Study of Target Voltage During DC Magnetron Sputtering

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Abstract

A new practical approach is proposed to detect and prevent target punch-through and gas contamination during DC magnetron sputtering. Using target voltage shift pattern, metal or gas contamination during thin film growth can be effectively detected and contained in real-time.

INTRODUCTION

DC magnetron sputtering technology is commonly used to deposit device level metals in the semiconductor industry. Due to its advantage of step coverage, it is widely used for seed metal and interconnect metal deposition. Sputter deposition parameters such as process pressure, target power, gas flow and shield design directly affect device performance [1,2].

Target erosion along with target usage is a known issue due to electron trajectories near the target surface [1,2]. Erosion patterns are different for different target materials. A lot of work has been done to optimize the target erosion pattern and therefore to extend target utilization [1,2]. Previous work addressed fine tuning the magnetron to wafer position to extend target utilization [2]. A significant challenge in semiconductor manufacturing is to prevent target punch-through when optimizing the target erosion pattern to extend target life and to reduce operational costs. An effective approach to detect target punch-through is highly desired.

Since DC magnetron sputtering is in a vacuum environment, gas contamination and vacuum leaks can cause major scrap. RGA scans can detect gas contamination or vacuum leaks. However, RGA scans are normally performed after one or more lots is processed and are limited to low pressure. Therefore, use of output process parameters during sputtering as a monitor is an optimal solution.

In this paper, we propose a new approach to use target voltage to detect and prevent target punch-through and gas contamination for high volume manufacturing. Au target punch-through and Ar gas contamination of multiple deposition chambers are discussed.

RESULTS AND DISCUSSION

Target Voltage Change during Target Punch-through

Due to differences in magnetic and electric fields, erosion patterns are different for different target materials and deposition chambers. At a certain position of the target surface, erosion can be much deeper. Target punch-through will occur if target life is not well controlled or if there are hardware malfunctions such as magnetron rotation and power supply issues. When target punch-through happens, the foreign material from the backing plate will be deposited on the production wafers.

To find an effective way of detecting target punch-through in real-time, we studied the target voltage shift during a Au target punch-through event. As shown in Figure 1, target voltage was stable between wafers before target life of 170 kWh. However, target voltage had a sharp drop when target life was at 175 kWh indicating the start of target punch-through and foreign materials being involved in the sputtering.

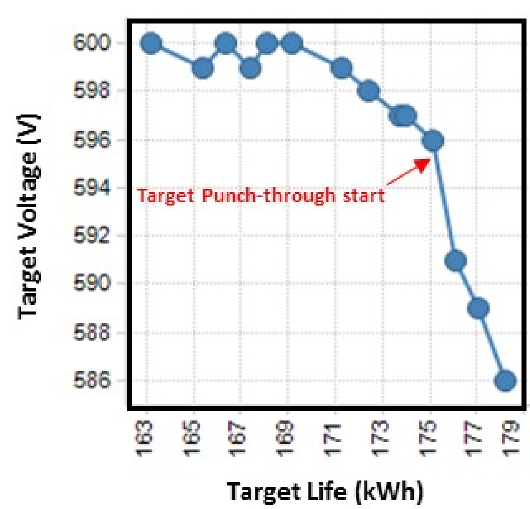

Fig. 1. Target voltage vs Target life of an Au target during target punch-through.

As shown in Figure 2, SIMS analysis of the deposited film confirmed target punch-through at 175 kWh. At target life of 173.8 kWh, indium content (material from backing plate) was at baseline level of ~10^{17} atoms/cm^3. At target life of 175 kWh, indium content increased to ~10^{20} atoms/cm^3. Even higher levels of indium content were observed after the target life reached 175 kWh. In this case, a significant target voltage shift correlated well with the start of target punch-through. Similar patterns were also observed for other target materials when punch-through occurred.

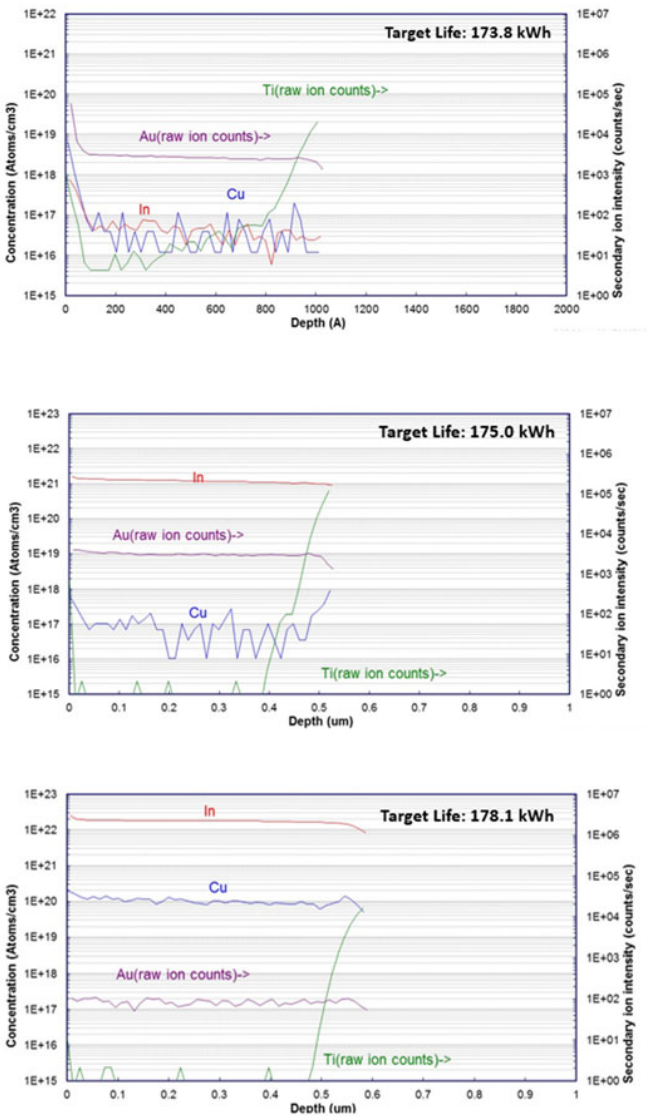

Fig. 2. SIMS analysis of deposited films at target life of 173.8 kWh, 175 kWh and 178.1 kWh.

Target Voltage Change during Gas Contamination

Process gas contamintion is another major issue for sputter deposition. Gas line contamination or vacuum leak are the main causes. Since reactive gases such as oxygen and nitrogen can lead to target surface bonding modification, a target voltage shift is expected when the process gas is contaminated. Figure 3 shows the target voltage shift of Ge and Ni targets during an Ar line contamination event. The plots show the target voltage started increasing from slot 11 and indicated the start of gas contamination. The target voltage continued increasing untill the peak of contamination.

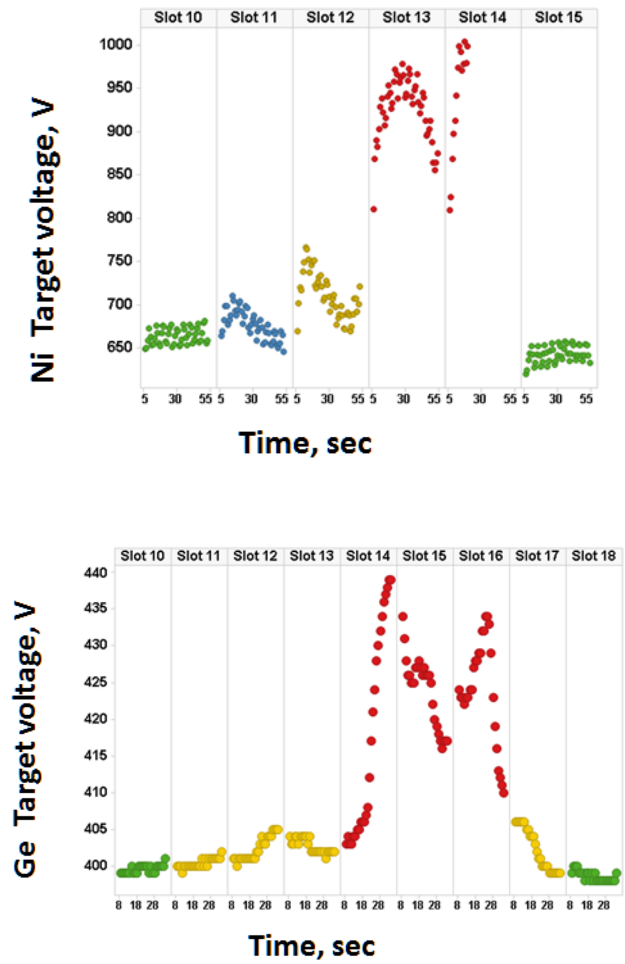

Fig. 3. Target voltage shift of Ni and Ge target during a process gas contamination event.

To define the sensitivity of the target voltage shift during gas contamination, we designed an experiment using N_2O gas mixed with process Ar gas for Pt sputtering. As shown in Figure 4, N_2O gas content was precisely controlled by a flow meter. Baseline target voltage was obtained for slot 1 without N_2O gas. Target voltage increased ~3V with 1sccm N_2O gas, and increased significantly when N_2O gas was at 5sccm. SIMS analysis of the oxygen level showed the contamination level in the deposited film (Figure 5). Oxygen content increased from baseline ~10^{18} atoms/cm^3 to ~10^{19} atoms/cm^3 with 1 sccm N_2O gas. Oxygen content increased to ~10^{20} atoms/cm^3 and above when N_2O gas flow was at 5 sccm and above. Data indicates the target voltage shift is very sensitive to even small gas contamination in the deposited film and can be used as a monitor for process gas contamination.

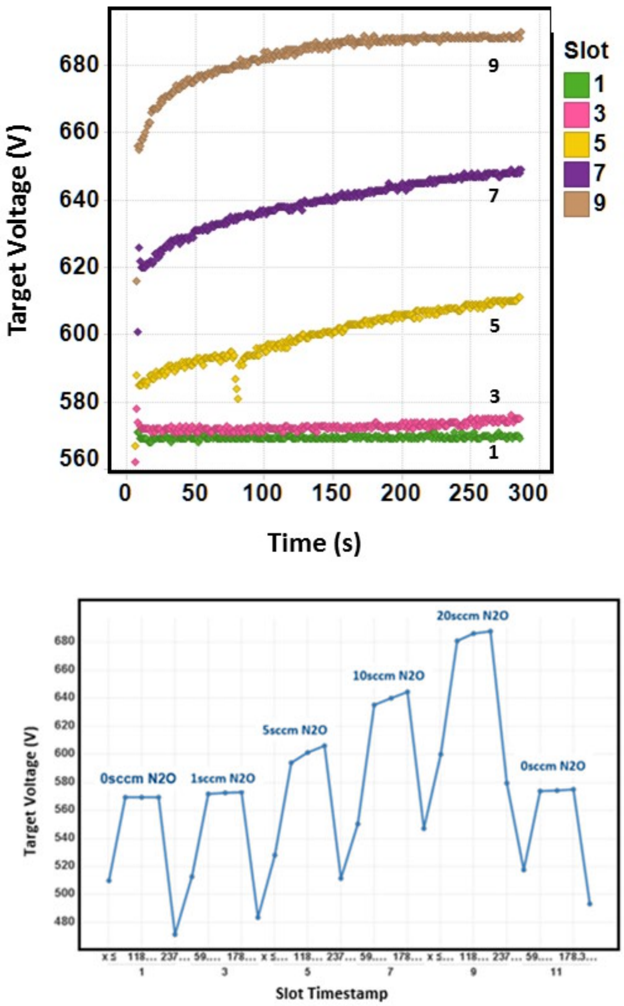

Fig. 4. Experiment result of target voltage of wafers with different level of gas contamination during Pt sputtering.

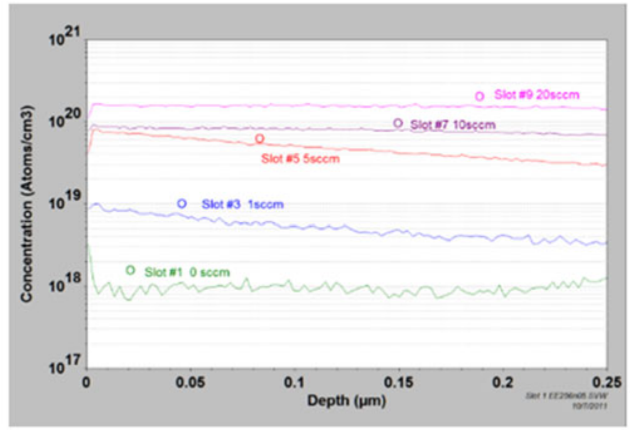

Fig. 5. SIMS analysis of oxygen level of films with different gas contamination during sputtering.

CONCLUSIONS

We studied target voltage shifts during target punch-through and gas contamination events, which demonstrated target voltage shift can be used as an effective approach to detect target punch-through and process gas contamination during metal sputtering deposition. Target voltage monitoring also can be used to catch other issues during sputtering, such as chamber pressure drifting due to pump efficiency, target manufacturing defects and target burning issues.

ACKNOWLEDGEMENTS

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ACRONYMS

DC: Direct Current
RGA: Residual Gas Analyze