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## ABSTRACT

### Signal shape study from process control by interferometry for STI CMP

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**Presentation** (oral and/or poster): **oral**

#### TOPIC:

Please select one or more fitting topic(s) for your contribution from the list. (1=first, 2=second etc. choice)

##### Process Level APC

- ☐ Plasma etch, CVD and ALD
- ☐ Sputtering, P3I, and e--beam
- ☐ Lithography
- ☐ Thermal, wet processing & CMP
- ☐ Backend

##### 1: Metrology and R2R

- ☐ APC for legacy tools

##### Fab Level APC

##### 2: Fab level process control methods

- ☐ Virtual metrology
- ☐ Yield management
- ☐ Factory data analysis
- ☐ IT infrastructure

##### Manufacturing Effectiveness and Productivity

- ☐ Unit process & equipment productivity
- ☐ Factory productivity and automation
- ☐ Factory modeling, simulation and optimization
- ☐ Cost optimization and end-of-life equipment issues
- ☐ Environment and Green Manufacturing

### Motivation

The Chemical-Mechanical Polishing technique applied to the Shallow Trench Isolation process is a critical step (refer to as STI CMP hereafter) in the semiconductor manufacturing. STI CMP consists of polishing the silicon dioxide (SiO<sub>2</sub>) upper the active areas with the high accuracy of STI thickness target (Fig. 1). A reliable control of the polishing time in relation to the polished material thickness shall be rigorously respected. Ineffective polishing action may lead to non-uniformity on the wafer surface and the unwanted “dishing” situation, which result in surface non-planirarity at transistor scale.

In this study, we focus on the interferometry endpoint detection for the STI CMP process (Fig. 2). The removed thickness is correlated to the laser intensity measured over time. In theory, the signal reflected from an oxide on silicon stack produces a perfect sinusoid. In the STI CMP process, the signal is deteriorated in terms of two factors: the polishing movements and the wafer patterns. In certain cases, these unwanted effects are stronger than the periodical signal of the SiO<sub>2</sub> layer, preventing the reliability of the endpoint algorithm (Fig. 3).

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**ABSTRACT**

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**Description**

Two designs of experiments (DOEs) have been performed to study the signal shape correlated with the wafer pattern the polishing recipe parameters, respectively. For each DOE, 25 wafers are available and three factors are tested at three levels. Given the fixed number of experiments, the D-Optimal scheme is employed to create the design matrix. In order to trace a signal long enough to configure the potential algorithm, wafers were polished with a fixed duration, including the over-polishing time. The interferometric signal responses are defined as the peak-to-peak signal amplitude, the periodical noise amplitude, and the signal level intensity. To analyze the influence of input factors over the responses, the ANalysis Of Variance (ANOVA) is performed. Repeatability and reproducibility are tested on the combination of input factors with the better signal-to-noise ratio response.

**Innovation**

The DOE with D-Optimality adopted in this research is an essential method that enables exploring the response surface in a very limited number of experiments. Particularly, in a high-mix manufacturing environment, it is very critical to optimize the effectiveness of the DOE model while economizing the production resource usage, such as wafer cost, equipment capacity, and human efforts.

This method also allows highlighting the relationship between the STI CMP environment and the shape of the detected signal. Moreover, by extrapolating the values obtained in the study domain, it is possible to find an optimal combination of input factors for which the signal to noise ratio is improved significantly. Finally, this study demonstrates the potential to implement the interferometry process control scheme on the technologies of which the signal is not exploitable under the current production conditions.

**Results**

In summary, we employed the DOE technique by varying the polishing recipe settings, in which the factor adjustments are easier to industrialize given the controllable domain remains in a realistic process window. The experiments are done under the technology with a bad signal-to-noise ratio. The results showed that no matter how the input combinations are manipulated, the signal-to-noise ratio is not improved (Fig. 4). However, the correlations with a high confidence level demonstrated that the interaction of the head and platen velocity mismatch directly affects the periodic noise frequency. The most influential parameters on the removal rate are the polishing head pressure and the platen speed, which gives a precise model of the removal rate according, conforming with the nature of the studied technology.

The second objective of the research is to study the technology design impact on the signal shape (Fig. 5). Optimal factor settings with an exploitable signal-to-noise ratio for endpoint detection can be obtained from the experimental results. The developed detection algorithm was validated over the three wafers with the selected input factor configuration.

## ABSTRACT

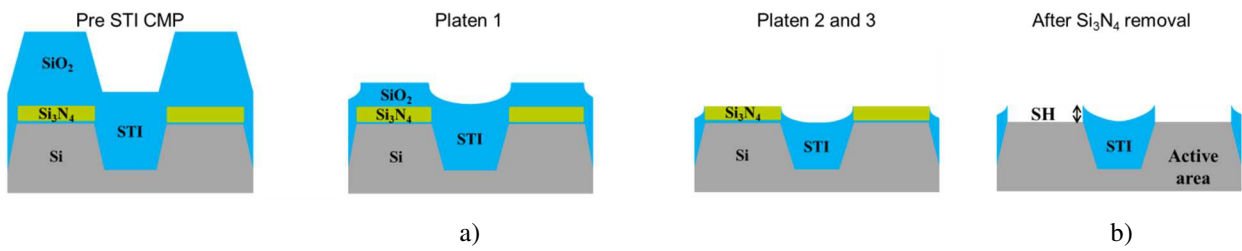


Fig. 1: Schematic representations of cross-sectional views of the materials stack at the CMP STI step for a) and the stack after the Si<sub>3</sub>N<sub>4</sub> removal and the SH between the Si and the SiO<sub>2</sub> STI for b).

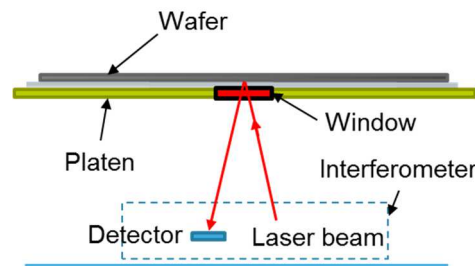


Fig. 2: Side view of the optical system assembly under the polishing platen

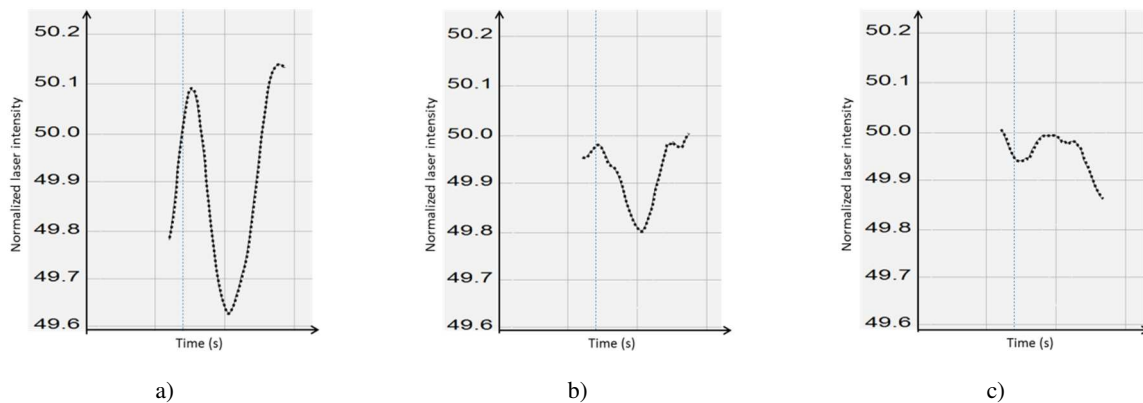


Fig. 3: The graphs show filtered products' signals collected from the optical system by interferometry. Each curve represents the signal intensity during the polishing process of platen 1. The a) has the smallest memory size, b) an intermediate size and c) the largest memory size. For a), the signal is correct for developing the detection algorithm in contrast to b) and c) which have poor endpoint detection.

## ABSTRACT

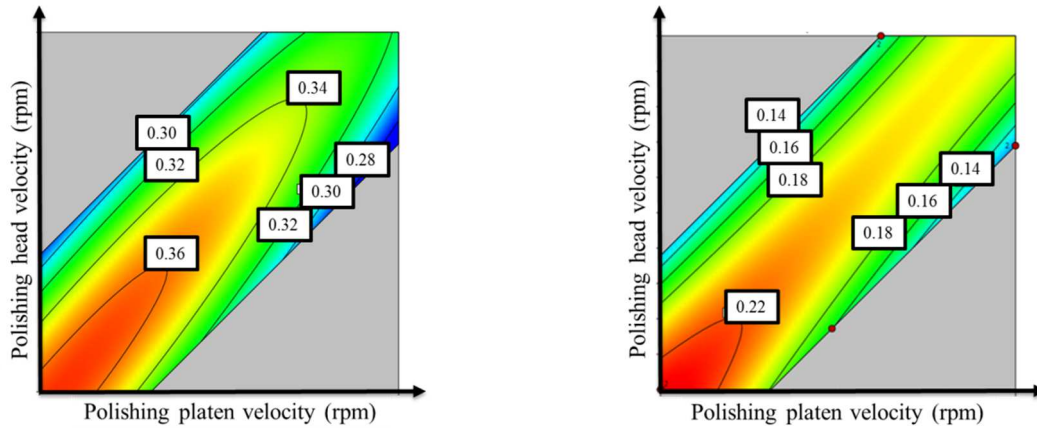


Fig. 4: This figure concerns the DOE of the polishing recipe factors influence on the interferometric signal. The two 2D contour plots of the periodic noise amplitude response a) and the signal amplitude b) plotted against combinations of polishing platen velocity and the polishing head velocity. For low platen and head speeds, the signal amplitude is improved. However, the noise amplitude has the same tendency as the signal amplitude, the signal-to-noise ratio is therefore not better.

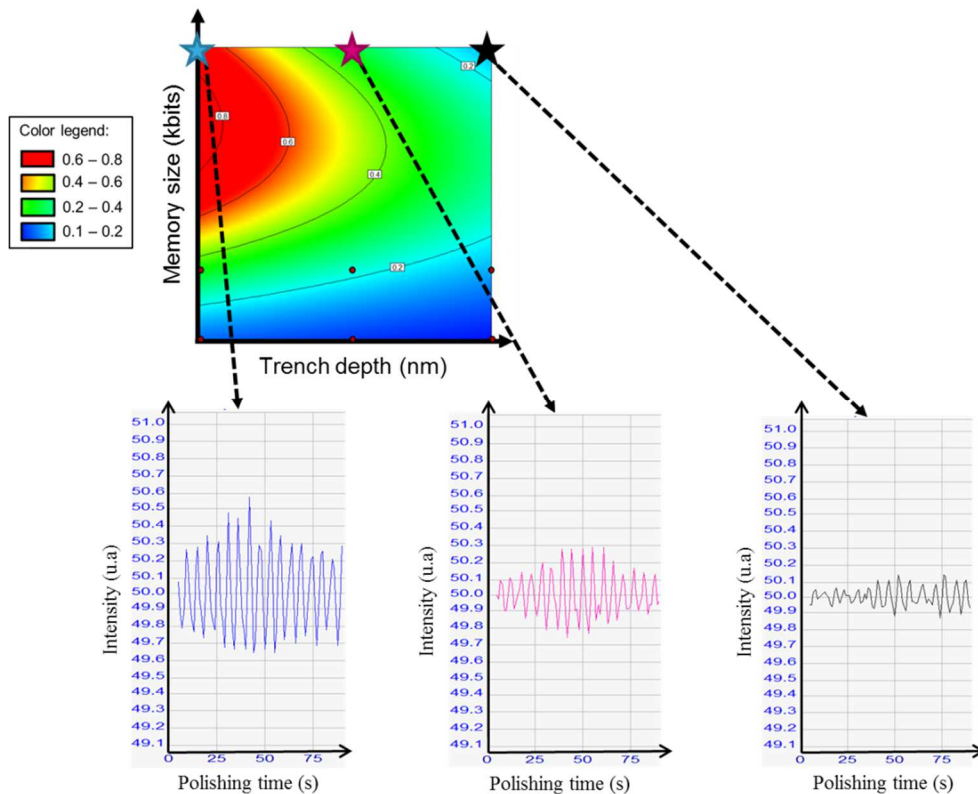


Fig. 5: This figure concerns the DOE of the product factors influence on the interferometric signal. Top left, the 2D contour plot of the periodic noise response plotted against combinations of the STI trench depth and memory size factors. For instance, 3 collected signals of the reflected intensity as a function of the polishing time illustrate that the higher the trench depth, the lower the periodic noise amplitude.