Application Note

Note #03/08

Critical Reactive Sputtering Process Control with the HPQS-IP Residual Gas Analyzer

BACKGROUND

PVD or sputtering processes are used to deposit metals (Al, Cr) and compound layers such as SiO_2, ZnO (a transparent conductive oxide or TCO), and TiN. PVD processes need to be properly tuned for optimal deposition rate and optical transmission and refraction properties in the thin film layer (Figure 1). The sputtering power and the concentration of the reactive gas within the process tool must be tightly controlled to avoid changes to the sputter (and therefore deposition) rate over the lifetime of the target. For example, when the oxygen content of the sputter gas environment is low relative to its optimal setting, the deposition rate is high; however, the resultant thin film transmits light poorly. Conversely, when the oxygen level is high, poisoning of the target can cause arcing, which can destroy both the target and the substrate. This application note describes the use of a high-pressure Residual Gas Analyzer (RGA) as an integrated, closed loop process control sensor for a PVD SiO_2 deposition process.

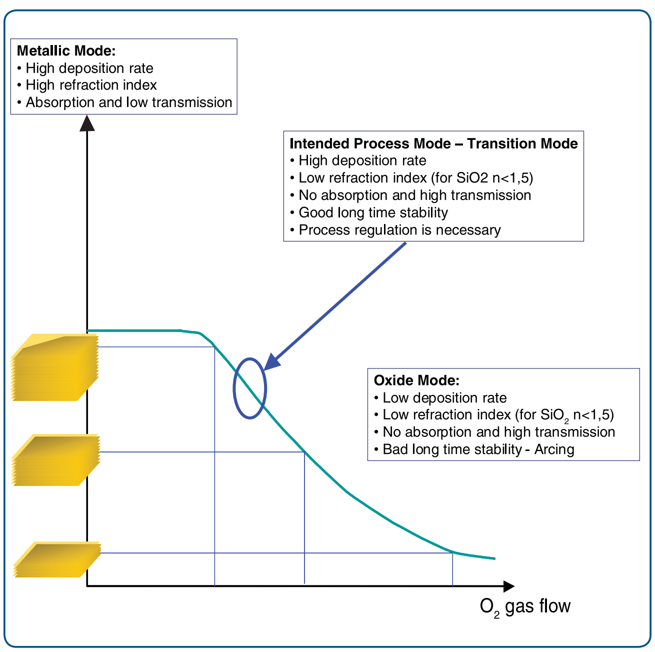

Figure 1 - Reactive process stages for a SiO_2 process

SOLUTION

Integration of the HPQS-IP residual gas analyzer into a PVD SiO_2 deposition process provides the control necessary to achieve the optimal process tuning previously described. The system is fully automated with Process Eye™ Professional software, and a digital and analog I/O interface integrated within the equipment controller. The digital interface triggers the RGA analytical stages (monitoring and calibration) while the analog output returns readings of the O_2 measurement to the magnetron power controller of the tool.

Figure 2 shows a control curve for the PVD SiO_2 deposition process. The RGA is calibrated against the total pressure gauge on the tool chamber without the magnetron in operation. The Ar/O_2 ratio is calibrated using an MFC-controlled gas mixture containing Ar and O_2 at a ratio close to the desired working point of the process and delivered at a pressure similar to that used in the process. In fast sampling mode, the calibrated RGA is used to accurately predict whether the Ar/O_2 ratio is rising or falling during the process. The analog value from the RGA that represents the gas mixture ratio is passed back to the tool controller, which then adjusts the magnetron control parameters (voltage and current) to maintain the process at the desired ratio set point.

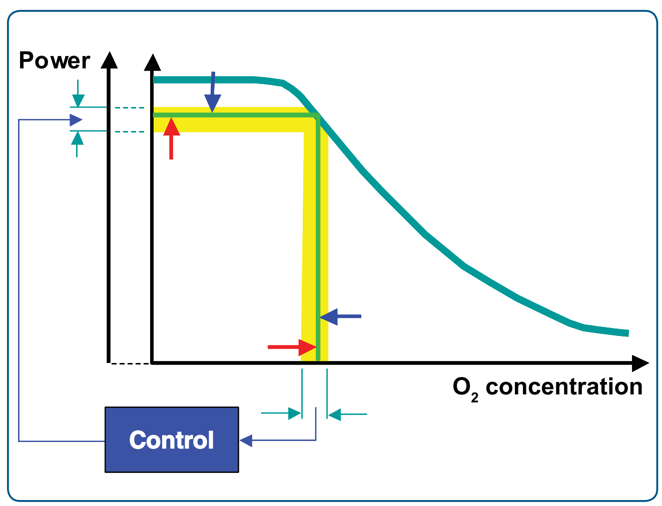

Figure 2 - Process control schematic

SOLUTION (CONT'D)

The RGA system monitors the O_2 partial pressure and controls the cathode power in order to maintain the desired O_2 concentration within the process chamber

- Within the process chamber, a fixed O_2 flow is maintained. If an increase in O_2 concentration is observed by the RGA, the controller increases the cathode power, causing the process to consume more O_2, which in turn lowers the O_2 concentration within the chamber to the original set point level.
- If the O_2 concentration falls, the cathode power is reduced causing the process to consume less O_2. This results in an increase in O_2 concentration, returning the O_2 level to the desired set point.

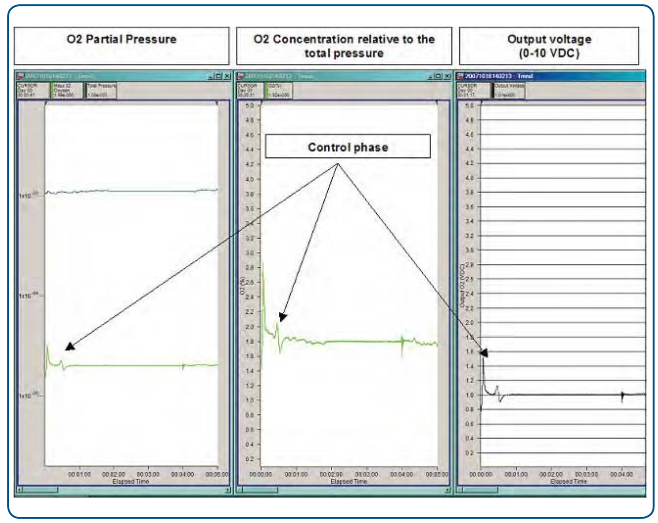

Figure 3 - Process Eye real-time charts

RESULT

Stable layer properties throughout entire target lifetime

The Process Eye Professional software displays different properties of the oxygen measurement. Figure 3 shows the trend windows of the measured oxygen partial pressures (Mass 32 relative to Mass 40 the argon sputter gas), the calculated O_2 concentration relative to the total pressure in the tool chamber, and the output voltage of the HPQS-IP simultaneously.

It can be seen that the use of the HPQS-IP RGA ensures that the correct sputter gas ratio is achieved very shortly after the process start and that stability is maintained throughout the entire process cycle with a fast response to changes. This guarantees the highest productivity without any loss in quality of the film being deposited (when the oxygen concentration is too low) or risk of damage to the target (when the oxygen concentration is too high). In addition to such automated operation modes, Process Eye also provides simple access to other RGA operations such as leak checking and pump down monitoring after a tool preventative maintenance cycle.

CONCLUSION

Control of the optical properties of PVD films is critically important in flat panel and solar cell production. Very small changes in the reactive gas mix may cause significant deviations in the film properties and quality. In addition, aging effects of the target have a significant impact on the film quality. The use of a HPQS-IP RGA automatically compensates for these effects. Process monitoring and control achieved with the integration of the HPQS-IP RGA and Process Eye software, ensures the long-term stability of the process and the quality of the end product.

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Technology for Productivity

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