Endpoint Detection in CMP Utilizing Thermal Imaging

Rick Anundson
Microelectronic Engineering
Rochester Institute of Technology
Rochester, NY 14623

Abstract -- The objective of this project was to develop a method for using thermal imaging to determine end-point in chemical mechanical polishing (C.M.P.) for a shallow trench isolation (S.T.I.) C.M.P. process and contact layer C.M.P. process. A two-dimensional thermal imaging camera was used to measure the pad temperature during processing. The pad temperature is an indication of the friction between the pad and the wafer being processed. As the polishing process transitions from one layer of material to the next layer of material the amount of heat generated will change. For the STI layer a 0.3 to 0.4 degree Fahrenheit (F) shift was found in the transition from LTO to Nitride and a 1.1 degree shift was found going from Nitride to Silicon substrate. The Contact layer results were inconclusive because seven of the eight experimental wafers could not be polished. The top layer of Tantalum film could only be polished on one out of eight wafers.

I INTRODUCTION

Endpoint detection in CMP is very desirable because it would reduce rework time and would create a more repeatable process. Current methods of polishing without endpoint detection require removing the wafer from the polishing pad, making an optical measurement for thickness and then placing the wafer back in the polishing tool. This procedure is time consuming and reduces the throughput of the tools. The endpoint detection could reduce the dishing affects associated with over-polishing and thus enhance device performance.

Endpoint detection in CMP has been attempted using several different methods. The methods include measuring the motor current, capacitence and optical sensors. Using pad temperature is a more recent inovation. Thermal imaging provides an in-situ endpoint detection method.

II EXPERIMENT

Two different groups of wafers (Group A and Group B) were developed for each of the processes. Group A was blanket layer of film on top of another blanket layer of film. This group was developed to determine if any temperature difference existed between the films. It was presumed that if a temperature difference could not be measured with the blanket film wafers, then a temperature difference with patterned wafers would be impossible to detect. The Group B was blanket layer on top of a patterned layer. This group was intended to simulate device topography wafers.

The S.T.I. process used a L.P.C.V.D. nitride film (~2600 Å) as the bottom layer polish stop. For the Group B wafers, a rectangular S.T.I pattern mask was used to pattern the nitride. A reactive ion enhanced etch process was used to pattern the nitride film. The nitride was then covered with a low temperature oxide L.P.C.V.D. film (~5000 Å). Figure 1 shows a general description of the S.T.I. processing. The wafers were then polished to detect an endpoint at the nitride layer. Figure 1 gives a cross-sectional representation of Group A and B for the S.T.I. layer.

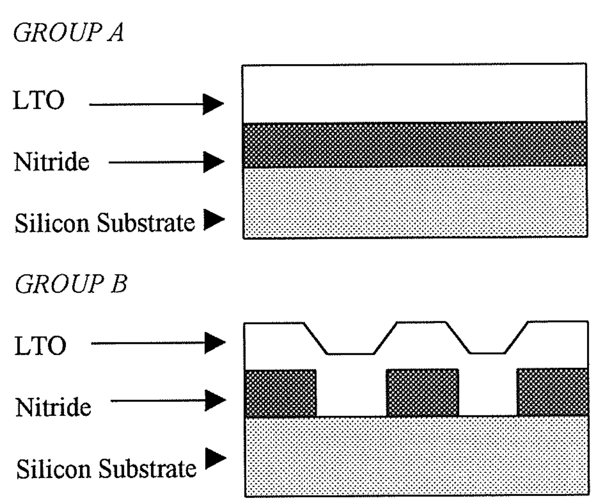


FIGURE 1: S.T.I. Layer Cross-Sections

The contact layer process used a low temperature oxide (L.T.O.) L.P.C.V.D. film (~5000 Å) as the inter-level dielectric layer. A contact hole mask was used to pattern the Group B wafers. A reactive ion enhanced etch process was used to pattern the L.T.O. film. A thin layer of Titanium Nitride (TiN) was deposited as the second layer (~2500 Å), and a third layer of Tantalum (Ta) was deposited on the wafers (~5000 Å). The Ta layer was used as a Tungsten layer is used in normal contact processing because the Tungsten film was not available. Figure 2 gives a cross-sectional representation of Groups A and B for the contact layer.

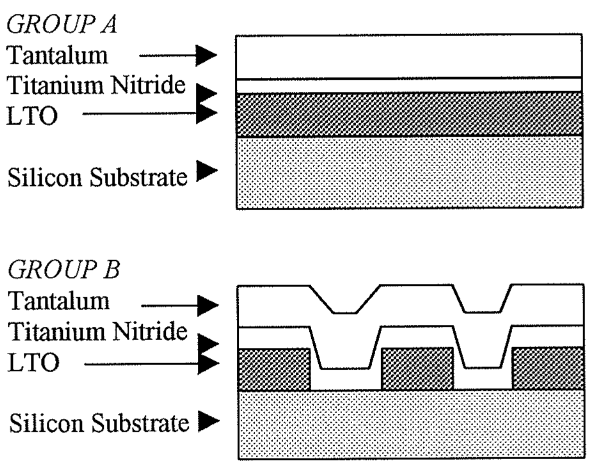


FIGURE 2: Contact Layer Cross-sections

The equipment used for the experiment was a Leco AP-600 Automatic Polisher (14") with a Rodel Inc. SUBA 500 pad. Wacker Colloidal Silica K1012 was used for the S.T.I. layer and Ultra-Sol Colloidal Alumina-Ferric Nitrate was used for the contact layer. The thermal imaging was done using an Agema Infared Systems, Thermovision 880. The thermal imaging system provided a two-dimensional image of the pad as seen in Figure 3. For the experiment a single point near the spindle was selected for data collection.

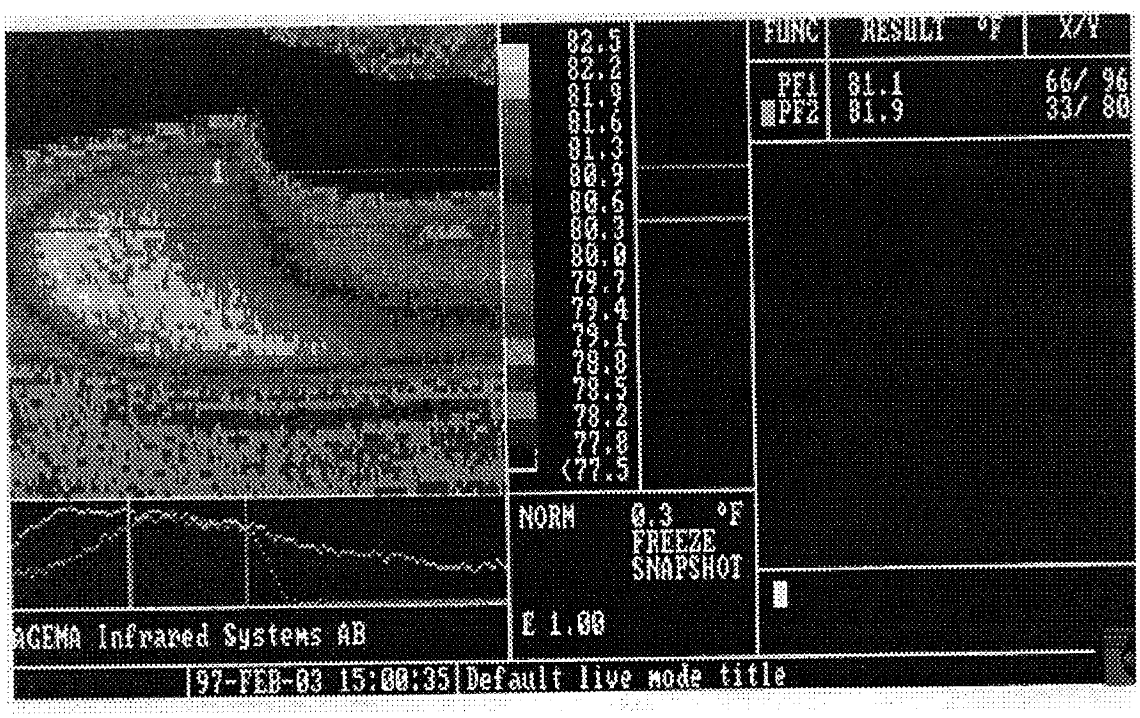
III RESULTS AND DISCUSSION

The S.T.I layer produced a noticeable temperature shift from one layer to the next. Due to the uneven film thickness and polish process the temperature shift was gradual. Since the layer transition was uneven, endpoints were defined as when 50% of the wafer was showing the next layer. A 0.3 to 0.4 degree F temperature increase was found for the transition from LTO to 50% Nitride. A 1.1 degree F temperature increase was found for the transition from Nitride to the silicon substrate. Figure 4 is a summary table of the S.T.I. results.

FIGURE 4: S.T.I. Layer Summary Table

	Average Spot Temperature (F)		
	LTO (100%)	*Nitride (~50%)*	*Silicon (~50%*
STI NO Pattern	77.03	77.45	No Data
STI Pattern	79.1	79.4	80.53

FIGURE 3: Thermovision 880 Output



The contact layer experiment produced poor results. For an unknown reason the Tantalum layer did not polish away except for one wafer. During the Tantalum deposition some abnormal processing occurred, but it is unknown if this actually had any affect on the Tantalum film. During the first attempted deposition the current and voltage dropped to zero at some point in the process. A second Tantalum deposition was then done and it processed normally. The one wafer that did polish did not provide conclusive results.

One set of data that did come out of the Tantalum was that pad temperature increased over an extended period of time. Figure 5 shows a graph of temperature over a thirty minute time period. The data was collected with intermittent (about every two to five minutes) stoppages to view the wafer surface. The graph indicates a linear increase in temperature over time for the Tantalum polish.

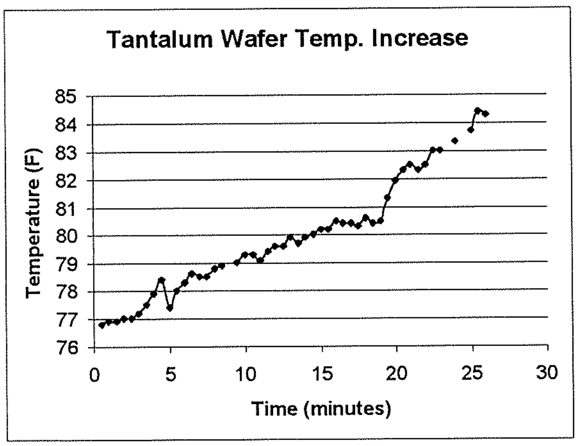


FIGURE 5: Tantalum Polish Temperature Rate of Increase

IV CONCLUSIONS

Pad temperature is a viable method of determining endpoint in the CMP process. Small temperature shifts of 0.3 to 0.4 degrees F were found for the STI layer at the LTO to Nitride interface. A 1.1 degree shift was found for the transition from Nitride to Silicon Substrate. Clearer endpoints would have been detected if the films and polish process were more uniform. The contact layer portion of the experiment did not produce any conclusive results. This was because the Tantalum film was only able to be polished on one out of the eight wafers.

AKNOWLEDGEMENTS

I would like to thank Dr. Richard Lane for his guidance in this project work. I would also like to thank Brian Martinick for his help in preparing the Leco Automatic Polisher.

REFERENCES

[1] Litvak, Herbert E. Tzeng, Huey-Ming. "Implementing Real-time Endpoint Control in CMP," *Semiconductor International*, July 1996, page 259-264.

VMIC-CMP International 3rd Annual Conference Proceedings. Santa Clara, CA. Feb. 19 and 20, 1998.

[2] Chen, L., et. al. *Pad Thermal Image Endpointing for CMP Process.* Page 28-35.

[3] Lin, C., Peng, S. *Pad Temperature As An Endpoint Detection Method in WCMP Process.* Page 52-56.

[4] Merkel, P., Myers, T. *Endpoint Process Development For Low Volume High Reliability Tungsten CMP.* Page 59-62.

BIOGRAPHY

Rick Anundson, born in Kane, PA on May 13, 1975, received his B.S. in Microelectronics from Rochester Institute of Technology in 1998. During his studies at R.I.T. he co-op'ed with Harris Semiconductor in Melbourne, FL, and twice with Intel Corporation in Rio Rancho, NM. He is currently working for Advanced Micro Devices in Austin, TX, for their Diffusion Process Engineering department. Rick enjoys quiet evenings by the fireplace, candlelight dinners, and long walks on the beach.