NICKEL PHOSPHORUS COATED SUBSTRATE MICRO-DEFECT REDUCTION THROUGH CHEMICAL MECHANICAL PLANARIZATION PROCESS OPTIMIZATION

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ABSTRACT

Chemical mechanical planarization (CMP) was known as a process to gain superfine surface finish with high precision mechanical parameters. It widely used within semiconductors wafer manufacturing and hard disk (HDD) industries. There're very few research done in HDD compared with silicon wafer. Micro defect formation caused by first step polishing in multistep polishing reducing the "good sector" and areal density in HDD substrate platter. In this study, micro defect reduction became the main objectives and as main response with others parameters including material removal rate and micro waviness. A 2 level 4 factor fractional factorial with center points Resolution IV, Design of Experiment (DOE) with total of 12 experimental runs was chosen for main effect and interaction screening purposes. All key factors such as platen rotation speed (rpm), applied pressure (g/cm2), slurry distribution points and slurry flow rate (ml/min) were then being optimized using Response Surface Method (RSM) setup of a set of full factorial 4 factors with center point, single replicate, 8 axial point and 2 alpha significance value with total 31 random runs. Results shows that all the input factors were affecting MRR and MD count except micro waviness which not respond to all input factors applied. Optimum input parameter setup were then established with setup of applied pressure (103.1 g/cm2), slurry distribution points (4/5 points), slurry flow rate (381.6 ml/min) and platen rotation speed (15.7 rpm). Predicted composite desirability gained to be 0.998, which can be satisfactory accepted. Verification runs from the parameter setup shows and concluded that the desired MD and MRR successfully achieved with 1.688% variation.

ABSTRAK

Pensatahan Kimia dan Mekanik merupakan satu proses untuk mendapatkan permukaan super-licin dan berketepatan ukuran mekanikal yang tinggi. Ia digunakan dengan sangat meluas dikalangan industry semi-konduktor dan pembuat cakera keras komputer. Bagaimanapun, terdapat kajian yang sangat sedikit dilakukan untuk dalam bidang cakera keras berbanding semi-konduktor. Kecacatan mikro yang disebabkan oleh penggilapan pertama didalam penggilapan berbilang tingkat telah mengurangkan “sektor baik” dan kepadatan areal didalam piring perakam cakera keras. Dalam kajian ini, pengurangan kecacatan mikro menjadi objektif utama dan tindak balas output utama bersama parameter yang lainnya termasuk kadar pembuangan bahan dan keberombakan mikro. Satu set 2 level 4 faktor faktorial pecahan dengan titik tengah Resolusi IV, Design of Experiment (DOE) dengan jumlah 12 eksperimen telah dipilih untuk menentukan faktor utama dan faktor interaksi dalam proses penyaringan. Semua faktor-faktor input utama seperti kelajuan putaran plat (rpm), tekanan permukaan (g/cm^2), mata pengedaran buburan dan kadar aliran buburan (ml/min) kemudiannya dioptimumkan menggunakan Response Kaedah Permukaan (RSM) dengan setting 31 eksperimen, eksperimen penuh melalui 4 faktor dengan titik tengah, 8 titik paksi dan nilai signifikan 2 alfa. Keputusan menunjukkan bahawa semua faktor-faktor input memberikan kesan terhadap MRR dan jumlah MD kecuali keberombakan mikro yang tidak bertindak balas kepada semua faktor-faktor input digunakan. Parameter input yang telah dioptimumkan kemudiannya telah dapat dibina dengan setup of tekanan permukaan (103.1 g/cm^2), mata pengedaran buburan (4/5 poin), kadar aliran buburan (381.6 ml/min) and kelajuan putaran plat (15.7 rpm). Jangkaan komposit yang dikehendaki adalah 0.998. Parameter yang telah dioptimumkan itu kemudian telah ditentusahkan dan satu kesimpulan dapat dibuat bahawa objektif MD dan MRR yang dikehendaki berjaya dicapai dengan ralat 1.688%.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

In Hard disk industries, the recording media which called substrates contains Al-Mg disk as based and plated with thin layer of nickel phosphorus to improve smoothness and hardness. With extreme demand of higher memory space in hard disk, manufacturers are pushing to the higher density of substrate platter. It can be achieved by reducing the height of the recording head to fly to strengthen the weak and smaller signals (Lei and Luo, 2004, Lei et.al, 2009). Reduction of flying head media needs super-smooth recording media platter to prevent head crash resulting data loss

1.2 Problem Statement

Most of the studies in reducing Chemical Mechanical Planarization (CMP) defects focusing on the slurry parameter such as abrasive particle size (Lei and Luo, 2004, Xie and Bushan, 1996), abrasive particle type and shape (Hong Lei et.al, 2009, 2010), oxidizing agent contents, additives to improve material removal rate and surface quality. Recent study starts to focus on friction modifier additives in slurry for improving surface topography and reducing surface defects (S.Sideq, S.Izman, 2013). Yong-Jin Seo, Sang-Yong Kim , Woo-Sun Lee (Yong-Jin Seo et.al, 2003) studied about the advantage of using POU slurry filters for reducing sub-micron defect of silicon wafer substrate. Heike Lauber, Sven Miinzberger (Heike Lauber, Sven Miinzberger, 2007) focused on post-polishing parameter and DIW rinsing optimization for CMP defect reduction for semiconductor substrate wafer. Most of the studies focusing on semiconductor wafer. At present, very less of the approach focusing on polishing parameter optimization for CMP defects reduction for hard disk substrate even there are a lot of study focusing on silicon wafer substrate.

From the data collected from one of the world leading hard disk manufacturer, from total of 32,224 defect points analyzed from 1611 substrate surfaces it showed that highest contributor of substrate micro defect was from CMP defect which were irregular pit and embedded particle as illustrated in Figure 1.0. Details of irregular pit and embedded particle defect formation will be discussed in Chapter 2 in literature review. It is mission critical to improve the micro defect count and optimize the CMP process.

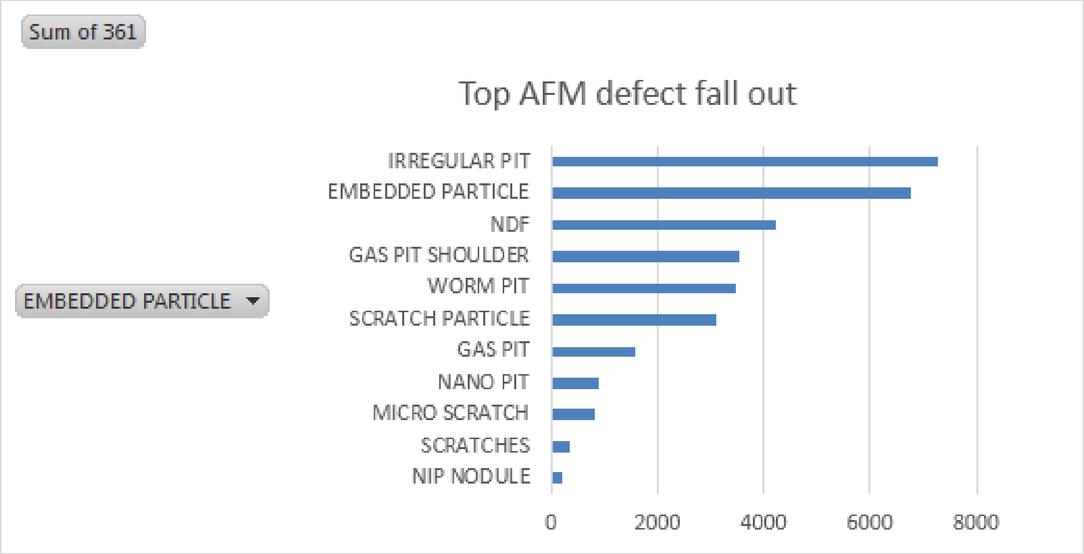

Figure 1.0: Microdefect AFM analysis fallout.

1.3 Objective of study

Objective of the study are:

1. To characterize the CMP process factors that influence to the process output response.

2. To identify the main factor and interaction factor that contribute to the CMP process response.
3. To optimize the CMP process from the experiment analysis result.

1.4 Scope of study

The scope of the study are:-

i. Polishing 2nd step of Al-Mg Nickel Phosphorus coated substrate disk, 1.27 mm thickness as work material by effect of Chemical Mechanical Planarization.

ii. The study will be carried out using double sided Precision Polishing Machine with polyurethane polishing pad and colloidal silica based slurry.

iii. The process input parameter to be tested are Pressure, Speed, Slurry discharge point and Slurry flow rate.

iv. The response performance to be analyzed are material removal (MRR), micro waviness, surface micro defect count.

v. Design of Experiment (DOE) design and analysis will be using Minitab Release 16.

vi. Surface quality analysis will be using Atomic Force Microscopy (AFM) for micro-defect detection scanning and count and surface topography.

This project is to study the 2nd step polishing parameters effect towards upstream (1st step) defects removal. Assuming all slurry related parameter already optimized including hybrid Al_2SO_3 slurry particle at 1st step polishing with lower slurry particle size 0.35~0.5µm, constant oxidizing agent which uses H_2O_2 0.5% - 1% concentration at of 1.3~1.7pH after mix and no interference from the polishing pads parameters characteristics. This study only includes the defect formation of the effect of 1st step polishing process and embedded particle as results of uneven thickness removal due to imbalance between mechanical and chemical removal and determination of the optimal 2nd step polishing parameter setup. This study will not covers the post-CMP cleaning and mechanical brushing to condition or pad conditioning.

1.5 Research Question

1. What are the optimum parameter setting for achieving the optimum substrate CMP characteristic?
2. What are the main influence factor or interaction of the influence factor that affecting output response of the process?
3. What is the predicted model can be generated for the output response?
4. What is the maximum variation percentage of error between experimental and predicted for output response?

1.5 Significance of study

Since the rapid technology changing which require higher substrate areal density which require the reduction of sub-micron defect and improvement of surface roughness and waviness, the outcome of the study will help to increase to improve the standards of the recording substrate to high-end product. It will also help to assist industries to select the optimum parameter setting for the manufacturing process.

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