2.5 nm positions with a 3 A/nm^2 bias current density as shown in Fig.5 [9].

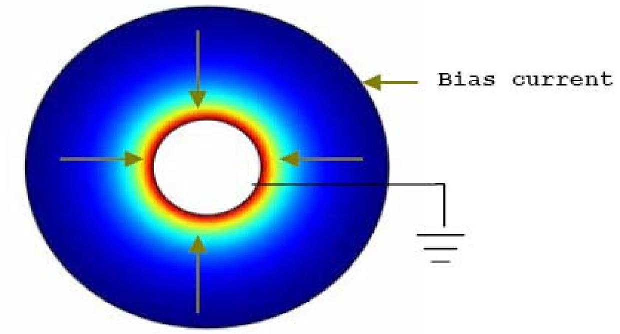

Fig.5 Geometry of the reverse bias current.

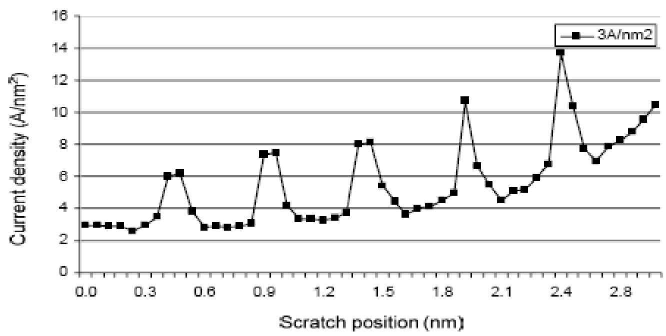

Fig. 6 Current density as biasing current at the rim.

It is seen in Fig.6 that a current density dramatically reduces when a scratch position is in direction to the center. It is also seen that a jump of current density is presented at each scratch position. These results seem to be similar to the previous result. It is intriguingly found that a jump height at each position in Fig.6 is about three times than that in Fig. 4.

3.3 Temperature dependence

The temperature raised due to a current is to be studied by using Eq. (8), a scratch depth is also set at 5 nm at the same 5 scratch positions with 3 different bias currents densities (1 A/nm^2, 2 A/nm^2 and 3 A/nm^2).

It is seen from Fig.7 that the Delta T is decreased when the distance on surface increases. It is also seen that a jump of Delta T exhibits at each scratch position. It seen Fig.7 that Delta T depends on scratches depth, bias current density and distance on surface. The Delta T is large at a deep scratch, a small radius and a large bias current density. In contrast, a low Delta T will occur at a shallow scratch, a large radius and a small bias current density.

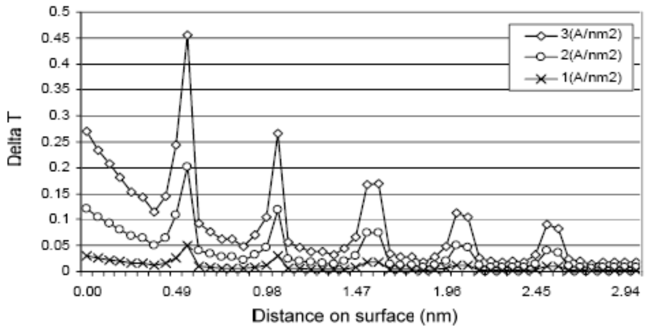

Fig. 7 Scratch position results on Delta T (ΔT).

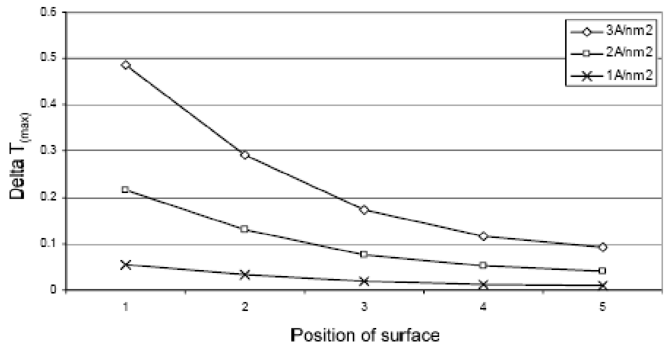

Fig. 8 Scratch position results on $\Delta T_{(max)}$.

For better understanding the thermal decrease at scratch position, $\Delta T_{(max)}$ is considered at 5 scratch positions. In Fig. 8, it shows the relationship between scratch position and $\Delta T_{(max)}$. It is found that $\Delta T_{(max)}$ tends to decrease at a long distance from a disk center. Moreover this decrease exhibits exponentially when the current is increase.

4. Conclusions

This paper shows study of current density phenomenon on scratched media by using relationship between heat energy (*Q*) and dissipation energy (*W*), applied by Joule heating. The following conclusions have been reached based on our study.

1). When bias current is applied from the center to the rim, the current densities depend on scratch depth, bias current density and distance on surface. When the scratch depth increases, the current density is also increased. If a scratch is far from the center, the current density will dramatically decrease.
2). When biasing a current from the rim to the center, these results seem to be similar to that biasing a current from the center to the rim. However, the amplitude of the first technique is about 3 times higher than that of the latter one.
3). The Delta T (ΔT) depends on scratch depth, bias current density and distance on surface. The Delta T (ΔT) is increased when the scratches depth increases. The Delta T (ΔT) is decreased when the bias current increases and the distance on surface is increased.
4. The Delta $T_{(max)}$ ($\Delta T_{(max)}$) tends to decrease at a long distance from a disk center. Moreover, this decrease exhibits exponentially when the current is increased.

Acknowledgements

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