Polish Rate, Pad Surface Morphology and Pad Conditioning in Oxide Chemical Mechanical Polishing

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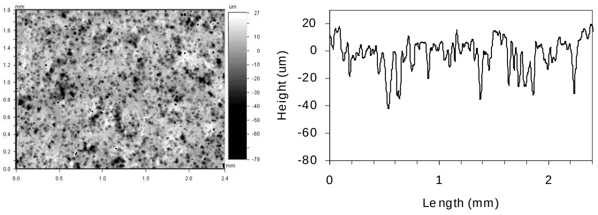
The stability of polish rate is a critical factor in the control of oxide chemical mechanical polishing processes. While it is generally accepted that polish rate stability, and even absolute polish rate, are highly coupled to pad conditioning, the mechanisms by which pad conditioning effects polish performance through modification of the pad surface state are poorly understood.

Pad conditioning is the act of removing or abrading a thin layer of the pad to refresh and maintain the polishing surface. In a state of the art process, conditioning is achieved through contact of the pad with a diamond abrasive disc. To enable advanced CMP processes, a more complete understanding of the relationships between pad conditioner design, conditioning process parameters, pad surface morphology and polish performance must be developed. The ability to manipulate pad conditioner surfaces by changing parameters such as diamond crystal size, diamond crystal morphology and crystal surface density has been utilized to generate a range of pad surfaces on a variety of pad platforms and in a range of different CMP applications. In addition, analytical techniques have been developed to quantify subtle variations in the pad surface morphology. The combination of these tools combined with an extensive database of polishing data, has enabled some significant insights into the mechanisms involved in the control and maintenance of polish rate through pad conditioning in oxide CMP.

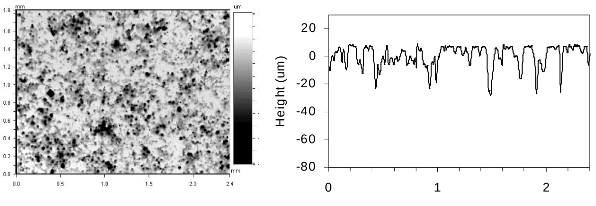
Successful design of a conditioning strategy for oxide CMP involves striking a balance between the influence of the conditioner and the wafer on the pad surface. Figure 1 illustrates 2.4 x 1.8 mm vertical scanning interferometry images of typical “conditioning dominated” and “wafer dominated” pad surfaces and representative line scans extracted from these image data. On the conditioning dominated surface, the pad has been subjected to a “break-in” process consisting of prolonged pad-conditioner contact without polishing wafers. The wafer-dominated surface is generated through prolonged wafer polishing in the absence of conditioning. As figure 1 illustrates, the effect of the pad-wafer contact is to deform pad surface asperities. Conversely, the effect of pad-conditioner contact is to restore and maintain a random distribution of surface asperities through the removal or modification of the damaged layer induced by pad-wafer contact. Polish rate stability can be realized by adjusting process conditions and/or conditioner surface design to modify the ability of the conditioner to correct the deformation caused by pad-wafer contact and thereby maintain a consistent pad surface.

When pad surface data of the type illustrated in figure 1 are represented in the form of a probability distribution as a function of pad height, characteristic features are observed. In most cases these distribution functions can be accurately modeled with 1 or 2 modified Gaussian or Pearson component peaks, from which a handful of characteristic fitting parameters can be extracted. This methodology allows for the quantification of both subtle and gross changes in pad surface statistics.

Numerous experimenters have demonstrated the phenomenon of an approximately logarithmic decay of polish rate in the absence of pad conditioning. In an analogous dynamic example, non-linear deviations from Prestonian polish behavior can be interpreted in the context of the competing effects of the pad-wafer and pad-conditioner contact. Figure 2 illustrates non-Prestonian polish rate behavior induced through insufficient conditioning. As the wafer down-pressure is increased, the wafer effect on the pad surface can begin to out-pace the conditioners ability to compensate, resulting in a depressed polish rate. The data in figure 2 show significant deviation from Prestonian polish behavior as conditioner aggressiveness is reduced. As the wafer down force, and hence the glazing effect of the pad-wafer interaction, is increased the deviations from ideal behavior become more significant. Evaluation of the pad height probability distribution functions associated with these various process conditions yields significant insight into the surface morphological mechanisms through which conditioning acts to effect polish performance. Additional data will further illustrate how this behavior can be modified and controlled with conditioner and process design. A review of the current and historical understanding of pad conditioning, as well as additional process examples and a general model for both *in situ* and *ex situ* conditioning will be presented.



Conditioning Dominated



Wafer Dominated

Figure 1 – Pad surface data illustrating pad surfaces dominated by pad-conditioner and pad-wafer contact.

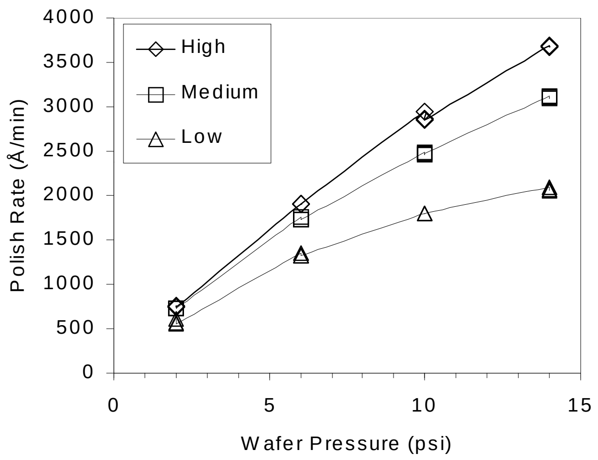


Figure 2 – Polish rate data illustrating deviations from Prestonian polish behavior. Three different conditioners

with varying relative levels of aggressiveness (high, medium and low) were used.