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A FACILE APPROACH OF FABRICATING ULTRA-THIN WEAR RESISTANT SI/SIN$_X$/C OVERCOATS FOR MAGNETIC TAPE RECORDING HEADS

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Introduction

Magnetic tape recording is one of the oldest data storage technologies, and it is still used today due to its low cost and long data storage life. Magnetic tape recording is a contact recording technology, where a thin flexible magnetic tape medium is pulled across an Al_2O_3/TiC (AlTiC) recording head surface at a high velocity while in direct physical contact with each other. As a result, one of the inherent problems faced in magnetic tape recording systems is an increase in the magnetic spacing over time with prolonged usage, due to continuous wear of the tape bearing head surface, which in turn leads to a deterioration of the magnetic readback signal [1]. The increase in the magnetic spacing at the head-tape interface can be due to several factors, such as pole tip recession (PTR), accumulation of wear debris on the head and surface roughness of the head and tape medium. Out of these factors, PTR is a major contributor to the magnetic spacing loss, due to a higher rate of wear of the softer magnetic read and write poles at the head-tape interface [2].

In order to reduce the rate of PTR and head surface wear, one approach is to apply a wear-resistant overcoat on the head. Until very recent times, commercial magnetic tape drive heads did not have any overcoats. Most of the overcoats previously developed by several groups either experienced early failure, and/or they were too thick (> 20 nm) such that they introduced a large magnetic spacing at the head-tape interface. With future tape drives expected to support higher areal density, there is a need to achieve even lower magnetic spacing [1]. According to the Information Storage Industry Consortium (INSIC) Tape Storage Roadmap 2012-2022, the magnetic spacing is targeted to reach 17 nm, corresponding to an areal density of ~ 50 Gbits/in^2 [3].

Carbon has been explored as one of the candidates for the overcoat material, due to its chemical inertness, high toughness, low coefficient of friction and high wear resistance. In particular, ultra-thin carbon overcoats deposited by filtered cathodic vacuum arc (FCVA) have shown desirable mechanical and tribological properties, and have been studied as overcoats for the head-disk interface in magnetic hard disk drives [4]. Recently, FCVA has been used to develop protective carbon overcoats on tape heads. While these overcoats have shown good wear durability [5, 6], the integration of the FCVA technique into current manufacturing processes is quite complex and costly. As such, a desirable overcoat design should be simple, inexpensive, controllable, and can easily be incorporated into the current tape head fabrication process.

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Therefore, in this work, a facile and novel approach of fabricating an ultra-thin wear resistant carbon overcoat onto tape heads by pulsed DC sputtering is presented. This combines its outstanding tribological properties with its ease of integration into existing tape head fabrication technology in the industry.

Experimental Methodology

To promote the adhesion between the carbon overcoat and the AlTiC head substrate, an interlayer of Si/SiN_x was first deposited by RF sputtering. Subsequently, the carbon overcoat was deposited by pulsed DC sputtering in the same system. The total thickness of the Si/SiN_x/C overcoat structure was maintained at ~ 7 nm (Si/SiN_x ~ 3 nm, pulsed DC carbon ~ 4 nm) to achieve a low magnetic spacing. The Si/SiN_x/C overcoat was deposited onto flat AlTiC substrates, as well as commercially available uncoated tape drive heads. A cross-section schematic of the overcoat is provided in Fig. 1a, and the transmission electron microscopy (TEM) cross-section of the overcoat is presented in Fig. 1b.

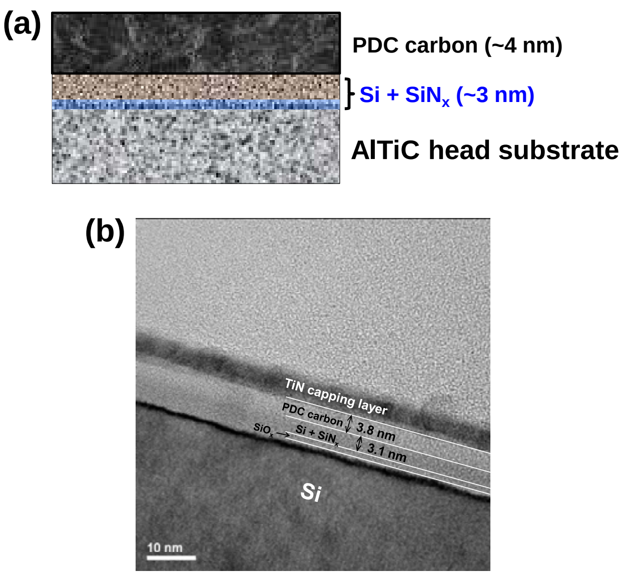

Fig. 1 (a) Cross-section schematic of the Si/SiN_x/C overcoat deposited on the AlTiC substrate of the tape recording head; (b) cross-section of the overcoat deposited on a silicon substrate imaged by TEM.

Ball-on-disk tribological tests were performed on the coated flat AlTiC substrate to obtain the coefficient of friction (COF), using a sapphire counterface ball and a contact pressure of 0.35 GPa. After the test, the samples and the ball were observed using an optical microscope. To investigate the wear behavior of the overcoat on tape head, the coated tape head was subjected to a tape wear test of 1 million meters against Linear Tape Open generation 6 (LTO-6) BaFe tape using a custom-built tape wear tester. The conditions of the tape test were set to simulate standard operating conditions of a conventional tape drive. Atomic force microscopy (AFM) measurements were performed to characterize the topography of the head surface after the wear test. Auger electron spectroscopy (AES) measurements were then conducted on the tested head to analyze the surface elemental composition.

Results

Fig. 2 shows the frictional data obtained from the ball-on-disk tests. The data of Si/SiN_x/C was compared to 1) a similar Si/SiN_x/C film structure but using FCVA deposited carbon, 2) a Si/SiN_x film structure without any carbon layer on top of it, and 3) a bare AlTiC substrate (without any overcoat). All tests were conducted using the same conditions and for 10,000 cycles. As can be seen, the COF of the Si/SiN_x/pulsed DC sputtered carbon film was maintained at a low value of ~ 0.15 throughout the wear test, which is comparable to Si/SiN_x/FCVA deposited carbon. Notably, the COF values of both the pulsed DC sputtered and FCVA deposited carbon film structures are several times lower than bare AlTiC and Si/SiN_x without carbon. This demonstrates the effectiveness of both pulsed DC and FCVA deposited carbon as wear protective overcoats.

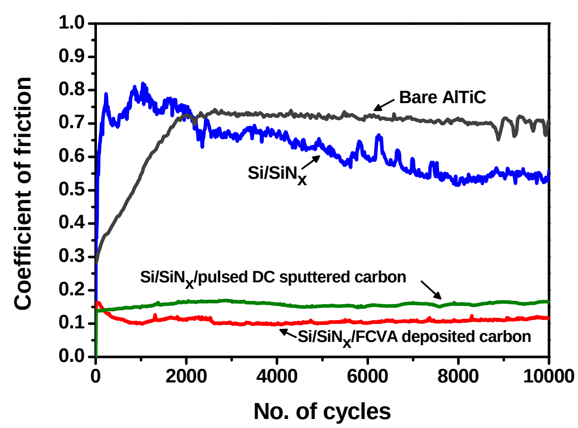

Fig. 2 Coefficient of friction data extracted from the ball-on-disk tribological tests.

After running 1 million meters of tape over the Si/SiN_x/pulsed DC carbon coated head, AFM measurements showed that the surface of the head

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was free of wear debris. Following that, Auger elemental surface mapping of carbon was performed in the vicinity of one of the read/write elements of the coated head, which is presented in Fig. 3. The bright areas indicate a high intensity of carbon detected on the head surface, suggesting that the carbon overcoat was still present on the read and write shield region as well as at several parts of the AlTiC. This result reveals the durability of the $Si/SiN_x/C$ overcoat under real tape drive conditions.

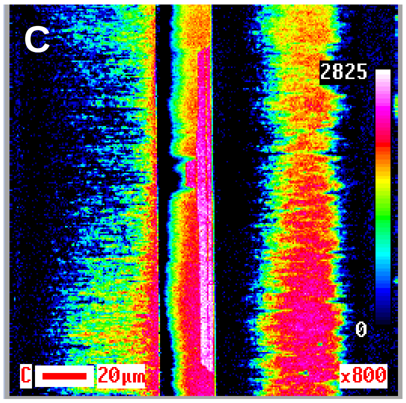

Fig. 3 Carbon Auger elemental map of the coated head's tape bearing surface after the 1000 km wear test with LTO-6 BaFe tape.

Currently, the carbon overcoat is being investigated by Raman and X-ray photoelectron spectroscopy (XPS) to understand its microstructure and bonding environment (such as sp^2/sp^3 carbon bonding fraction).

Conclusion

The findings in this work highlight the outstanding properties and performance of the fabricated ultra-thin $Si/SiN_x/C$ overcoat in wear protection of the tape head. While providing a low magnetic spacing, the designed overcoat was able to protect the AlTiC surface throughout the duration of the tribological wear tests, which were performed on flat AlTiC substrates and coated commercial tape heads. The simplicity of this fabrication technique for pulsed DC sputtering of carbon gives it an added advantage over FCVA deposited carbon for it to be easily adopted and integrated into existing manufacturing processes.

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