Compensation of Process Drifts using a Run-to-Run Thickness Controller vs. Open-Loop Algorithm on Metal Sputter Systems.

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Primary Area of Interest:

Process Control and Productivity Improvements

INTRODUCTION

Metal sputter deposition processes are characterized by a decrease in deposition rate from lot to lot as the sputter target life degrades. This paper is to present lessons learned from the implementation of a run-to-run thickness controller that compensates for low as well as high drifts in deposition rate.

The controller performance has been measured against the common method of open-loop compensation which is typically employed internally to the sputter tool itself.

PROCESS CHARACTERIZATION

The decrease and inconsistencies in deposition rate are driven by various reasons:

- Material that builds up on chamber shields
- Target erosion uniformity
- Supplied power
- Variations in gas flow, pressure

OPEN-LOOP COMPENSATION

The internal control method assumes that the magnitude of the drift is constant over a sputter target life. From experimental data a fix formula (linear, polynomial) is set up to compensate for the drop in deposition rate by adding additional deposition time or power to the recipe as the target life increases.

APC ALGORITHM

As we will show, metal sputter deposition can greatly benefit from an Run-to-Run controller.

(1) Low drift processes (e.g. Cobalt and Nickel)

Thickness model updates are performed through periodical monitor wafer measurements. The controller itself utilizes simple EWMA rules to update controller states.

(2) Process with high drift (e.g. Copper)

The EWMA algorithm does a good job for small drifts. For larger drifts, as is the case for the copper process, the error between calculated deposition rate and the real deposition rate increases. However, if combined with open-loop compensation, quality could be improved.

A second and new algorithm utilizes two methods to update controller states. After collecting initial data, the APC application switches from EWMA to a more complex predictor algorithm. The predictor algorithm uses a linear regression and estimates the deposition rate for the next lot and adjusts deposition time accordingly. This method allows removing the lag that comes with the EWMA algorithm. Overall performance is equal or even better if measured against the open-loop / EWMA system.

Model updates are performed through monitors and periodical product wafer measurements.

RESULTS AND CONCLUSION

(1) Quality and productivity

All methods have shown a very mature performance. Quality has often dramatically improved by a better Cpk, excellent centering of the thickness control chart and less out of control situations.

The main point of productivity improvement are time saving, equipment availability and reduced test wafer cost.

(2) Flexibility and easiness

Open-loop compensation is limited to simple one-step processes. Individual sputter target and equipment behavior is not considered and the interaction between open-loop and EWMA algorithm is not quite understood (one controls the other?). Also, transparency to manufacturing personal is usually poor (What was the real deposition time?).

Two step and above sputter deposition processes along with re-sputter techniques is nowadays a manufacturing practice which is required for sub-90nm products. As the limit for open-loop compensation is exceeded, we are at the point where an APC application proves it worth.

Current work focuses on implementing a run-to-run thickness controller for two step sputter processes at our manufacturing site.

References

[1] Moyne, J.; del Castillo , E.; Hurwitz, A.M.; *Run to Run Control in Semiconductor Manufacturing*; CRC Press (2001)

[2] Smith, T.H.; Boning, D.S.; Stefani, J.; W. Butler, S. *Run by Run Advanced Process Control of Metal Sputter Deposition*; IEEE Transaction on Semiconductor Manufacturing, Vol.11, No.2, May. 1998.