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Study of facing target sputtered diamond-like carbon overcoats for hard disk drive media

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ABSTRACT

The demand for higher areal density in the hard disk drive industry has fuelled extensive research efforts and focuses on magnetic spacing reduction. In the head–disk interface arena, one of the key focuses is to reduce the carbon overcoat thickness without compromising the overcoat protection performance. Thus, in the search for alternative methods to reduce the carbon overcoat thickness, the facing target sputtering (FTS) process for diamond-like carbon deposition has been investigated. The resulting properties have been presented in this paper, with comparison to conventional diamond-like carbon (DLC) layers by other processes such as chemical vapor deposition and reactive sputtering with nitrogen. X-ray reflectometry results showed that facing target sputtered DLC samples displayed significantly higher density, at 2.87 g/cm^3, as compared to hydrogenated and nitrogenated DLC samples. This was attributed to the higher sp^3 content, as obtained by X-ray photoelectron spectroscopy measurements. As a result of the high sp^3 content, hardness of the FTS deposited samples was higher than that of the hydrogenated and nitrogenated DLC samples. In addition, the surface energy of FTS samples was observed to be comparable, but lower, than that of nitrogenated DLC samples through contact angle measurements. Clearances comparable to that of conventional DLC samples were achieved and the sample disks were flyable. Wear performance tests also revealed more wear resistance for the FTS deposited DLC samples, but also higher head wear.

1. Introduction

To increase areal density of disk drives, magnetic spacing reduction has always been one of the key research focuses in the hard disk drive industry. In the head–disk interface (HDI) arena, efforts on overcoat or lubricant thickness reduction have been ever-present in the quest for spacing reduction. This approach is very challenging, given the already minute magnitude of the carbon overcoat and lubricant layer thickness. In recent years, there have been explorations on alternative carbon deposition processes [1,2] for thinner media overcoat. For years, there have been studies on filtered cathodic vacuum arc process for media overcoat due to its reportedly high sp^3 content, hardness and density [3–6]. However, despite its promising properties, this process is plagued by issues such as high particle count, due to its arcing nature, relatively low deposition rate and its incompatibility with current mass manufacturing tools. As a result, the FCVA process is still confined, in hard disk drive (HDD) industry, to the deposition of the DLC layer as a slider overcoat.

Facing target sputtering (FTS) process was first introduced by M. Naoe et al. [7,8] in 1978, where they reported the deposition of magnetic metal films using two facing targets and a perpendicular magnetic field (to the target surface). A patent on a FTS device was filed in 1991 by Pioneer Electronic Corporation, Japan [9]. The first report on properties of FTS deposited carbon was seen in 1997 [10] where K. Noda et al. reported on the Raman spectroscopy results and surface morphology of FTS deposited carbon and demonstrated that FTS process for carbon can take place at argon gas pressure of as low as 2.7 mPa and can avoid plasma damage. J.R. Shi et al. [11] also reported on the beneficial effect of decreasing Ar pressure on sp^3 content and hardness. However, if nitrogen flow rate was increased during the FTS deposition of a-C:N$_x$ [12–16], decrease in sp^3 fraction, hardness, modulus and corrosion performance of the studied layer was subsequently observed. In addition, low friction coefficient and good wear resistance for FTS samples were also observed [15]. Poh et al. have reported the use of hybrid-FTS configuration in Circulus M12 production tool. Improved performance of hybrid-FTS over conventional magnetron sputtering has been reported [16]. However, FTS is expected to be much better than hybrid FTS in terms of the sp^3 content and hardness and such carbon has not been studied in a production tool.

In this paper, we evaluate and investigate the suitability of production tool FTS process on the development of ultra-thin carbon layers for HDD media overcoat. The properties of FTS deposited diamond-like carbon (DLC) were characterized and the observed

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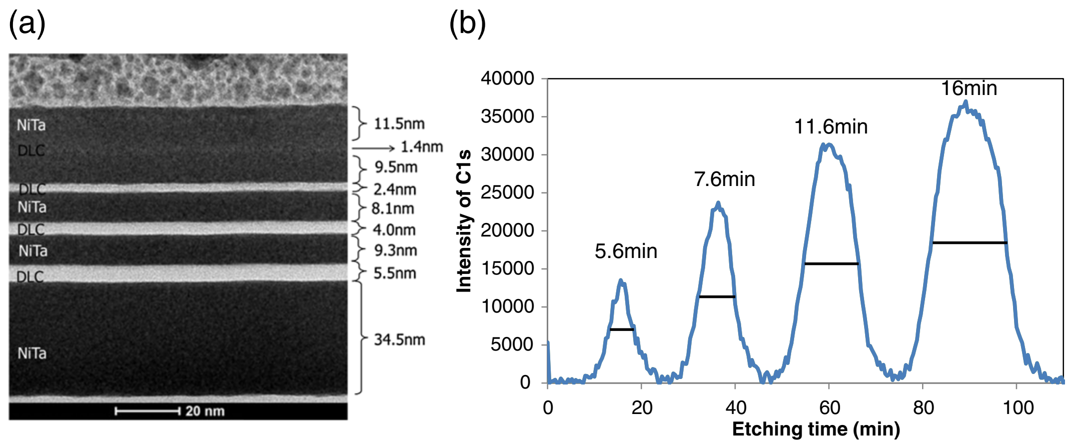

Fig. 1. (a) TEM image of the cross section of FTS deposited samples for thickness calibration; (b) XPS depth profile of the same samples for etch rate.

results were investigated in relation to the sp^2/sp^3 content. In addition, the surface energy, the flyability performance and wear tests of the FTS deposited DLC were also evaluated.

2. Experimental details

Sample deposition was carried out in the sputtering chambers of Intevac 200 Lean system. The studied sample structures were of glass substrate/NiTa-36 nm/DLC layers. FTS samples were deposited using Intevac confined dense plasma (CDP) source using the following deposition parameters: a) sputtering power = 2 kW, b) Ar gas flow rate = 15 sccm; c) pass-by speed of 54 mm/s, d) no substrate bias. The FTS process involves 2 parallel rectangular shaped carbon (99.999%) targets (with complementing magnets behind), with the substrate perpendicular to the target plane. The close-loop magnetic and electric field confine the electrons and the plasma density between targets increases due to the high electron concentration. The increased plasma density allows for the deposition process to take place at a low working pressure. The working pressure was observed to be 0.147 Pa. a-C:H_x layers were deposited using chemical vapor deposition process, with the following deposition parameters: a) anode voltage = 60 V; b) emission current = 0.6 A; c) bias voltage = 120 V; d) Ar gas flow rate = 2 sccm; e) C_2H_2 gas flow rate = 24 sccm while a-C:N_x layers are deposited using DC reactive sputtering process, with the following deposition parameters: a) sputtering power 0.5 kW; b) Ar gas flow rate = 40 sccm; c) N_2 gas flow rate = 20 sccm.

The deposited layer thicknesses were measured and monitored using both transmission electron microscopy (TEM) and X-ray photoelectron spectroscopy (XPS) depth profile (Fig. 1). FEI Tecnai X-TWIN TEM system was operated at 200 kV to view cross section of the sample after focus ion beam cut. XPS measurement was conducted on a PHI Quantera SXM Scanning X-ray Microprobe with a monochromatic Al $K\alpha$ source. The system was operated at 15 KeV, 40 W, 45° take-off angle, 55 eV pass-energy with 0.1 eV energy gap and 200 μm size of beam. XPS depth profiles were performed with the ion energy of the Ar^+ sputter gun at 500 eV and the sputtering area of 2 mm × 2 mm. The density of the DLC films was measured by high resolution X-ray reflectometry (HR-XRR) at grazing incidence in the X-ray demonstration

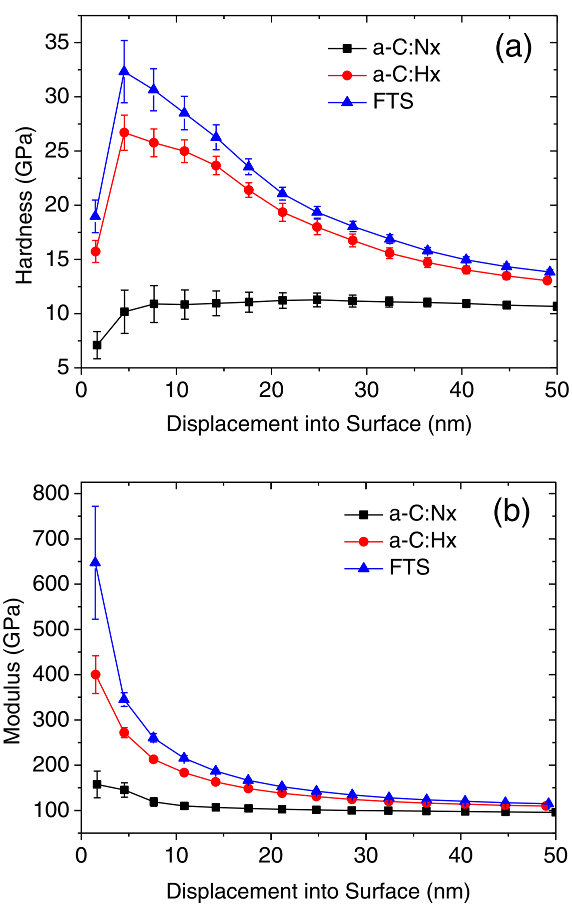

Fig. 2. Plot of (a) hardness; and (b) modulus; with displacements from surface for the three types of DLC samples.

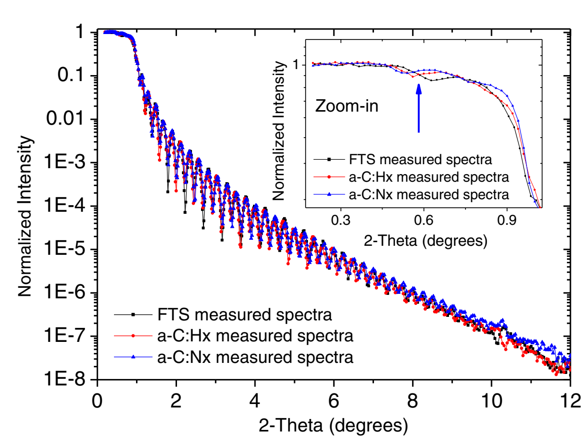

Fig. 3. Plot showing XRR spectra of the three different kinds of DLC with zoom-in plots showing the increase of the critical angle with increasing density, X-ray wavelength λ = 1.540 Å.