Integrated Model for the Chemical-Mechanical Polishing Based on A Comprehensive Material Removal Model

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ABSTRACT: The architecture of an integrated model for chemical mechanical polishing is proposed in this report. For details on the report, the readers are referred to J. Luo, D. Dornfeld, Z. Mao et. al. ' Integrated model for the chemical-mechanical polishing based on a comprehensive material removal model,' Six International VMIC conference, March, 2001.

I. INTRODUCTION

The chemical-mechanical polishing (CMP) is a quite complicated process. The understanding of the different roles played by the input values and their interactions, is critical for the optimizations of cost, material removal rate, non-uniformity, micro-scratches and the control/design of CMP. Although various models have been developed to explain the fundamental mechanism of CMP from the different viewpoints of slurry flow, slurry abrasive abrasion and chemical etching, there are still needs to explain the roles and complicated interactions between the input values in a comprehensive way. Recently, a material removal model to describe these interactions, which are quite different from those in conventional polishing or lapping processes due to the small pad hardness and different size scales of the pad asperity and the polishing abrasives, has been developed by Luo and Dornfeld ([1]-[2]). There are several motivations to extend the material removal model into a more comprehensive, or namely, integrated CMP model. **First, the current material removal model can only explain material removal process in solid-solid contact mode. An extension is needed to cover material removal process in other contact modes. Secondly, in the current model the synergy effect of the chemical and mechanical elements in the contact interface of abrasive particle and wafer surface is simply represented by a 'dynamical' hardness value H_w of wafer surface [1]. Understanding the basic electrochemical mechanism is needed to clarify what input values and how they influence this fitting parameter**. **Thirdly, other important output values such as the non-uniformity (NU), surface scratch, dishing and etching, which is related to the material removal mechanism as well as other parameter such as the pressure distribution, can be addressed in a more comprehensive model with the material removal mechanism clarified [9].** Integrating all the above parts into one model is not a simple task to be completed in short time. A framework describing the basic architecture of the integrated model will be a useful first step. In this report, we propose a framework for an integrated model. It is composed of layers of sub-models. Showing what, how and where these sub-models come into the integrated model, it can help clarify the most important features of the integrated modeling and simplify the modeling process.

II. ARCHITECTURE OF THE INTEGRATED MODEL

Based on the discussion in the introduction, the basic framework of the integrated model can be as in Fig. 1. There are basically five layers of sub-models in the integrated model. In the first layer of sub-models are simply the output values including the material removal rate, non-uniformity, dishing, etching and scratching. The formulation of material removal rate on each single location behaves as the inputs for the non-uniformity, etching and dishing. Following them is the second layer of sub-models including the material removal model and the pressure & velocity distribution modeling and pattern density characterization. Non-uniformity, etching, dishing and scratching are functions of the distribution of pressure times velocity as well as the material removal mechanism. The numerical methods including finite element method (FEM), boundary element method (BEM) and computational fluid dynamics (CFD) and dynamical analysis may be used to model the pressure and velocity distribution in the second layer [7]. The lowest layer of the input values representing the bulky material and geometry features of the pad, slurry and wafer, behaves as the input values for the pressure distribution model and the analysis of the velocity distribution. The material removal models are the core part of the integrated model. It can be separated into two sub-models in the third layer, one based on the solid-solid contact mode, which has almost been done in the comprehensive material removal model by Luo and Dornfeld [1], and the other based on the non-directly contact mode. The material removal mechanisms are quite different for these two contact modes, which influences significantly the roles played by the sub-models in the lower layers, such as chemical, fluid and abrasion models. The abrasion in the solid-solid contact mode is principally two-body abrasion and the material removal by three-body abrasions is negligible. Chemicals in this mode influence the material removal principally through their enhancing effects on the two-body abrasion. Their direct contribution on material removal, or namely, etching, are not apparent in comparison with the mechanical removal, except when the mechanical removal is small in situations of small abrasive concentration [4]. In the non-directly contact mode, the abrasion is principally three-body abrasion. The material removed due to the three-body abrasion is a function of the shear stress introduced by the fluid flow. (The shear stress and the fluid film thickness change with the slurry viscosity and velocity [8].) Chemical enhances the three-body abrasions by reducing the surface energy of the work. However, the etching of work and the following mass transport cannot be neglected. In summary, the solid-solid contact region can be considered as a mechanical dominant region where the chemical removal is negligible in comparison with the two-body abrasion. The non-directly contact region can be considered as a chemical dominant region where the chemical removal is significant in comparison with the mechanical removal. Realization and clarification of these differences help to apply correct strategy in the modeling process.

In the default fifth layer are the input values including the slurry abrasive geometry, pad topography and so on. Two important issues exist with this layer. First it is needed to identify in this layer the most important features of consumables including pad, slurry abrasive and slurry chemicals. What features are important is determined by the two different contact modes. Features playing important roles in solid-solid contact mode may be negligible in the non-directly contact mode. Second issue is on how to model these features. Some of them can be based on physical evidence. For example, SEM pictures of slurry abrasives can be used to model the geometry of the abrasive [1]. The dynamical light scatting can be used to measure the distribution of the abrasive size. Other may be based on previous theoretical models.

II. 1. ARCHITECTURE OF THE COMPREHENSIVE MATERIAL REMOVAL MODEL BASED ON SOLID-SOLID CONTACT MODE

The portion in the dashed line box in Fig. 1 epresents the developed comprehensive material removal model for solid-solid contact mode. The detailed framework of the model is shown in Fig. 2 An important feature of the model is that the material removal can be separated into two parts, one the material removed by a single abrasive, and the other the number of active abrasives. Two sub-models evaluating these two parts comprise of the highest layer in Fig. 2 The product of the active abrasive number and the volume removed by a single active abrasive is equal to the total material removal at the wafer surface.

II. 2. ARCHITECTURE OF THE MATERIAL REMOVAL MODEL BASED ON NON-DIRECT CONTACT MODE

Up to now, there is no comprehensive material removal model developed for the non-direct contact mode. Based on the literature, the framework of the material removal in the non-direct contact mode can be proposed as in Fig. 3.

III. CONCLUSION

In this report, architecture of an integrated CMP model is proposed. Basically, the integrated model is composed of layers of sub-models, explaining the material removal mechanism. Showing what, how and where the sub-models come into the integrated model, it helps to clarify the most important features of the integrated modeling and simplify the modeling process.

IV. REFERENCES

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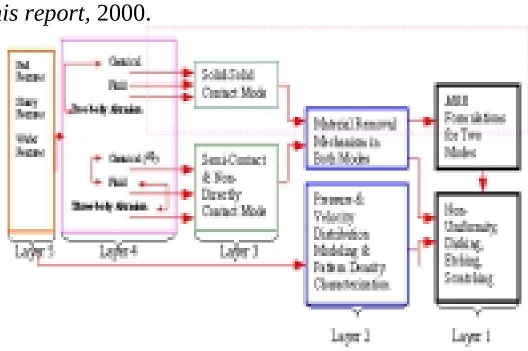

Figure 1 Basic framework of the integrated model

Figure 2. Framework of the comprehensive material for solid solid contact mode

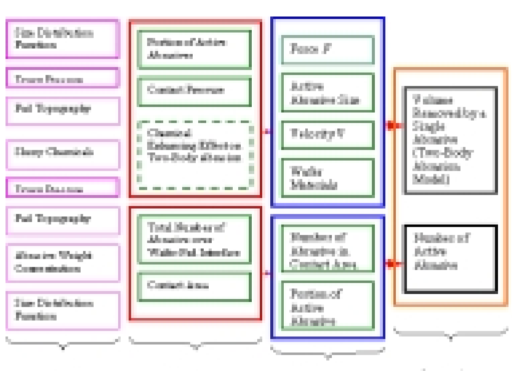

Figure 3. Framework of the comprehensive material removal model in solid-solid contact mode