plasma process group

Simple Ion Beam Solutions

Mitigation of deposition rate drift in SiO_2 IBD process

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The deposition rate drift of SiO_2 in ion beam deposition (IBD) process is mitigated by implementing a baking step. Each time the chamber is vented, the surface of the chamber absorbs moisture which is then desorbed during the deposition process. A baking step prior to the deposition process run will dry out the chamber surface through thermal outgassing, promising a low level of moisture during the following process run.

Introduction

SiO_2 is one of the most essential materials for optical coatings deposited by Ion Beam Deposition (IBD) process. We found that the deposition rate of SiO_2 measured with Quartz Crystal Monitor (QCM) has relatively large drift (up to 7%) during a ~5 hour run. In the same test, Ta_2O_5 and TiO_2 were also studied but did not show similar deposition rate drift. In this investigation, Argon ions from a 16cm RF ion source sputter the SiO_2, Ta or Ti target, and oxides of those materials are deposited onto the substrate in an oxygen gas environment. Severe drift in deposition rate makes it difficult to accurately deposit the desired thickness, which results in the degradation of the optical performance of the deposited coatings.

Problem description

During a multilayer process, the SiO_2 deposition was measured with a QCM and the results are plotted in Figure 1. There is ~7% decrease in the deposition rate over the first 300 min, after which the rate becomes relatively stable. Through further tests, it was found that the rate drift disappears when the same test is repeated without venting the chamber. Once the chamber is vented even for as short as 10 minutes the rate drift returns.

One of the major impacts of venting is absorption of gases in the air into the chamber wall. Nitrogen, a major component of air, tends to be easily pumped out before running a process. Oxygen, the other major component of air, is used as a

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background process gas and small addition due to the thermal outgassing will not cause impact. Water vapor, a third component, is a notorious contaminant which can cause process disruption if not addressed.

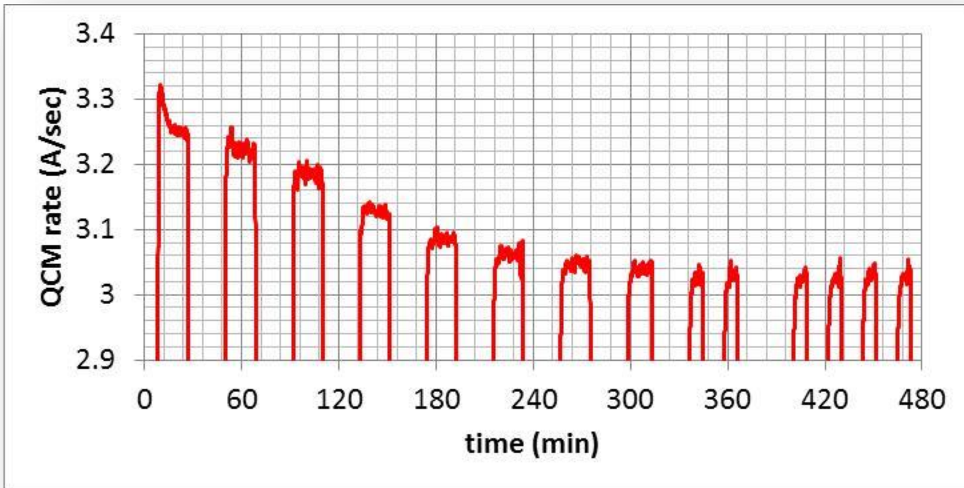

Figure 1. SiO_2 deposition rate measured with QCM. Rate decreases by ~7% over the first 300 minutes.

What seems to occur is that:

(1) Once the chamber is vented, water vapor is absorbed to the chamber wall.
(2) The chamber is pumped down. Some of the absorbed water vapor comes out during pumping, but a relatively large amount of the absorbed water vapor remains inside the chamber wall.
(3) The chamber begins to heat up when the ion beam is turned on. The remaining water vapor slowly desorbs through the thermal outgassing process. This water vapor somehow creates a drift in the SiO_2 deposition rate reading. It is unclear if the actual SiO_2 target sputter rate has drift, or the sputter rate remains stable but the QCM reading is fooled by the water vapor. This is because the deposited material might not be pure SiO_2, but it might contain either significant H_2O or form $SiO_x(OH)_{4-2x}$, while QCM still assumes the deposited material is pure SiO_2 and calculates the deposition rate based on the mass of deposited film on its sensor head.
(4) Once the chamber wall is dried no more outgassing occurs (approximately 3-5 hours) and the deposition rate becomes stable.

Web published March 10, 2016

Proposed solution

If thermal outgassing during the process is the reason for the deposition rate drift, one solution will be to let the chamber outgas completely before the process run. This can be achieved by a chamber bake. For this test, we installed a heater in the Techne IBD chamber to allow a bake-out every time the system was vented.

The results, presented Figure 2, shows the typical pressure trend including bake-out. The baking starts once the high-vacuum valve is opened. The bake time is optimized to 30 minutes and the chamber temperature reaches about 100°C. The pressure increase is clearly seen with ion gauge during the baking step (solid line in Figure 2) indicating that water vapor or other gaseous materials are thermally outgassed due to the heater. The green dotted line in Figure 2 shows the typical pressure trend without a baking step. Actual pressure reading is higher with bake indicating that there is thermal outgas during the bake. After an additional 13 minutes of pumping, the chamber is ready for its process run. Due to its small chamber volume and high pumping speed, the Techne system is ready for process run within 60 minutes even with the baking step included.

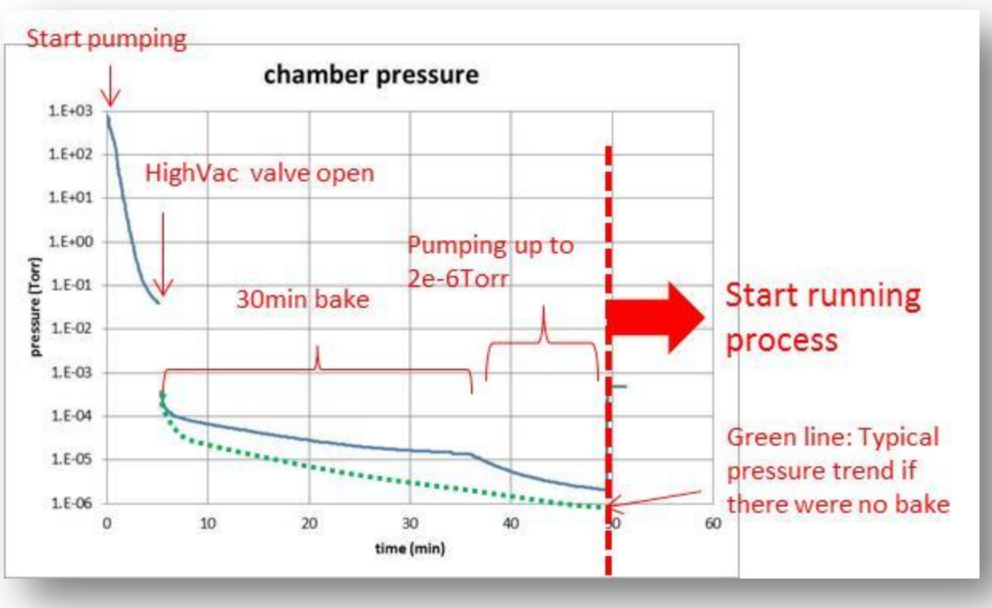

Figure 2. Typical pressure trend during baking step.

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The same multilayer coating was deposited again after a baking step. The results of the SiO_2 deposition rate are shown in Figure 3, where it appears the rate drift has disappeared. This test result indicates that the baking step prior to process run is an effective method to eliminate the observed SiO_2 deposition rate drift.

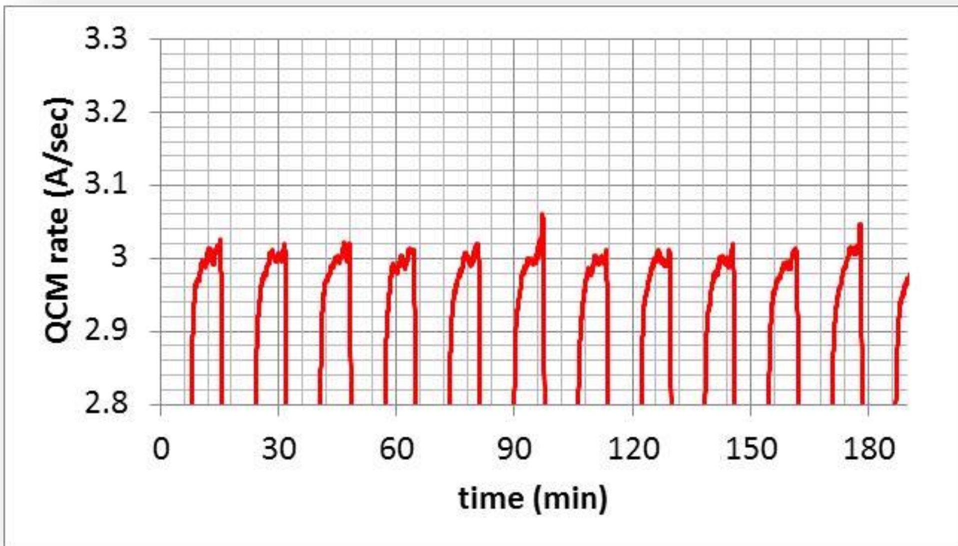

Figure 3. SiO_2 deposition rate is stabilized with chamber baking prior to the process run.

Conclusions

Deposition rate of SiO_2 has large drift in QCM reading. Our testing with Techne IBD system reveals that the drift is due to water vapor or other gaseous materials absorbed when the chamber is vented and demonstrates that the rate drift can be eliminated by implementing a baking step prior to the process run.

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