Pad surface micro-structure as driver for oxide removal, case study for 3D-printed CMP polishing pads.

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Abstract

Surface properties of polishing pad are key parameters to manage material removal rate (MRR) in Chemical Mechanical Polishing (CMP). This work details the evolution of the oxide and tungsten polishing rates during the initial pad conditioning (pad break-in). The goal is to identify and correlate the effect of different dressers on pad surface properties and polishing rate / selectivity on different materials. Limited research has been done to highlight the relationship between pad properties and MRR. In this study, White Light Interferometry (WLI) has been used to analyze dressers aggressiveness and pad surface properties.

The results show that oxide and tungsten polishing rates can be modulated by changing the conditioner disk type. The use of WLI allows us to identify the pad main parameters that affects the removal rate.

Keywords: Chemical mechanical polishing, pad surface properties, White Light Interferometry

I. INTRODUCTION

For microelectronic manufacturing, groove design and surface properties of polishing pads are key factors for Chemical Mechanical Polishing (CMP). The planarization performance is notably driven by polishing pad properties and especially their role on the direct contact area, friction, and slurry distribution. These parameters have to be controlled to fine tune and improve different CMP processes. Few researches have been done to highlight the relationship between pad surface roughness and the material removal rate (MRR) on standard manufacturing pads [1-2-3-4].

Moreover, the pad surface is known to be affected by the pad dresser [5-6] depending on diamond shape and design.

In order to analyze pad micro-structure, different measuring methods can be used such as confocal laser scanning microcopy or White Light scanning Interferometry (WLI) [7]. In this study, WLI [8-9] allows us to extract a picture of a dedicated pad area. Based on it, some analysis are performed on different parameters from groove depth, to evaluate pad cut rate (PCR), to extract groove width, and all functional roughness and volume characteristics (Sq, Spk, Svk…). Therefore, this characterization technique is a smart solution for CMP process enhancement and control.

In this paper, the effect of conditioning aggressiveness is studied on a new generation of 3D-printed Dimension^{TM} pad. This innovative pad generation, with specific design shown in Fig 1, are fabricated using 3D-printers. This allows to improve micro-structure control layer by layer and hence to tune removal rate for dedicated applications. The goal of this study is to identify and correlate the effect on pad properties and polishing rate / selectivity. To do so, we evaluate three dressers with different diamond design and shape during initial pad conditioning. Throughout the evaluation, MRR tests for TEOS oxide and W materials were performed and pad surface roughness and PCR were analyzed, accordingly.

II. STUDIED SAMPLES

a. Pad

A Dimension^{TM} pad with an hexagonal pattern was used (Fig.1). It is a soft pad notably dedicated for W buffing application. The contact area of this kind of pad is around 48%.

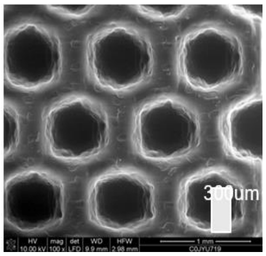

Fig.1: SEM top view of a Dimension^{TM} pad micro-structure with its innovative groove design.

b. Dressers

In this work, the pad surface has been modulated thanks to different types of conditioners (A, B and C). These three kinds of commercially available dressers, provided by different suppliers, have also

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been characterized by WLI. This preliminary analysis determines diamond characteristics: height, length and density, as shown in Table 1. Thanks to this data, we can rank the different disks in term of aggressivity according to diamond design: A is the less and C is the more aggressive one.

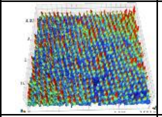
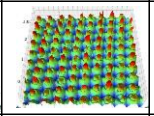
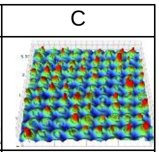
	A	B	C
WL interferometry picture (9mm^2)			
Diamond width (µm)	Between 60 & 80 µm	Between 100 & 140 µm	Between 160 & 230 µm
Diamong height (µm)	≈ 45 µm	≈ 80 µm	≈ 80 µm
Density (on 9 mm^2)	530	95	84

Table.1: WLI analysis on 9mm² of the three different dressers allowing to characterize their aggressiveness (height/ length/ density).

III. EXPERIMENTAL CONDITIONS

In this work, all tests were performed with 300 mm wafers, on AMAT Reflexion LK tool. The slurry used is a standard commercial slurry, which has a selectivity close to one between blanket oxide and blanket tungsten wafers.

Same initial conditioning was used for all tests with DI water (DIW) with a fixed downforce. All blanket wafers were processed with standard process to evaluate MRR on TEOS oxide and W materials.

Oxide thickness measurements were performed using a thirty-seven points recipe on ellipsometer and tungsten thickness was calculated from thirty-seven points sheet resistance measurement.

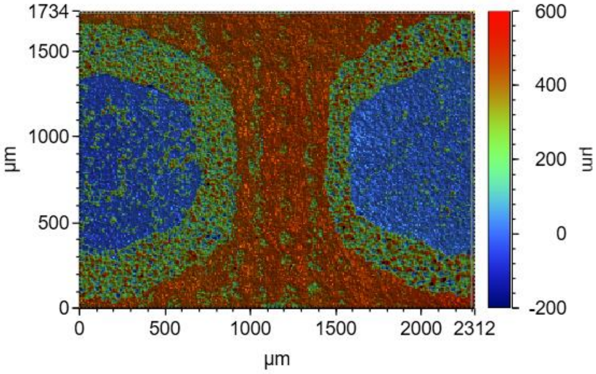


Fig.2: WL Interferometry picture of a 3D Printed pad view allowing to characterize atypical design and micro-structure.

All pads surfaces were characterized with a Bruker White Light Interferometry profiler by sampling seven points along the entire radius every two inches. This characterization technique allows us to extract a picture of a dedicated pad area shown on Fig. 2. We can extract from it several parameters: grooves depth, PCR, width, functional roughness parameters.

IV. RESULTS & DISCUSSION

a. Removal rate evolution

In order to evaluate MRR evolution during initial pad breaking, it was partitioned into five steps. After each step, blanket oxide wafers and blanket tungsten wafers were polished. The Fig.3 summarizes the evolution of both materials MRR at each step of the initial conditioning for the three tested dressers. The Fig 4. compares the associated Oxide/W selectivity.

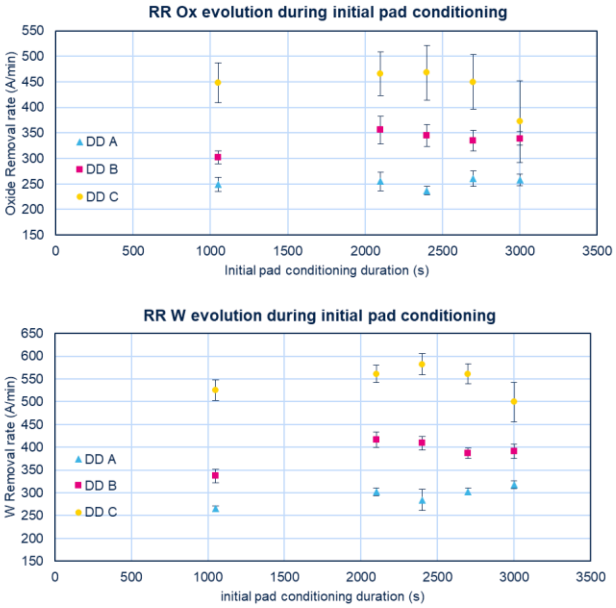


Fig.3: Evolution of oxide (top) and W (bottom) MRR during first conditioning step for three different conditioners.

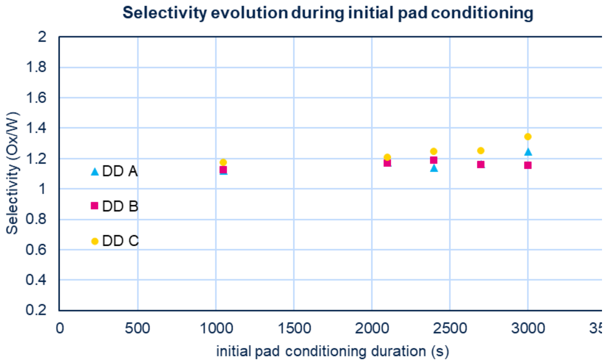


Fig.4: Evolution of oxide/W selectivity accordingly to MRR presented in Fig.3

The Fig 3. firstly highlights the direct effect of disk aggressivity on MRR: the more aggressive the DD is, the more the MRR increases for both materials while keeping a good selectivity close to 1.2. The process time can therefore be modulated by two only by choosing appropriate conditioner. The second information highlighted by both Fig 3. & Fig.4 is the MRR stability along pad breaking.

In conclusion, this study shows that oxide and tungsten polishing rates can be modulated by changing the conditioner disk while keeping a reasonably good and stable Oxide/Tungsten selectivity.

We can thus assume that the conditioner type has an impact on pad surface properties and controlling the pad texture trough disk is a key factor to enhance Oxide and W MRR.

White Light Interferometry is used to identify the pad main parameters that affect the removal rate. First, we focus on PCR by measuring groove depth. Fig. 5 compares the remaining groove depth for each dresser along pad radius.

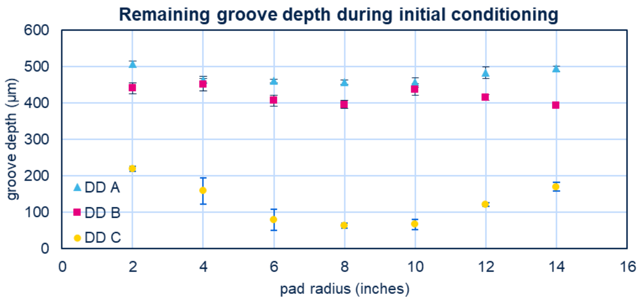


Fig.5: Groove depth measurement along pad radius for each dresser.

By comparing the results from dressers B & C, we can conclude that for a same diamond height (80 µm), the PCR becomes more important with the increase of the diamond size. The dressers A & B which have very different properties lead to almost equivalent PCR but different MRR. Thus, polishing rate is not only linked to groove depth and slurry volume inside, but also to diamond shape within the initial pad breaking.

To continue this study, we only focus on dressers A & B in order to highlight which pad surface property is directly correlated with MRR.

The contact area depending on different dressers is measured on WLI pictures. Fig 6.a) shows pad length used for analysis and Fig 6.b) compares the results obtained for each dresser along pad radius.

It can be noticed that for the same PCR, feature width from dresser A and B increase from 515 to 542µm which is coherent with a higher probability of contact surface area. Indeed, disk B leads to larger contact area and can have an impact on material RR.

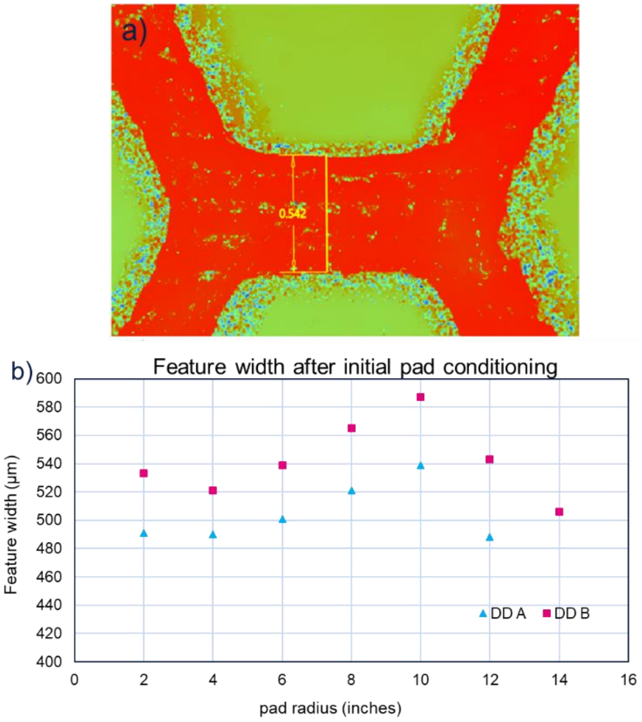


Fig.6: a) Feature pictures and b) Feature length measurement along pad radius for each dresser.

More precisely, roughness parameter (Sq, Spk, & Svk) were also studied to compare both disks as summarized in Table 2. We observe that Sq is twice higher for disk B compared to disk A. In the same time, pad roughness shows the same level of Spk while Svk is increasing for disk B compared to disk A.

In one hand, same asperity height (Spk) and more contact area for dresser B indicate that more contact point are available for mechanical removal of material, especially Oxide MRR.

On the other hand, higher valley depth (Svk) and more contact area denote more pores and volume available for chemical reaction to enhanced W MRR.

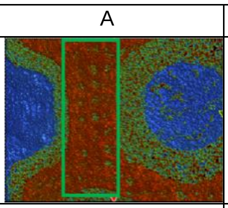
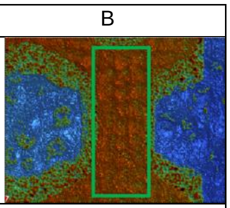
	A	B
WLI picture (done at 4 inches from the center)		
Sq (normalized)	1	1.8x
Spk (normalized)	1	1
Svk (normalized)	1	1.6x

Table.2: Summary of WLI analysis on roughness parameters obtained on pad with the two different diamond disks.

We can conclude that disk B, with larger and higher diamonds compared to disk A, allows higher contact area hence higher Oxide RR and leads to higher W RR due to more chemical retention.

V. <u>CONCLUSION</u>

In this work, we focused on the evolution of oxide and tungsten polishing rates during the pad initial conditioning (pad break-in). We have shown that dresser choice is key for process setup (MRR) and pad conditioning. We have used a smart methodology to understand the impact of dresser on the initial pad break-in by using WL interferometry to characterize dressers type impact on pad surface properties. Based on it, the results show that oxide and tungsten polishing rates can be modulated by changing the conditioner disk, depending on diamond size, while keeping a good selectivity for W buffing application. This MRR modulation on this new pad generation is mainly correlated with two major parameters: surface contact area and porosity. This result is interesting for W CMP process: without changing pad and slurry, we can tune MRR by choosing the optimal dresser to adjust process conditions, based on requirements needed for each technology-node.

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Topic Area: Consumables, equipment, and metrology

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