ABSTRACT

Modifications to the Dual Emission Laser Induced Fluorescence (DELIF) procedure used to collect images of the slurry layer between the polishing pad and wafer during Chemical Mechanical Planarization (CMP) have provided a means to attain instantaneous, high spatial resolution images of slurry film thickness. Presented here is a technique to determine the calibration factor that correlates image intensity to slurry film thickness. This presentation will discuss how to determine slurry layer shape near wafer features, pad roughness, and pad compressibility.

1. INTRODUCTION

The majority of the experimental research done to determine what is happening to the wafer, pad and slurry during CMP involves polishing, then examining the wafer or pad ex-situ. To gain a deeper understanding of the pad-slurry-wafer interactions, many research groups have focused their efforts on simulations and modeling CMP tribology [1, 2]. Modeling CMP has proven to be extraordinarily difficult due to the plethora of variables involved in the process. Experimental verification of the models often involves ex-situ [1, 2] observations or indirect observations in-situ [3]. Experimentalists have had difficulty verifying the results produced by the modeling because it is difficult to “see” exactly what is happening under the wafer during polishing. Over the past decade, Tufts University has explored the polishing mechanism in CMP in-situ using both modeling [4] and experimentation [5] using the DELIF technique. Recently, the DELIF setup has been modified such that we can attain instantaneous images of the slurry layer thickness at high spatial and temporal resolution during polishing. It is now possible to make measurements at pad asperity scale resolution.

2. Experimental Setup

Experiments are performed on a laboratory scale Struers RotoPol-31 table top polisher, which is similar to the industrial polisher, SpeedFam-IPEC 472. A 3 inch diameter optically transparent glass wafer is used during polishing in place of a silicon wafer and wafer carrier. Images are acquired using 4 different
wafers: a flat wafer, a wafer with 27 µm deep wells, a wafer with 14.5 µm deep wells, and a wafer with 5 µm deep wells. The slurry is diluted 10X to minimize polishing and maintain constant wafer topography over the course of an experiment. The polishing pads used were Fruedenberg FX9 pads.

3. Dual Emission Laser Induced Fluorescence

A complete discussion of how DELIF is used to measure fluid film thickness can be found elsewhere [6]. This section will briefly explain the procedure specific to this experiment. First a Nd/YAG laser emits a pulse at 355 nm. That energy is absorbed by the polishing pad material and re-emitted with an emission peak at 392 nm. The slurry is mixed with Calcein dye. The Calcein re-emits the light with a spectral peak at 530 nm. The emitted light passes through a zoom lens to a dichroic beam splitter, which reflects wavelengths shorter than 496 nm and transmits longer wavelengths. The reflected and transmitted light passes through some additional filters and is collected by 2 cameras, A and B. The filter regions for the cameras are indicated in figure 2. The images are affected equally by non-uniformities in the excitation source and therefore taking the ratio of B/A corrects the overall intensity data from the 2 cameras. All data processing discussed is done on these B/A images.

4. Image Analysis

The two wafers with the square wells of known depth can be used to determine the calibration factor, X. Since the polishing pad rebounds a certain unknown distance into each wells, it is not possible to simply say that the average intensity under a well is equal to the height of the well. However, the difference in intensities between the 14.5 µm and the 27 µm deep wells is roughly equal to the difference in step heights, 12.5 µm. X is calculated in equation 1:

\[
X = \frac{27 - 14.5}{I_{27} - I_{14.5}}.
\]

where \( I \) is the pixel intensity. This calibration is based on the assumption that the asperities can expand to their full height inside the wells and are not in contact with the bottoms of the wells.

Figure 1 shows the amount of asperity compression relative to wafer step height. In the case of the 14.5 µm and 5 µm deep wells, some of the compression factors calculated were negative. There were quite a few more negative values of compression in the 5 µm case than the 14.5 µm case. It is unlikely that the asperities are expanding when they travel from inside to outside the wells, so these negative values of the compression factor most likely mean that there is close to zero expansion under the wells for those images. The dashed lines on this graph indicate the height of the wells in the wafer. In the 14.5 µm and 27 µm case, there is a significant separation between the average slurry thickness line (solid) and the line wafer height (3-4 µm). This difference can be thought of as the asperity expansion distance. In the 5 µm case, the slurry film thickness line is within error of the wafer height line, also supporting the idea that there is minimal asperity expansion in these shorter wells. The asperities may actually be in contact with the tops of the 5 µm wells.

REFERENCES