Triboelectromagnetic Phenomena at a Simulated Material Combination of a Head/Magnetic-Recording-Disk

Keiji Nakayama

Mechanical Engineering Laboratory
Namiki 1-2, Tsukuba, Ibaraki 305-8564, Japan
nakayama@mel.go.jp

ABSTRACT

The head slider of a magnetic recording apparatus is currently covered with a diamond like carbon (DLC) film, while the magnetic recording layer of the disk is overcoated with hydrogenated carbon film (HCF). The head materials of DLC film were simulated with diamond, while the disk overcoat layer was simulated by a hydrogenated carbon film coated on glass substrates. Triboelectromagnetic phenomena were investigated in the simulated tribosystem. It was found that the triboelectromagnetic phenomena observed in the simulated tribosystem, and their intensity strongly depend on the hydrogen content in the carbon film. This is because the resistivity of the film greatly increases with the hydrogen content.

Keywords: head-disk-interface, triboelectro-magnetic phenomena, tribo-electron, tribo-ion, tribo-photon

1 INTRODUCTION

High-density magnetic recording disk with a 100 Gbit/in^2 are currently under development in the magnetic recording industry. To increase the recording density, it is necessary to reduce as small as possible the gap between the flying head slider and the rotating magnetic recording disk. The ultimate would be an in-contact type magnetic recording apparatus, where head and disk directly contacts during operation. It is intended to develop this. In this in-contact type system, dynamic physical and chemical phenomena at the head disk interface (HDI) are important. One of the most important things necessary to realize the high density in-contact type recording disk is prevention of decomposition of the thin perfluoropolyether (PFPE) lubricating oil film coated on the hydrogenated carbon film (HCF).

However, the decomposition mechanism has not yet been fully clarified, though an attempt has been made to explain this process by reference to influential factors such as frictional heating.

In contrast, triboelectromagnetic phenomena occur at the frictional contacts. The phenomena embrace tribo-charging, triboplasma formation, and triboemission of electrons, ions and photons. These phenomena cause tribochemical reactions on some lubricants producing high molecular weight products [1]. Such phenomena depend strongly on the sliding material nature, especially on their electric nature (2). The materials of the real head slider are currently overcoated with a diamond-like-carbon film (DLC), while the magnetic recording layer of the disk is overcoated by a hydrogenated carbon film.

The purpose of the present study is to investigate triboelectromagnetic phenomena at the HDI using a simulated material combination of diamond/HCF (Dia/HCF) which simulates DLC-film/HCF.

2 EXPERIMENTALS

2.1 Preparation of Carbon Films

Hydrogenated carbon films having a thickness of 20 nm were deposited on a K+ ion exchanged glass substrate (Ra < 1 nm) in a mixed gas atmospheres of H_2 and Ar containing different H_2 gas content , V_{H2} in the sputtering gas using amorphous carbon

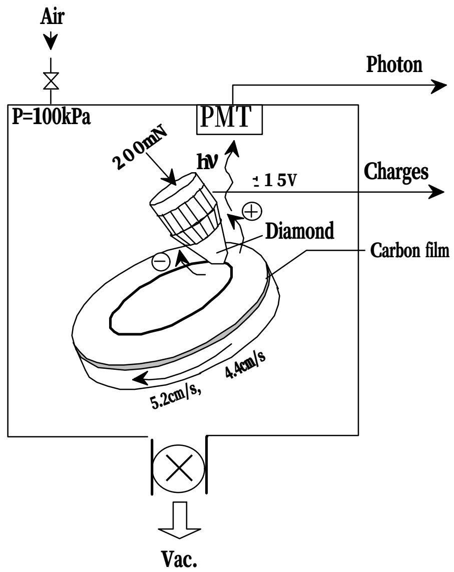

Fig. 1 Triboelectromagnetic phenomena measuring apparatus

as the target in a DC magnetron sputtering apparatus..

2.2 Sliding Experiments

The shaded part of the pin in Fig. 1 is the detector of the negatively and positively charged particles. Photons were detected by a photomultiplier tube (PMT), which is sensitive to wavelengths of 399 to 650 nm. Surface potential and friction coefficient were measured using an electrostatic voltmeter and four strain gauges, respectively. The diamond stylus was a cone having an included angle of 90 degrees and a tip radius of 300 μm (for charges and friction) and 100 μm (for photons). The signals were sampled every 100 μm, and then amplified using a pre-amplifier and a main amplifier and then accumulated by an integrator. Sliding experiments were conducted under an applied normal force of 200 mN in ambient air having a relative humidity of 52 – 53 percent (for charges and friction) and in dry air (for photons).

3 RESULTS AND DISCUSSION

Hydrogen contents in the carbon film were measured by a hydrogen forward scattering technique using a Rutherford backscattering Spectrometer. Figure 2 shows the relation between the hydrogen content in the carbon film, C_H and the hydrogen content in the sputtering gas of Ar and hydrogen gas mixture V_{H2}.

Figure 3 shows the dependence of negatively (top) and positively (middle) charged particles and surface potential (bottom) on a sliding time in the carbon film with C_H = 27 at.% in the simulated tribosystem of Dia/HCF, where negatively charged particles are the mixture of electrons and negative ions and positively charged particles are the positive ions. It is seen that charged particle emission and tribo-charging are observed definitely. Photon emission was also observed in separate experiments.

Figure 4 shows the dependence of the triboemission intensity of negatively and positively charged particles and photons, and friction coefficient on hydrogen content, C_H in the carbon film. The intensity of the

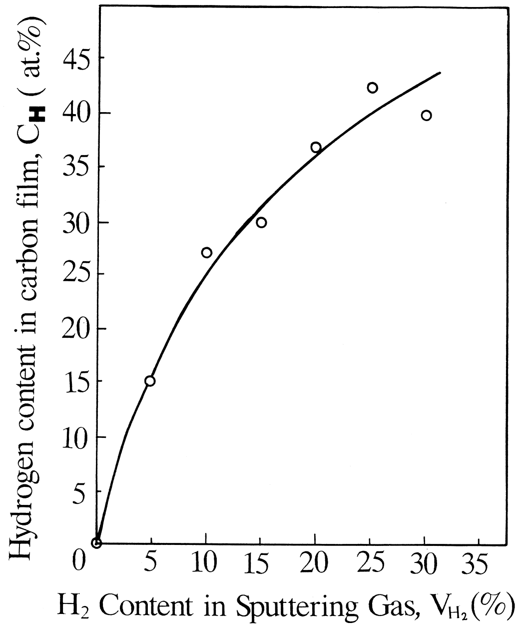

Fig. 2 Relation between hydrogen content in sputtering gas, V_{H2} and hydrogen content in carbon film, C_H

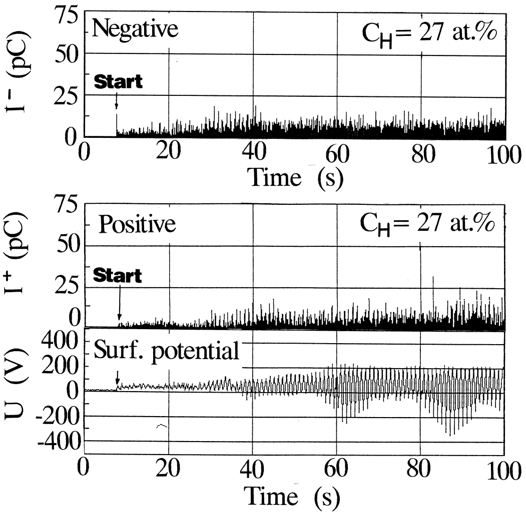

Fig.3 Dependence of the triboemission intensity of negatively (top), positively (middle) charged particles and tribo-charging (bottom) on sliding time.

charged particles and photons and the friction coefficient were all low, in the region of C_H < 20 at%. These low values were transited to high values in the region of 20 at% < C_H < 35 at% for the charged particles, 20 at% < C_H for photon, and 15 at% < C_H < 30 at% for the friction coefficient.

From Fig. 4, it can be concluded that the triboelectromagnetic phenomena are low in the low hydrogen content region and transit to high values with increase of the high hydrogen content. As triboelectromagnetic phenomena cause the decomposition of organic molecules [1], use of high hydrogen content of the carbon film should be avoided for over coating of the magnetic recording disk. It has been observed that heavy film breaking down occurred in the high hydrogen content region and that the transition of the electron emission intensity from low to high was attributed to the formation of the fresh surface due to the film breakage [3].

However, it is difficult to explain such a huge increase of emissions (of the orders of 10^3 to 10^4 times with increase of C_H) by only the film breaking. Previously, it has been found that the triboemission intensity increases in the order of insulator > semi-conductor > conductor [2]. This is because the emission mechanism of insulators and conductor are different and the semi-conductor has both of insulator and conductor mechanisms.

Figure 5 shows the relation between the hydrogen content and the resistivity of carbon film. It is seen that resistivity of carbon film increases exponentially with the hydrogen content in it.

The charge and photon intensities in Fig. 4 were replotted against the resistivity of the carbon film using the relationship in Fig. 5 to give Fig.6. It is seen that the tribo-particle emissions transits from low to high values with the resistivity. This trend is very similar to those on various kinds of solids [2]. In addition, it can be said that the transition of the tribo-particle emission along with the increase of the hydrogen content is mainly caused by the change of the triboemission mechanism from low emission intensity in conductors to high emission intensity in insulators with an increase of the resistivity. Additional to the

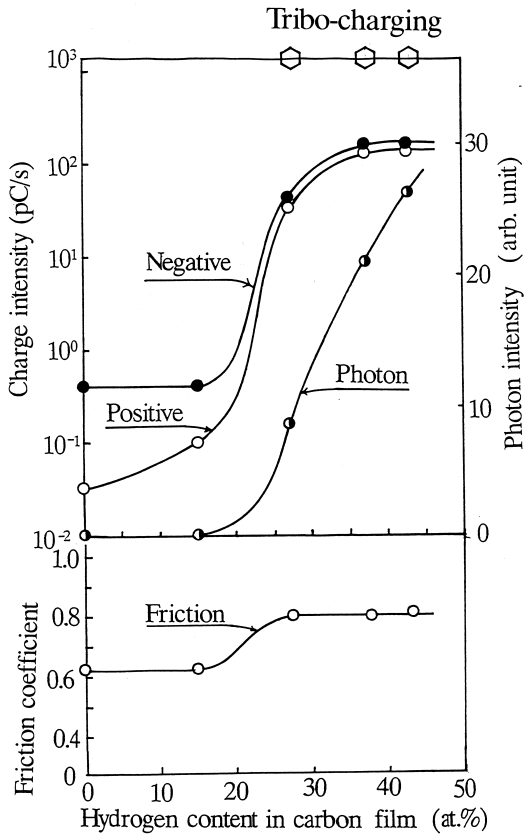

Fig. 4 Dependence of triboemission intensities of the negatively and positively charged particles and photons (above) and friction coefficient (below) on hydrogen content in carbon film

effect of the resistivity, the increased fresh surface contributed to the transition of the tribo-particle transition from low to high.

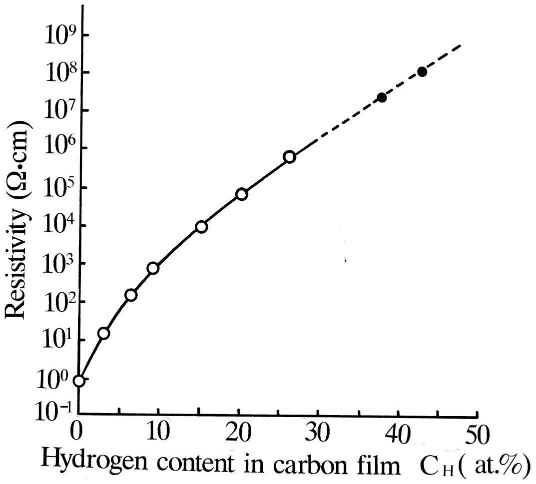

Fig. 5 Relation between the resistivity and hydrogen content in carbon film

4 CONCLUSIONS

Triboelectromagnetic phenomena in a head/disk interface were investigated using a simulated tribosystem of a diamond/hydrogenated-carbon-film. The following conclusions were drawn.

1) triboelectromagnetic phenomena were observed in the simulation tribosystem. This demonstrates that triboelectro-magnetic phenomena occur in the HDI tribosystem.
2) triboelectromagnetic phenomena transits from low to high intensity with an increase of hydrogen content in carbon film. This is because the resistivity of the carbon film increases greatly with an increase in hydrogen content.
3) These results support the idea that the overcoat films with low resistivity should be developed to avoid the decomposition of perfluoropolyether lubricating oil.

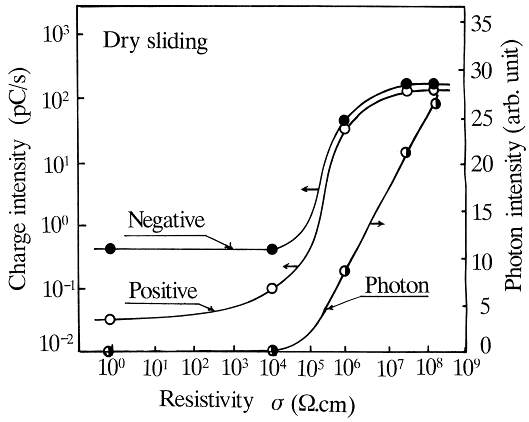

Fig. 6 Dependence of charge intensity and photon intensity on resistivity of solids

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