Simple Ion Beam Solutions

IBAD Coatings: Long Duration QCM Rate Stability

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Optical coatings that are over 170 layers of design *substrate|(HL)^{85} H|air* were deposited using the Techne dual ion beam sputtering system to examine deposition rate stability. In particular, quartz crystal microbalance (QCM) data were analyzed for rate drift. The reactively sputtered materials investigated were TiO_2 from a Titanium target (*H*) and SiO_2 from a Silicon target (*L*). Statistical analysis is applied to the data for quantitative results presented in this paper.

Introduction

Ion beam sputter deposition with an assist ion beam has been used in industry for years to produce dielectric coatings used for optical devices [1-3]. An ion beam assisted deposition (IBAD) system utilizes two sources as depicted in Figure 1. One ion beam source (deposition source) is directed at a target material to be sputtered. The system geometry is designed so the sputtered target material arrives at the substrates while ions from the second source (assist source) are also arriving.

For designs of thin film optical filters that require multiple layers, an IBAD system may take several hours to deposit the desired structure onto the substrate. Coating time can approach 40+ hours depending upon the type of thin film design. It is therefore essential the system maintain a stable deposition rate for the coating duration.

Deposition rate for an IBAD system is controlled by several parameters such as the ion source beam current and energy, assist source conditions, target angle and system geometry [4,5]. Most of these parameters remain constant (or fixed) for a coating process. However, the rate can be influenced on how equipment such as target face and source grids age within the IBAD. Variation in deposition rate can be tracked using a quartz crystal microbalance (QCM). Other variations in rate can be inferred by carefully monitoring the ion source conditions. For simplification purposes, the assist source was not used for this study.

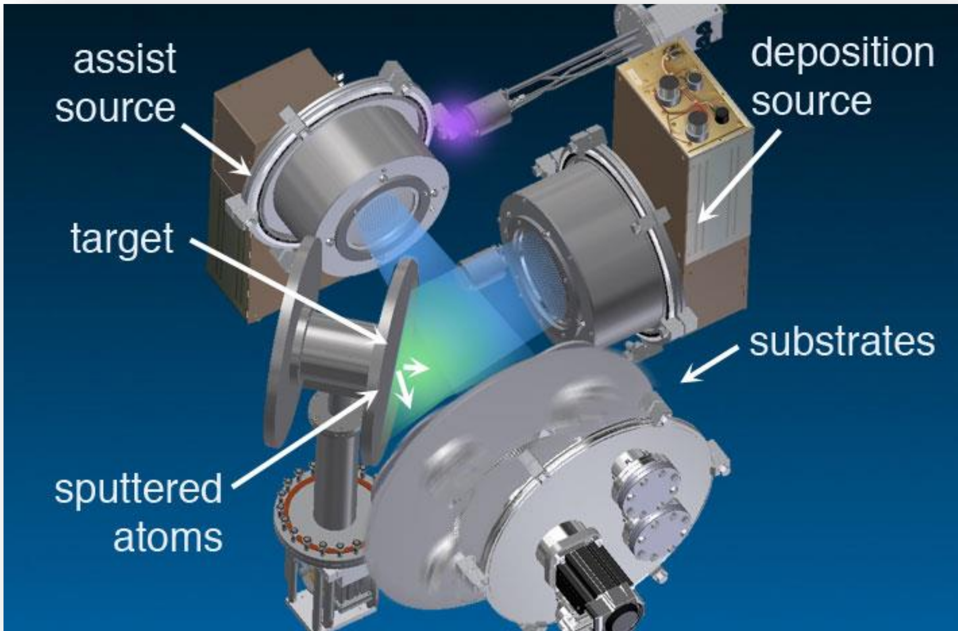

Figure 1. Dual ion beam sputter system layout.

Experimental Apparatus and Procedure

Multilayer mirror filters were deposited on glass slides in the Techne dual ion beam sputter system. The 16 cm radio frequency (RF) deposition source was operated on Argon and the beam conditions were optimized to match industry standards (e.g. 600 mA beam current and 1250 V beam voltage). The high index (*H*) material TiO_2 was reactively deposited using a Titanium target and similarly, the low index (*L*) material SiO2 was reactively deposited using a Silicon target. For both materials, oxygen was supplied to the target and the partial pressure was optimized for each material. A typical deposition rate for these materials on the planetary fixture with shadow masks was 1.66 Å/s for *H* and 2.67 Å/s for *L*.

This case study utilized a multilayer mirror design $substrate|(HL)^{85}\ H|air$ centered near 900 nm. This multilayer mirror does not have any particular use optically and only serves as a test sample that requires about 40 hours to deposit. The layer times for H and L were 815 and 833 seconds, respectively. This investigation deposited 4 of these filters for a total system time of about 160 hours.

For each test, the Techne system was baked at 100˚C and pumped to $3x10^{-6}$ Torr for water vapor removal. The deposition source was warmed up for 10 minutes. The targets and substrates were also sputter cleaned for 10 minutes. Using the Techne software and data logging features, fifteen ion source parameters from the IBEAM 703 RF source power supply were recorded every second for the duration of the run.

An Inficon SQC-310 deposition controller monitored two quartz crystal microbalances fitted with an alloy type crystal. Both crystals were located near top dead center of the planetary fixture as depicted in Figure 2 and were cooled using a Lytron chiller. For each run, crystal 1 was new while crystal 2 had a life near 70% (coated from the previous run and with 100% life being a new crystal). In this fashion, used and new crystals could be compared during the same run. The crystal tooling factors were adjusted to match calibrated single layer rate data previously acquired. Rate and thickness data were also captured every second on the Techne controller.

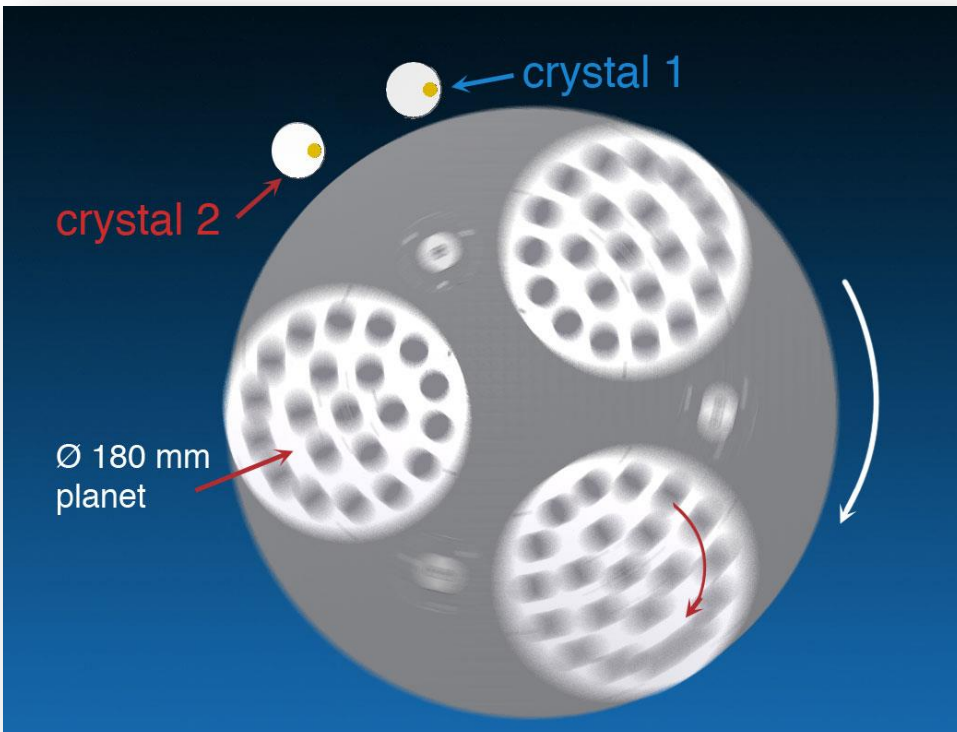

Figure 2. QCM location near the planetary fixture.

For monitoring purposes, a shorter multilayer mirror filter design centered at 650 nm was used to capture the uniformity of the coating on the planets prior to and following the four longer 40 hour runs. This design, *substrate*|$(HL)^6$ *H*|*air*, also used TiO_2 for *H* and SiO_2 for *L* and additional coating details are described elsewhere [6,7]. The filters were analyzed for center wavelength transmittance values using a Semiconsoft MProbe equipped with an Ocean Optics spectrophotometer.

Results and Discussion

Typical QCM rate data for the first 12 hours is presented in Figure 3. The monitored deposition rates for crystal 1 are about 1.67 Å/s for *H* and 2.68 Å/s for *L*. Transitions between the materials are observed by rapid changes or spikes in the deposition rate. For some layers, the rate appears noisy with low frequency fluctuations in the data. These disturbances may be induced by thermal or particulate issues.

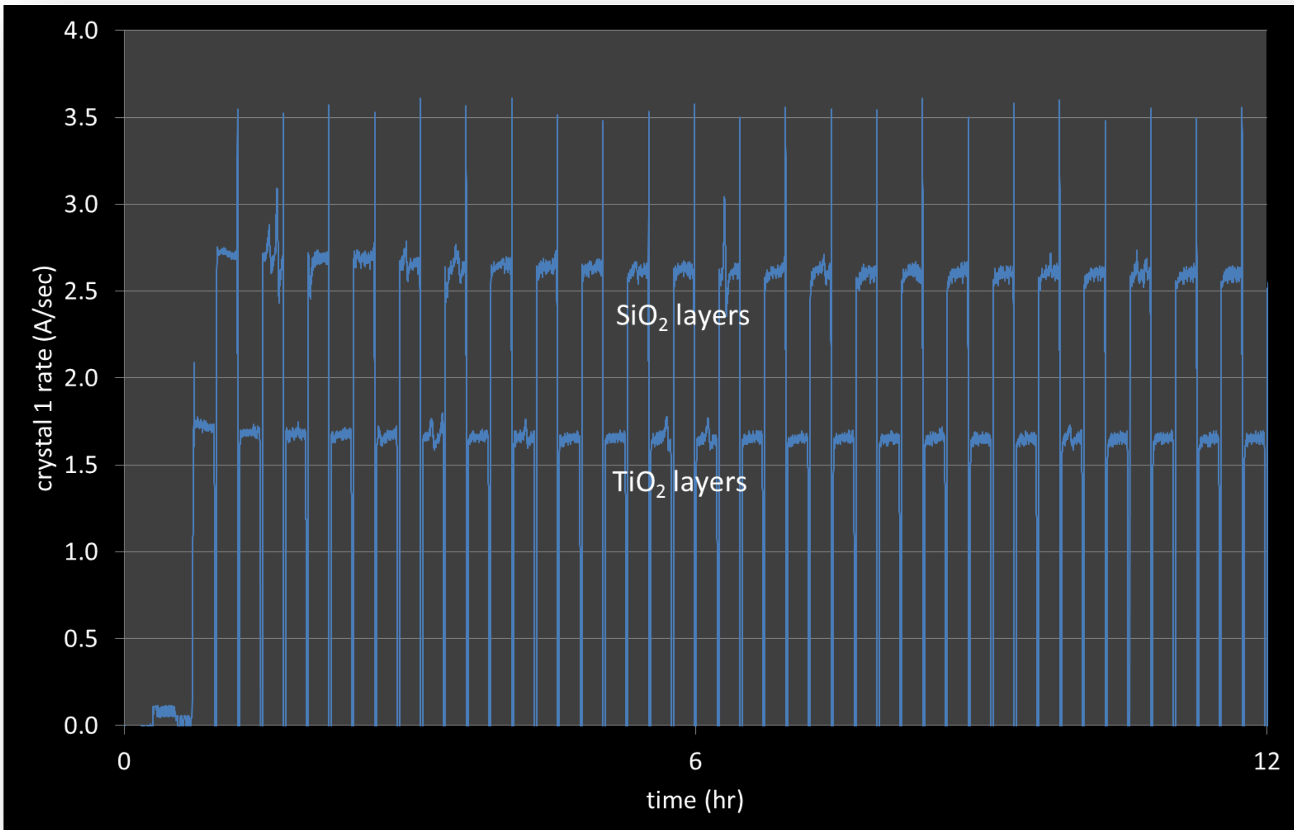

Figure 3. Crystal 1 rate data for the first 12 hours.

A complete picture of the rate information is presented in Figure 4 where the H and L layer data are plotted for the entire 40 hour deposition duration. From these data, it appears the rate drifts downward slightly during the first 3 to 4 hours of coating time, which is typical behavior of a new crystal [8]. After the crystal is coated, the deposition rate appears to be more stable. The data also show significant noise near 33 hours for both materials.

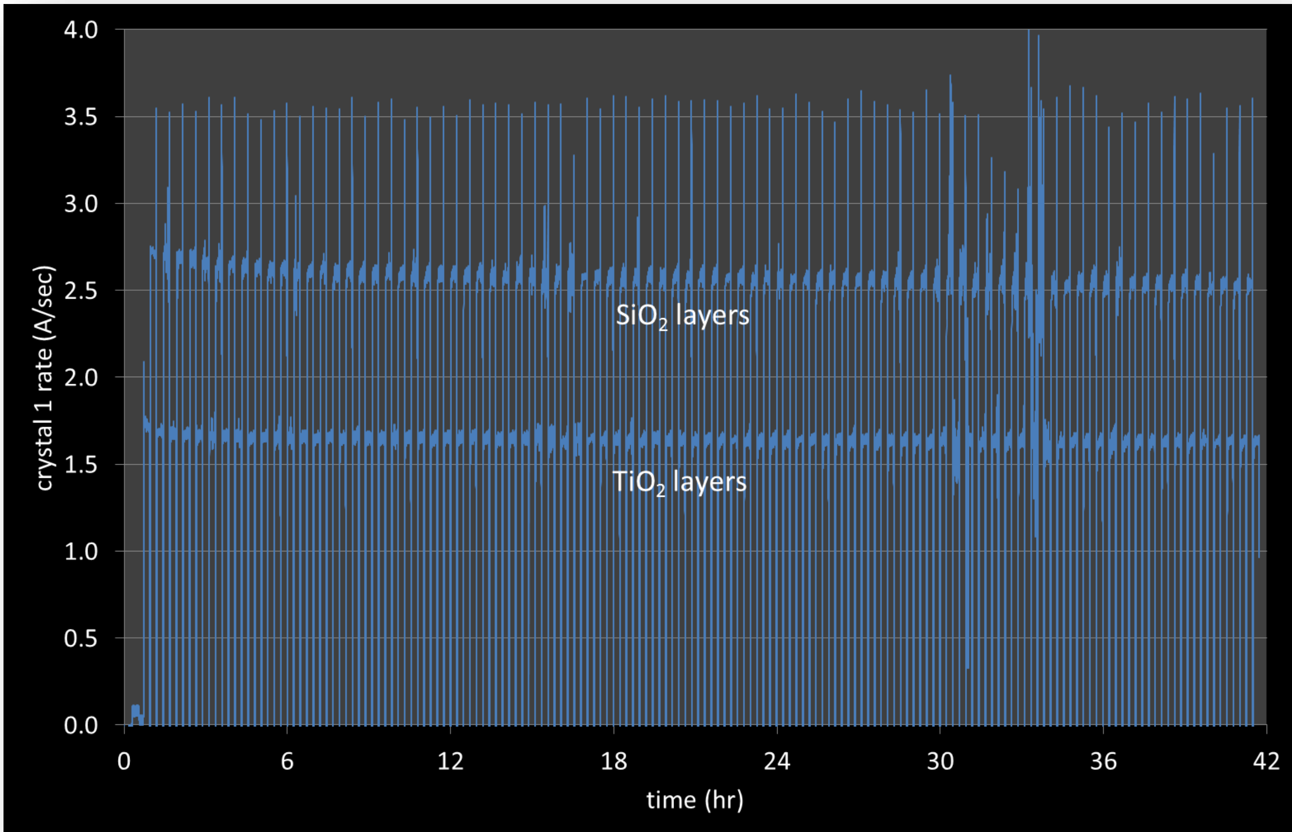

Figure 4. Crystal 1 rate data for a 170 layer coating.

For comparison purposes, crystal 2 data from this run are plotted in Figure 5. At the beginning of the run, crystal 2 is at 70% life. As these data indicate, the rate does not drift downward during the first few hours like that observed with crystal 1. Also, the data in Figure 5 show the rate is more stable with less noise than that observed for crystal 1 (Figure 4).

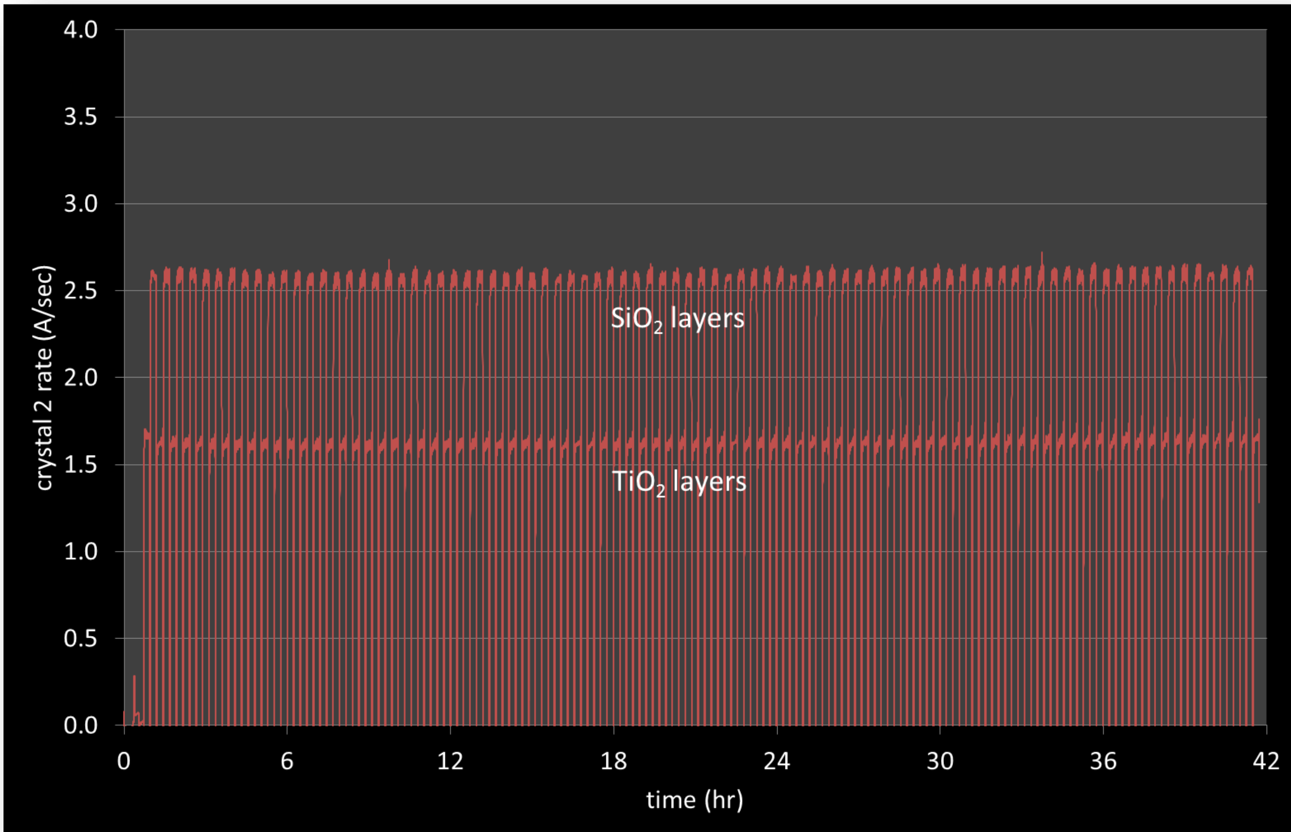

Figure 5. Crystal 2 rate data for a 170 layer coating.

Using a statistical approach, the average and standard deviation were determined for each crystal and each material. These are tabulated in Table 1 for the four long duration runs. The rates did decrease slightly after 160 hours of coating time which can be expected with target conditioning over such a long duration.

Run	Crystal 1 average rate		Crystal 2 average rate	
	H	L	H	L
1	1.67 ± 0.03	2.68 ± 0.04	1.69 ± 0.06	2.75 ± 0.07
2	1.69 ± 0.03	2.73 ± 0.05	1.68 ± 0.04	2.76 ± 0.06
3	1.65 ± 0.03	2.68 ± 0.06	1.64 ± 0.05	2.67 ± 0.04
4	1.64 ± 0.04	2.59 ± 0.06	1.62 ± 0.04	2.57 ± 0.03

Table 1. Average rate values in Å/s for the 40 hour runs.

Before and after center wavelength variation measurements are plotted in Figure 6. These data indicated the coating uniformity did not change after 160 hours of system use.

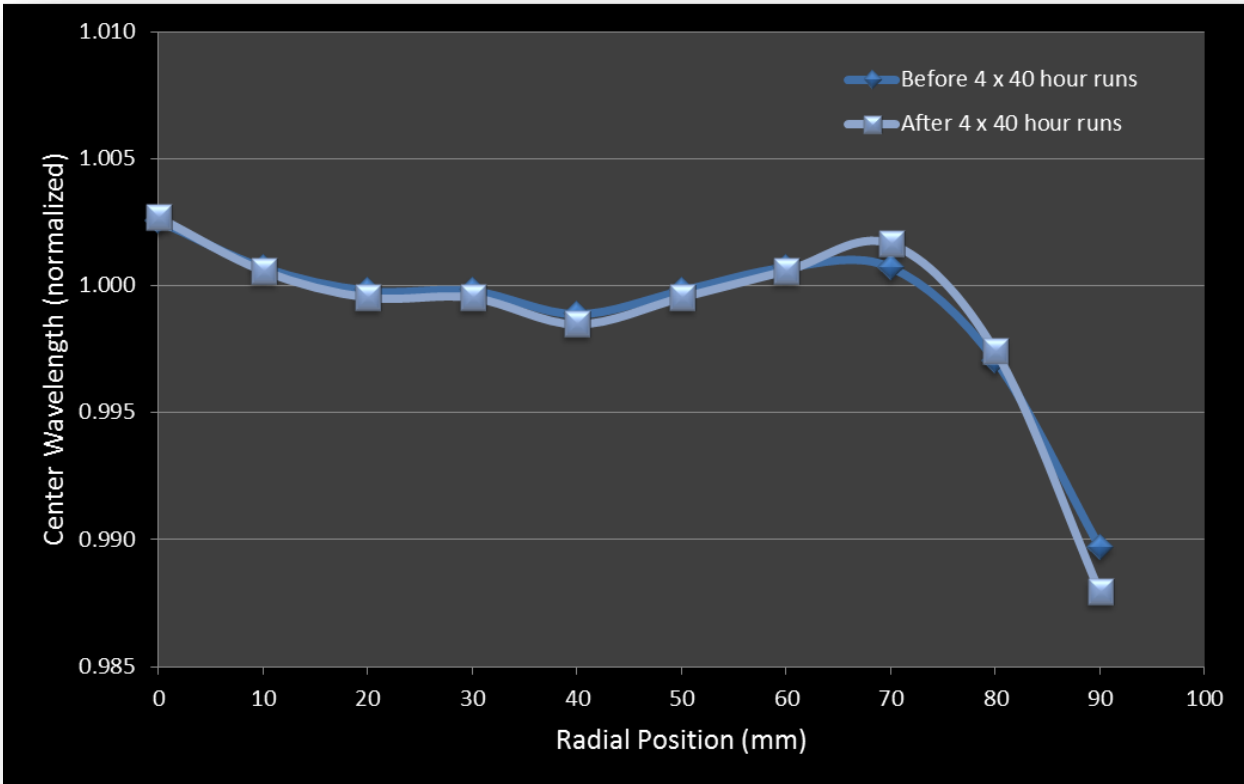

Figure 6. Before and after center wavelength variation on the planet.

Conclusions

Quartz crystal rate data was captured for four long duration deposition runs. The QCM data indicated drift present with new crystals for the first 3-4 hours of coating time which was not observed for partially used crystals. After 160 hours of coating time, the overall rate decreased slightly due to target conditioning but the coating uniformity on the planets remained unchanged. Careful consideration should be performed to select the QCM location. Factors such as exposure to thermal shock and particulates can degrade the quality of data. Additional research is planned.

References

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