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Online Deployment of Robust Metrology Prediction Model

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Metrology prediction based on equipment sensor data, i.e. virtual meteorology, is generally regarded as a methodology to improve efficiency of metrology instrument usage. In addition, a robust model with solid physical understanding can be used as a benchmark to monitor the health-of-equipment and capture anomalies at an early stage. This ability helps preventing the catastrophic malfunction of process equipment, which malfunction can result in long downtimes and even massive yield loss. In this paper, we demonstrate an online deployment of a robust prediction model for silicon carbide (SiC), capping layer thickness in a dual damascene copper process in a 65 nm mass production line.

Yield-Aware™ Fault Detection & Classification (YieldAware™-FDC) centric data infrastructure[1)] was used to collect the sensor data from SiC Chemical Vapor Deposition (CVD) equipment to build the initial model. The collected time series sensor data were converted into statistical summarization sectioned by process steps, i.e. indicators. Optical metrology was used to measure actual SiC thickness data for the learning data set. The indicators and the measured thickness were aligned by wafer identification and run through the multivariate model algorithm to indentify key indicators. For SiC thin film thickness, indicators from the plasma power and process pressures were identified. These findings make sense considering that, in our experience with processes and equipment, plasma power and process pressure are the direct variables of SiC deposition rate. The prediction model based on the key indicators was deployed to the online prediction executor to predict SiC thickness in real time as wafers were processed in the CVD equipment. This prediction model has been deployed and used online for more than one year at the time of the writing of this paper.

Figure 1 shows a comparison of measured SiC thickness and that which was predicted by the online executor combining multiple via layers of the same process recipe. The correlation coefficient between measured and predicted was > 0.9. Thus, the deployed online model is capable of predicting the optically measured SiC thickness with a small error. Fig.2 demonstrates virtual metrology for SiC thickness using the online model for the series of wafers processed at the same via layer formation step. In this example, only 4 wafers out of 25 wafers in each lot were optically measured and the SiC thickness for remaining wafers was estimated from the key indicators. The predicted value tracks equipment variability as well as wafer variability. Therefore, the predicted thickness can be used as an alternative SiC thickness measure. The number of wafers that are routed to metrology instrument can be reduced further to improve its usage efficiency. The online model captures the health-of-equipment as well as thickness variability. When the gap between measured and predicted value becomes larger than normally observed, either the process equipment or metrology instrument is suspected to have anomalies, and a root cause drill down report is triggered. In Fig.3, the predicted value tracked the measured value closely for most of the month-long period, however, the gap became significant at the end. The prediction from the indicators remained steady while measured value widely fluctuated. Thus, the metrology instrument was suspected, and the light source in the instrument was found to have an issue. The robust online model provides diagnostic information for health-of-equipment.

In summary, the online metrology prediction model with solid physical understandings works as an excellent virtual metrology. This minimizes usage of the metrology instruments. In addition, the early stage detection of equipment anomaly is demonstrated using the robust model to prevent the catastrophic malfunction of equipment. We conclude that expanding the coverage of such a robust prediction model with YieldAware™-FDC infrastructure can improve the over all operational efficiency in an advanced semiconductor factory.

Reference

[1] Hideki M. et al, Proceedings of 2008 International Symposium on Semiconductor Manufacturing, Tokyo, Japan

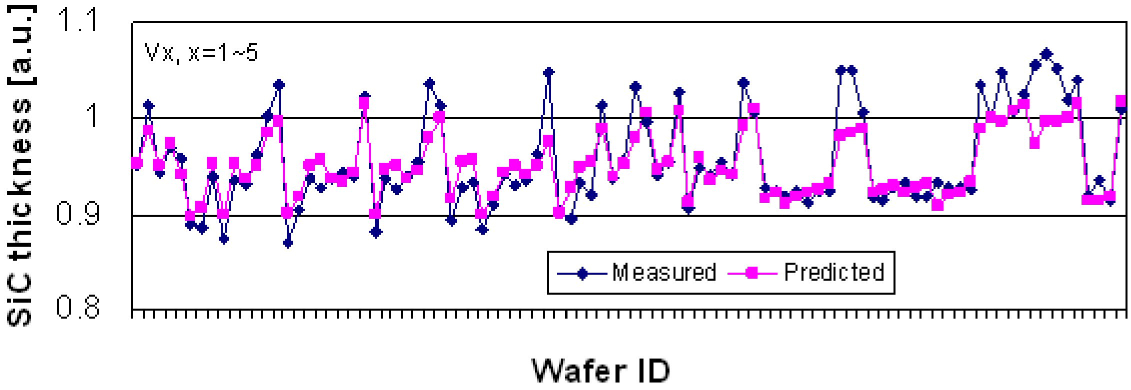

Fig.1 Comparison of SiC thickness measured and that predicted by the online executor combining multiple via layers of the same process recipe

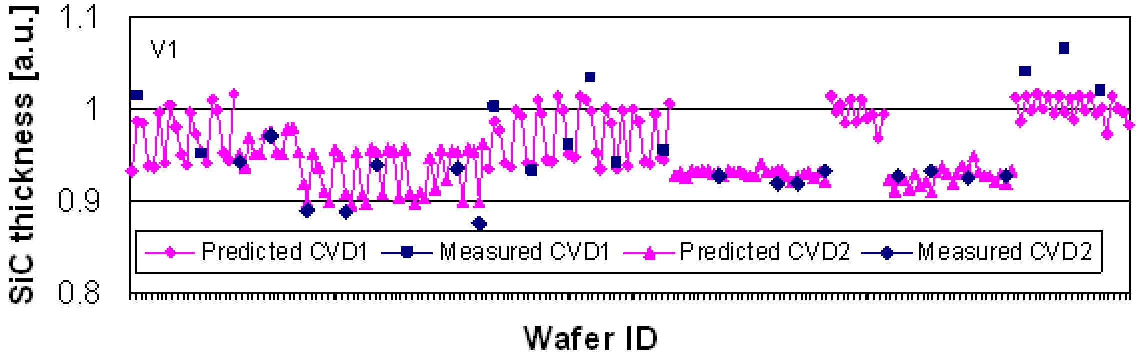

Fig.2 Demonstration of virtual metrology for SiC thickness using the online model

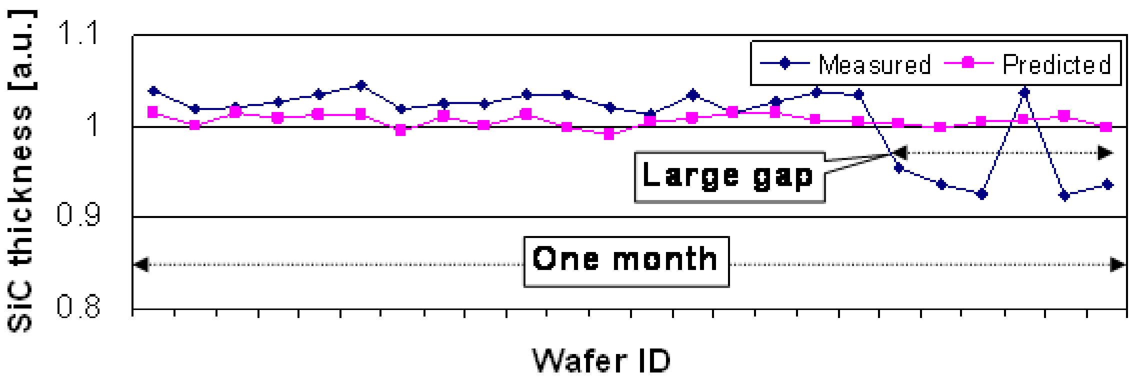

Fig.3 Gap between predicted and measured SiC thickness. In the region with the large gap, the optical measurement tool had an issue in the light source.