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Study of Chromium Hard Mask Formation and Wall Angle Control for Deep Etching Application

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Abstract

Burnish head is widely used for burnishing process which is one of the critical ways to remove such asperities from the disk surface prior to assembly into hard disk drive. To achieve glide performance for ultra-low flying height, disk media with asperities that exceed the flying height of the magnetic head must be eliminated. One of critical parameter of burnish head is the rail dimension which required very deep etching at > 30 microns. To produce such etching depth, a Cr hard mask is needed. Wet etching process for Cr film was selected to form the Cr hard mask. In this study, the interactions of wet etching condition with the Cr hard mask were investigated in terms of the process impact to the mask wall angle. The chemical reaction was studied and discussed here in term of mass transportation condition. XPS revealed that the etch byproduct was Cr nitrate ($Cr(NO_3)_3$) and Cr oxide (Cr_2O_3). These byproducts passivated the metal surface and limited the fresh etchant arrival onto unetched surface. From the etched topography study, the process is said to be under mass transport control, and the reaction rate was determined to be influenced by the rate of mass transfer of reactants and products to and from the surface.

Keywords: burnish head; media asperity; deep etching; hard mask formation; wall angle; CD

1. Introduction

For the magnetic memory disk manufacturer, the thin magnetic film has been coated on the substrate which is to receive and store information. The read/write heads which interact with each of surface are called "flying" heads. The rotation of the disk at high speed make heads ride on an air bearing between

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the disk and the head. The confrontation of asperities (protrusions and the like) on the disk surface and a read/write head during high-speed relative movement between the two will cause an anomaly such as damage to the head or an error in the information transfer [1].

A burnishing head is made to remove any asperities on the disk surface and designed as a flying head which passed over the surface to be burnished. This head requires very deep etch feature which is more than 30x of etching depth of read/write head design. To achieve a very deep etching on Alumina Titanium carbide (AlTiC) substrate, the metal hard mask method must be applied instead of using polymer-based mask during dry etching process with CF4 gas. Metal mask that will be used as an etch mask must have low etch selectivity compared to AlTiC substrate to enable a good etched critical dimension (CD) control. CD is also related to "undercut" control, that is the amount of line broadening due to the action of the etching both below the resist layer, in horizontal direction [2, 4].

In this paper, the study of chromium hard mask formation is presented to support etch depth target at 30-60 micron on AlTiC. The geometry control i.e. etch undercut, etch wall angle, and the etching product were discussed here.

2. Experimental setup

2.1. Sample preparation

The 1×1 inch AlTiC coupons were prepared. 6 microns Cr film was deposited on the top of coupons by physical vapor deposition (PVD). Then 8 microns thick of positive photoresist, AZ4999, was spin-coated on the Cr film, baked at 120 °C for 1 hour and patterned via photolithography. (AZ4999 served as wet etching mask for the Cr film.) Photoresist baking was required to achieve good surface adhesion of photoresist during wet etcing process

2.2. Wet etching process

The patterned chromium coupon was then directly etched with an etchant -- a mixture of 9% cerium ammonium nitrate ($(NH_4)_2Ce(NO_3)_6$), 6% nitric acid (HNO_3) and water, at room temperature. This etchant was formulated to selectively etch chromium [3]. The coupons were etched under cyclic dipping until chromium in exposed area was completely removed. Figure 1 shows the detail of cyclic dipping process. The dipping time for each cycle of this study is 5, 15, and 20 seconds respectively. Manual agitation was applied during dipping for 2 strokes/seconds. Deionized water rinsing and N2 drying time were fixed at 1minute.

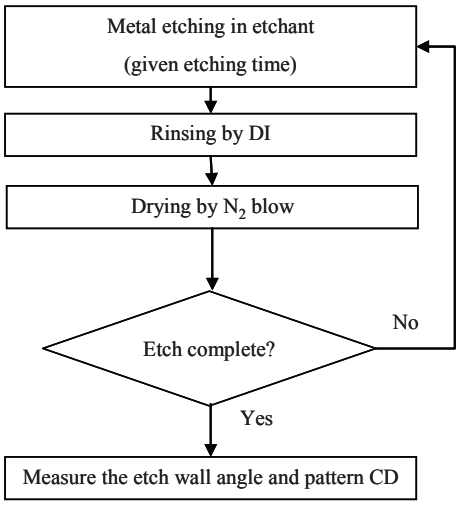


Fig.1. Detail of cyclic wet etching process

2.3. Etch dimension and pattern inspection and measurement

Etched patterns were inspected using a high power microscope through the photoresist. Chromium coupons were cross-section cut and imaged in scanning electron microscope (SEM) to measure the etch wall angle and etch dimension. This etch wall angle and dimension were used to calculate the etch rate of each cyclic etching condition.

2.4. Etch products analysis

Etch byproduct was found on the top surface of exposed area of chromium coupon. To understand the chemical reaction, etch product was analyzed by X-ray photoelectron spectroscopy (XPS) with Al Kα source and spot size of 200 microns. Both wide scan and narrow scan spectra were collected to study the etch product chemistry.

3. Result and discussion

3.1. Etch topography characterization

Figure 2 shows ~~the~~ images of chromium coupon with photoresist pattern after wet etching. The etch line of chromium layer can be observed through the photoresist layer. The distance between edges of chromium underlayer and the edge of photoresist top layer roughly suggested a difference of etch dimension. The three images show longer wet etch iteration time has longer etch undercut in lateral direction of chromium pattern.

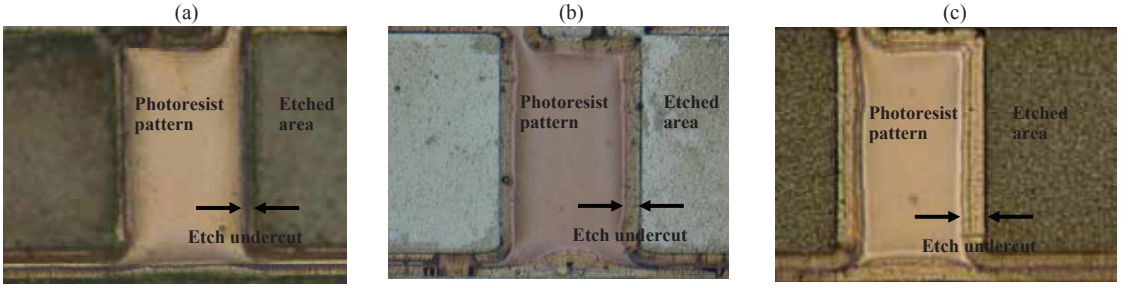


Fig. 2. Images under microscope of; (a) chromium coupon with photoresist pattern ~~after iteration~~ repeated wet etching at 5 sec/cycle; (b) 15 sec/cycle; and (c) 20 sec/cycle

Figure 3 shows the chromium pattern underlayer and photoresist top layer on the AlTiC substrate. The SEM images confirm that etch undercut in lateral direction increased as a function of iteration time increases. All feature dimensions were measured and tabulated in Table 1. The etch time of each condition was collected and used for etch rate calculation.

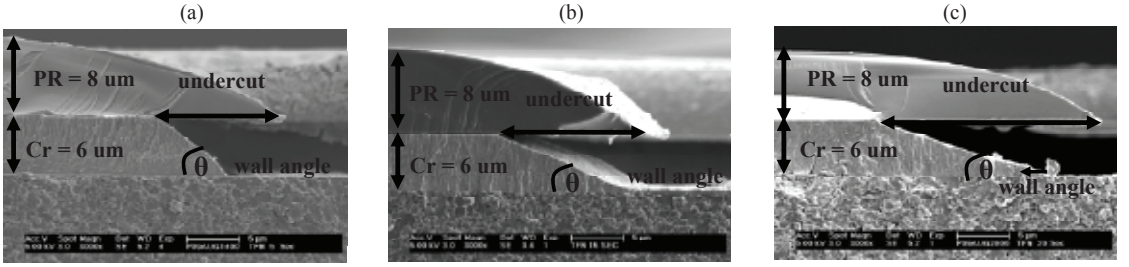


Fig. 3. SEM cross-section images; (a) chromium coupon with photoresist pattern after iteration wet etching 5 sec/cycle; (b) 15 sec/cycle; and (c) 20 sec/cycle

Table 1. Etch topography and etch rate of each wet etching condition

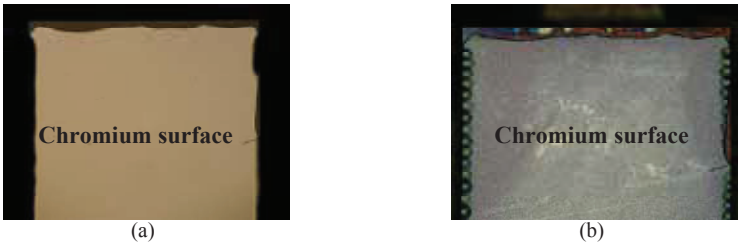
Wet etching condition	Etch undercut in latteral direction (microns)	Etch wall angle (degrees)	Etch time (minute)	Etch rate (micron/min)
Iteration etching time = 5 sec/cycle	11.89	40.06	29	0.207
Iteration etching time = 15 sec/cycle	13.14	22.04	54	0.111
Iteration etching time = 20 sec/cycle	20.47	18.66	70	0.086

The information in Table 1 clearly shows that the chromium etching rate increased as etching time per cycle reduces. The shorter time meant that the etchant arrive at the exposed chromium surface faster. The iterated wet etching increased the etchant availability. The lateral undercut increased as the wet etching time increases.

To understand the wet etching process control, one need to understand the solution/metal interface reaction [2]. The reaction between etchant and chromium at surface and etchant availability is limited by the transport of etchant by diffusion and convection phenomena. From the etch topography study results, the process is said to be under mass transport control and hence are strongly dependent to the motion of the etchant during the etching process.

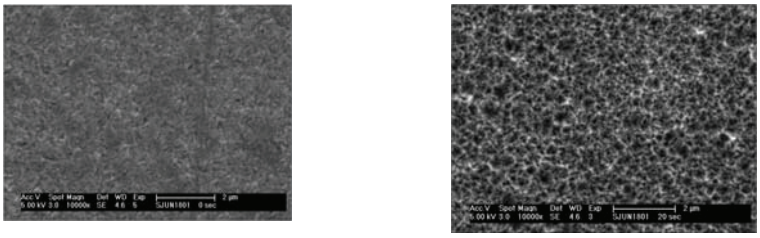
3.2. Etch product characterization

Three 1x1 inch chromium coupons were prepared. Coupons were dipped into etchant and taken out to dry under ambient condition. The etch surface was then inspected by the microscope and SEM. Figures 4 and 5 showed that etching event happened immediately upon etchant contact with the chromium surface.



(a) (b)

Fig. 4. Chromium coupon surface under microscope; (a) before wet etching; (b) after wet etching



(a) (b)

Fig. 5. Chromium coupon surface under SEM at 10kX magnification; (a) before wet etching; (b) after wet etching

The XPS wide scan spectra on the surface of chromium coupon after etching is shown in Fig. 6. The summary of the relative atomic concentration percentage of elements detected is tabulated in Table 2.

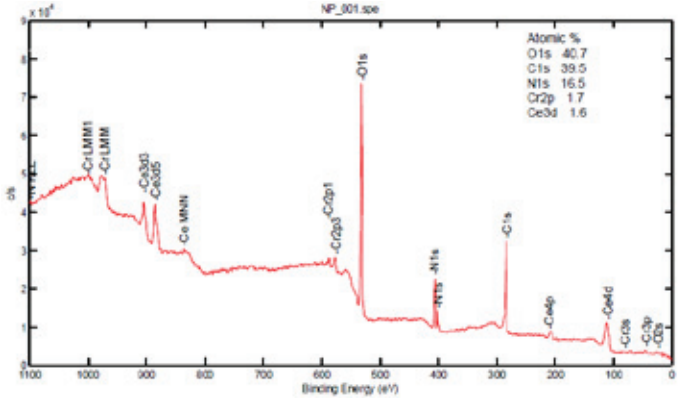


Fig. 6. XPS wide scan spectra on the surface of chromium coupon after etching

Table 2. Summary of the relative atomic concentration percentage of elements detected on chromium coupon surface after etching

Chromium coupon after etching	Relative atomic concentration percentage				
	C	N	O	Ce	Cr
Coupon no.1	39.5	16.5	40.7	1.6	1.7
Coupon no.2	28.1	19.9	48.0	2.0	1.9
Coupon no.3	31.5	18.2	46.5	1.9	1.9

The XPS narrow scan spectra of O1s and Cr2p3 obtained on all samples are shown in Fig. 7. The summary of area fraction percentage of possible chemcial state detected on all samples is tabulated in Table 3.

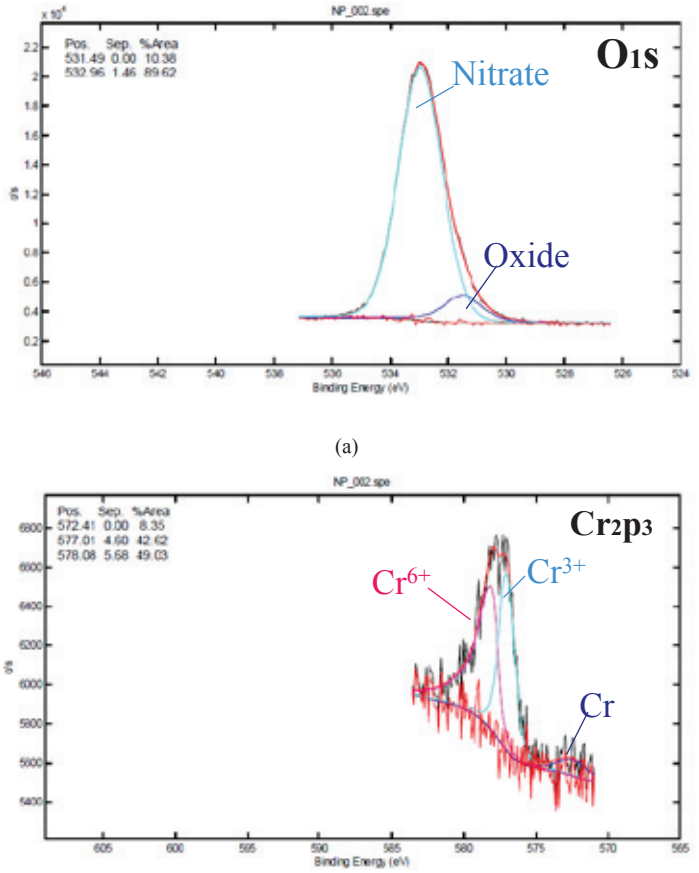


Fig. 7. XPS wide scan spectra on the surface of chromium coupon after etching

Table 3. Summary of area fraction percentage of possible chemcial state detected on chromium coupon surface after etching.

Chromium coupon after etching	Cr			% of Cr^{6+} in Cr in bulk	O		%Oxide in O in bulk
	Cr	Cr^{3+}	Cr^{6+}		Nitrate	Oxide	
Coupon no.1	8.35	42.62	49.03	0.8335	89.62	10.38	4.2247
Coupon no.2	7.89	43.26	48.85	0.9282	94.04	5.96	2.8608
Coupon no.3	7.72	43.10	49.18	0.9344	92.08	7.92	3.6828

The narrow scan results indicated that after etching, the surface was mainly made up of Cr, Cr nitrate and Cr oxide. These etch byproducts formed a very thin layer of about 1-2 nm.

4. Conclusion

From the etch topography, the process is said to be under mass transport control. The reaction is influenced by the rate of mass transfer of reactants, etchant, and etch byproduct on the exposed Cr surface. XPS showed that etch byproduct on the surface is made up of Cr, Cr nitrate and Cr oxide. The information of etch topography and etch product study can be used to design the process condition to achieve the physical critical dimension of wet etching process of chromium hard mask formation.

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