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Simple Ion Beam Solutions

IBAD Coatings: Assist Beam Influence on the Deposition Plume

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This paper provides a first order description of assist beam influence on the deposition plume in the Techne dual ion beam sputtering system. The deposition plume was experimentally determined and mathematically modeled for basic cases when the assist beam is on and off. Using a mathematical model, shadow mask shapes and coating uniformities are predicted. These are presented and compared against experimental results.

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.

In order to produce uniform coatings with an IBAD tool, some machines will utilize a planetary type fixture for substrate manipulation (Figure 2). Small substrates are loaded onto planet holders which are in turn mounted to a hub. The hub revolves around a sun gear which forces the planets to simultaneously orbit and rotate. The gearing is selected so planetary position does not repeat for several cycles.

The motion of the planetary substrate holder will then average the arriving sputtered material. Coating produced on a planetary may be sufficiently uniform for many applications. For others, shadow masking may be used to further improve the uniformity of the coatings or maximize production yields. For predictable results, substrates are all mounted with their surfaces at the deposition plane.

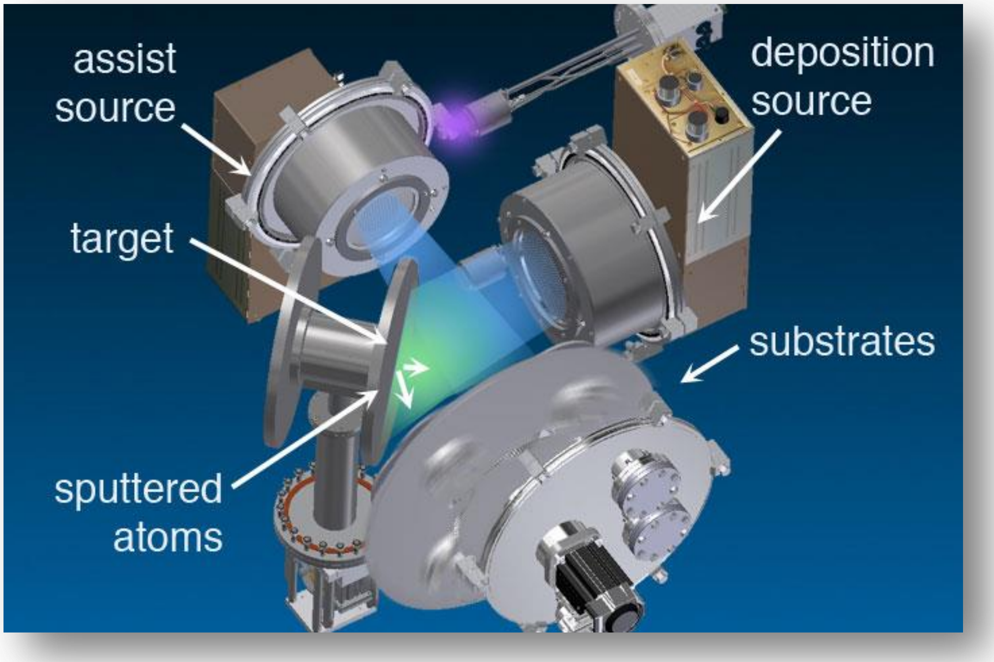

Figure 1. Dual ion beam sputter system layout.

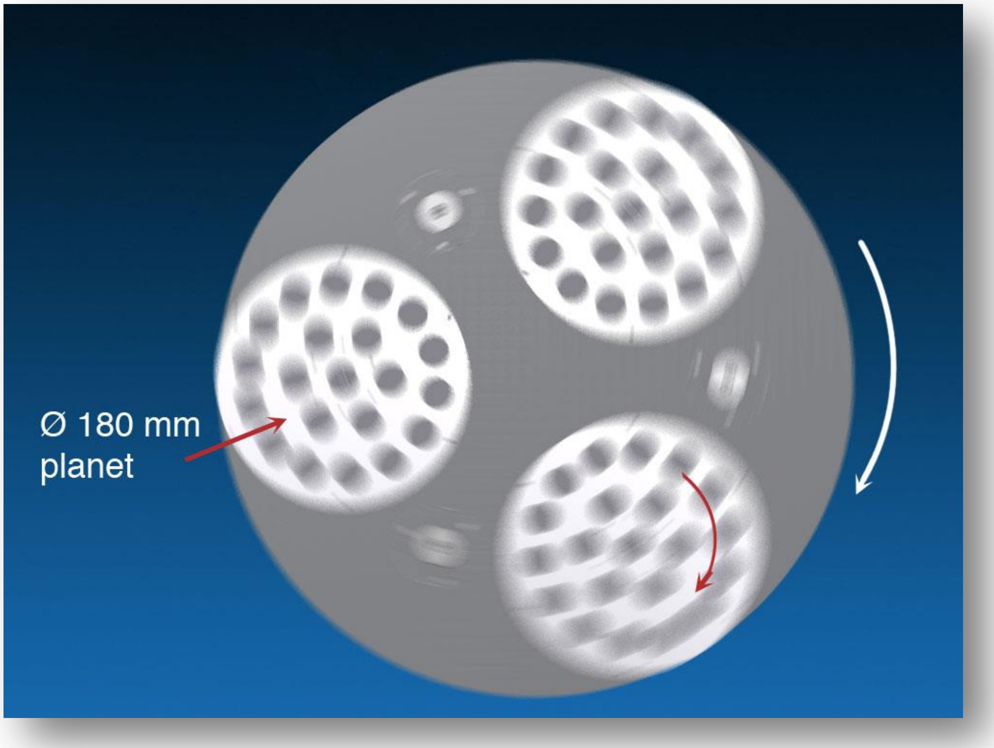

Figure 2. Planetary fixture schematic.

For this investigation, the sputter plume at the deposition plane was experimentally mapped with and without the assist beam at typical conditions. A mathematical model [4] of the plume was then adjusted with the empirical results for improved accuracy. The model was then utilized to examine a small area (dA) on the planetary and integrate the path of the part to estimate the coating uniformity [5]. Then the model was used to predict a shadow mask shape required for a desired coating uniformity.

Experimental Apparatus and Procedure

Single layers of TiO_2 were deposited on glass slides mounted at the deposition plane in the Techne dual ion beam sputter system. The glass slide witness pieces remained stationary and were strategically placed to map the deposition plume. 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 material TiO_2 was reactively deposited using a Titanium target while 25 sccm of Oxygen was supplied to the target.

The single layer coatings were analyzed using a Semiconsoft MProbe equipped with an Ocean Optics USB4000 spectrophotometer. Coating thickness and deposition topography was mapped over an area of 80 cm x 80 cm.

The process was repeated with the assist beam ON. For high contrast purposes, the assist conditions were slightly energetic with an ion energy of 400 eV (e.g. beam voltage was 400 V). The source was operated on 100% Oxygen with a flow rate of 10 sccm and beam current was 200 mA.

The planetary utilized a gear ratio of 47:123. This meant for every revolution around the sun, each planet would rotate about 2.617 times. Figure 3 shows the path created by a small area (dA) before the fixture returned to its original position. The typical rotation speed was set to about 0.3 rps which set the realignment duration to about 157 seconds.

Results and Discussion

After the calibration tests were performed, the mathematical model was adjusted for improved agreement between experiment and theory. The model of the deposition plume (with assist beam OFF), is plotted in Figure 4 where normalized deposition rate is plotted for the deposition plane on the planetary fixture. The coordinate $x = y = 0$ represents the center of the planetary. System geometry determines the maximum rate which is slightly to the right of the origin.

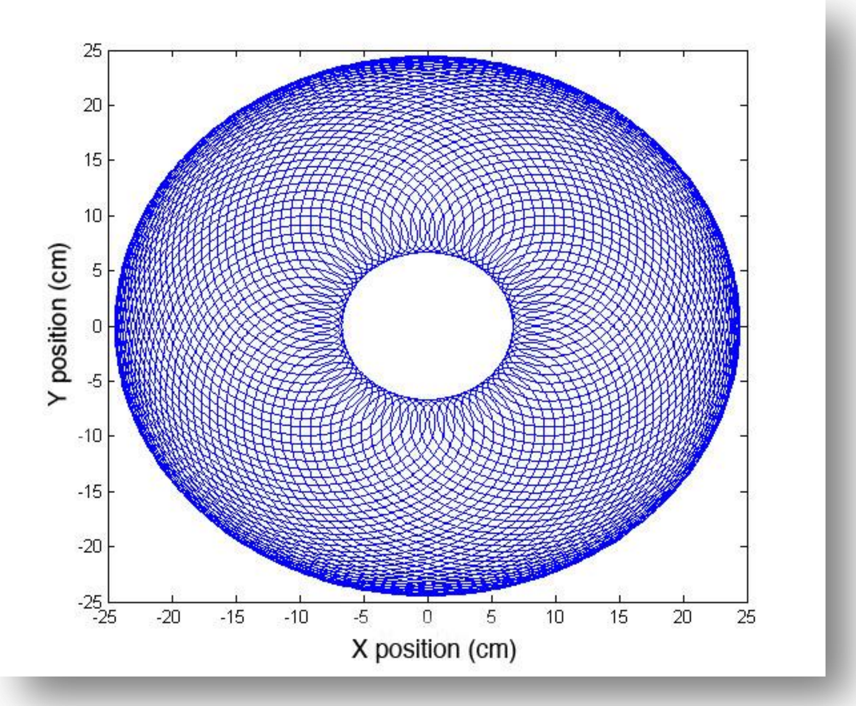

Figure 3. Path of a part on the planetary fixture.

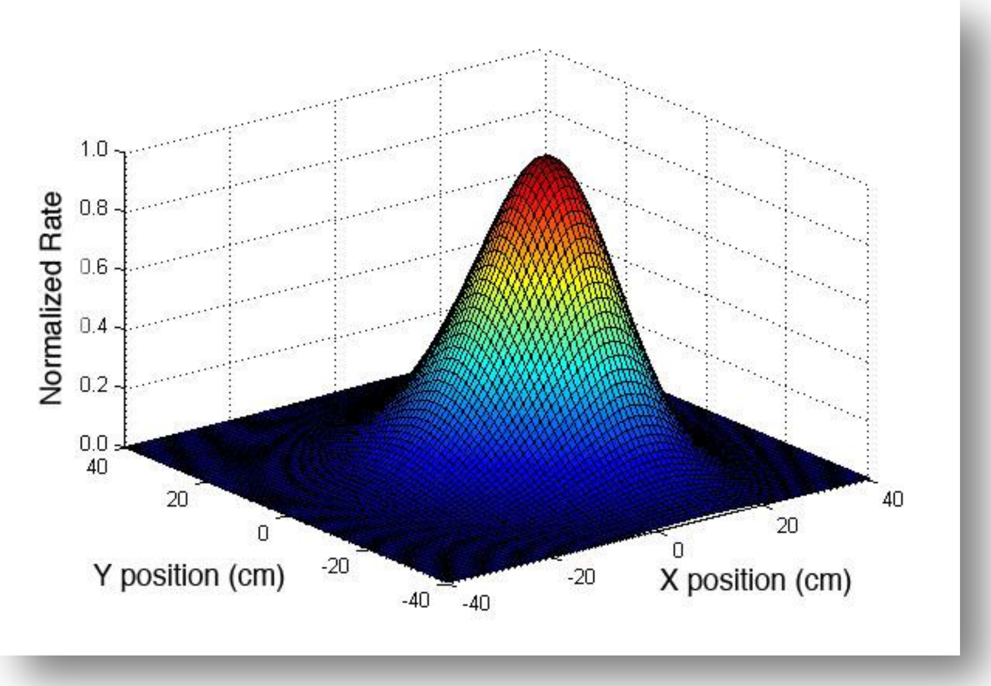

Figure 4. Deposition plume modeled without assist beam.

The assist beam was characterized as an etch or material removal zone as depicted in Figure 5. The assist beam was pointed slightly to the left of planetary center which produced the overall deposition plume as shown in Figure 6. The modeled deposition plume was in close agreement with the calibration results on the system.

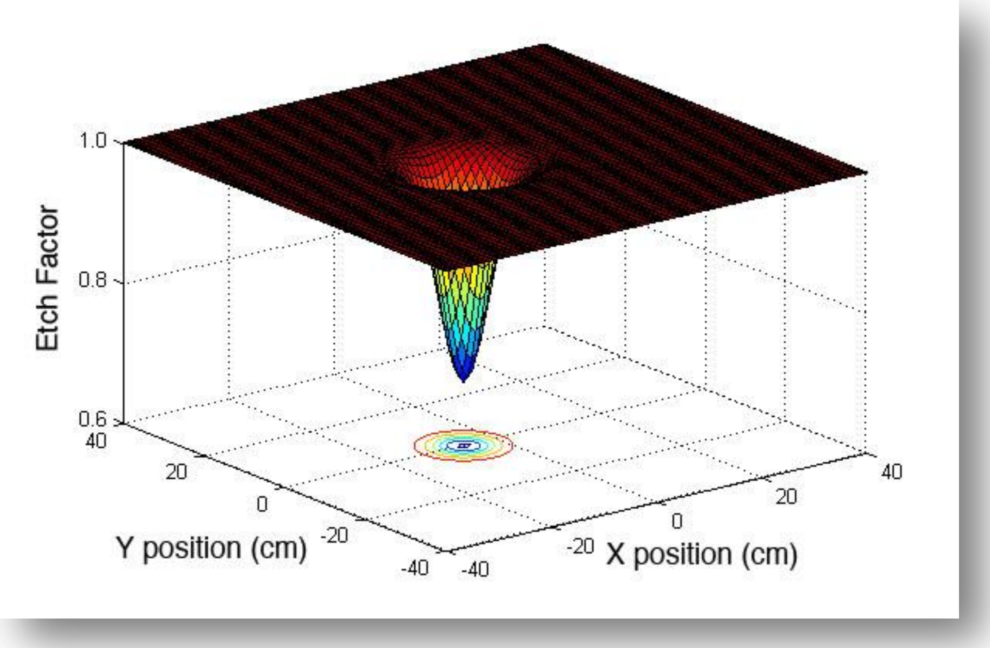

Figure 5. Assist beam – modeled as etch or material removal.

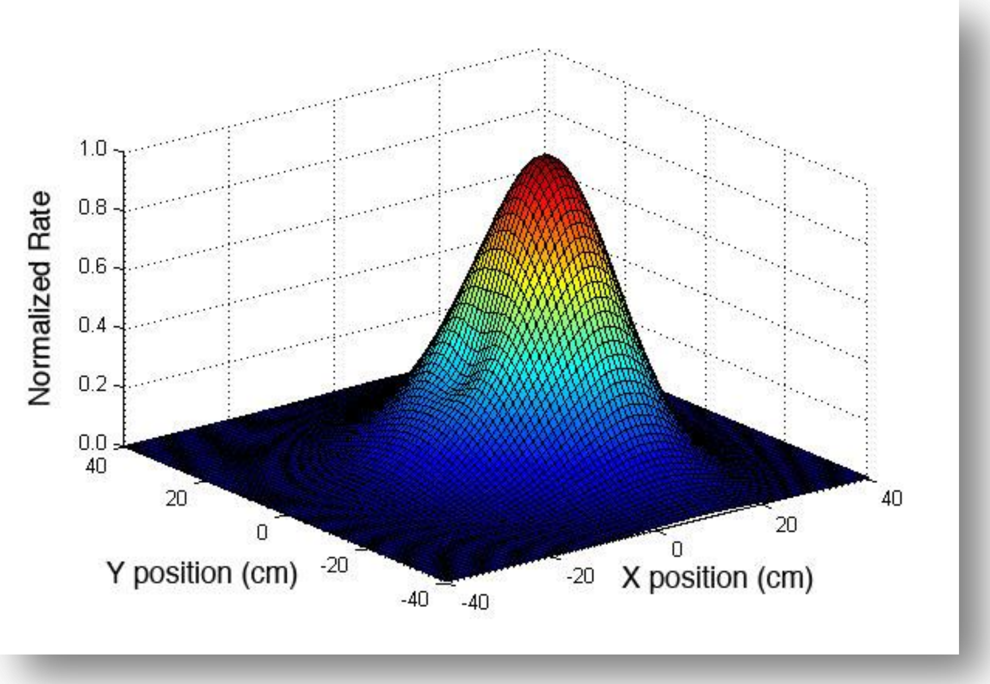

Figure 6. Deposition plume modeled with assist beam.

After determining the deposition plume with and without the assist beam on (Figures 4 and 6), a general shadow mask shape was determined for a typical uniformity requirement of ±0.5%. The theoretical shadow mask shapes are presented in Figure 7. Using this data, actual shadow masks were fabricated using a CNC and installed.

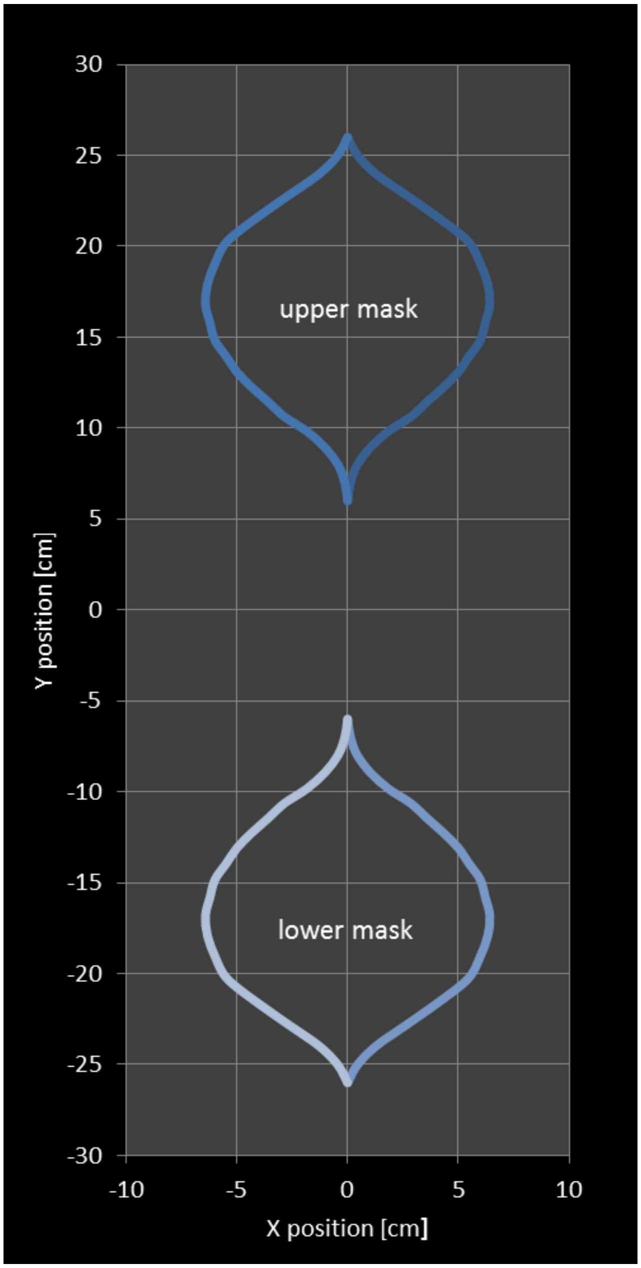

Figure 7. Theoretical shadow masks shape and locations for ±0.5% uniformity.

Next, the theoretical deposition rate was determined by integrating the modeled plumes in Figures 4 and 6 along the path shown in Figure 3. The integration also took into account the theoretical shadow masks shapes in Figure 7, subtracting this component of deposition. The process was repeated for different radial positions and the results are plotted in Figure 8.

For comparison purposes, the deposition rate data from actual runs are also plotted in Figure 8. For both cases, there is reasonable agreement between the theory and actual. The shadow mask design is considered a first iteration so improvements between theory and actual are obtained by a few design iterations. For this study, the combined deposition and assist model demonstrates its usefulness with good agreement to actual data.

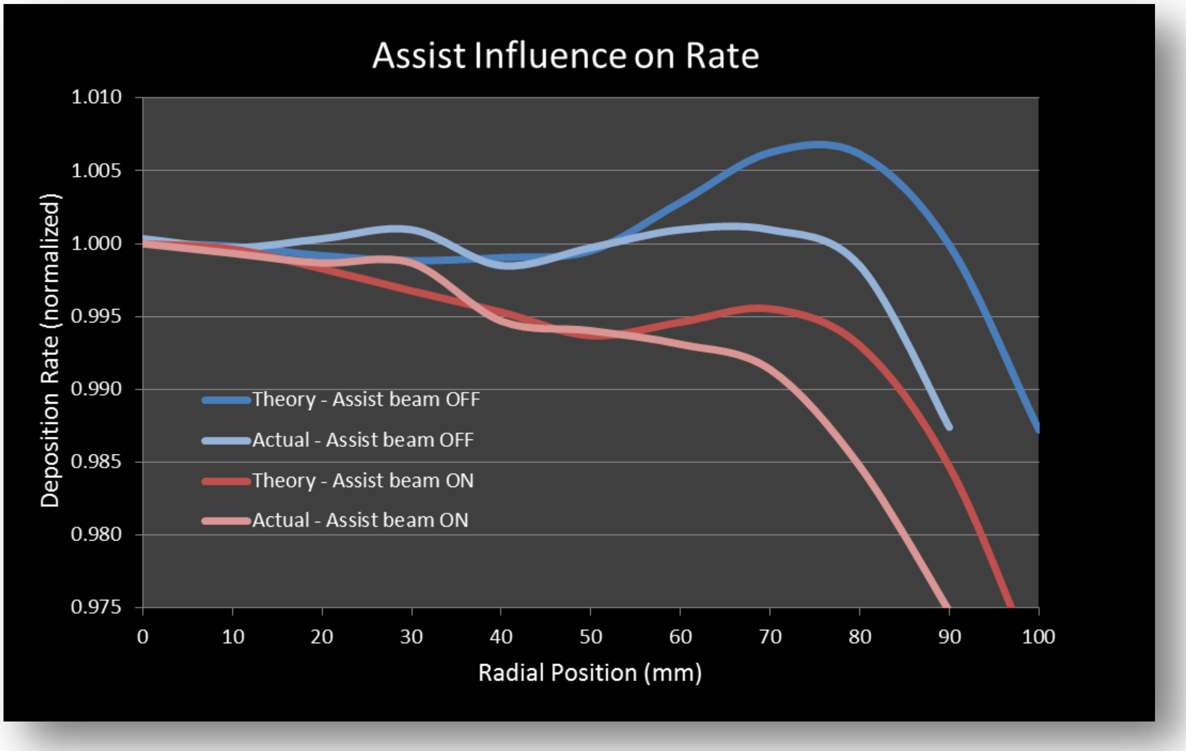

Figure 8. Deposition rate profiles with and without the assist beam.

Conclusions

Using a mathematical model of the deposition plume in conjunction with a model of the assist beam, theoretical deposition rate profiles can be estimated. The assist beam can be modeled as etch or material removal. Once the assist conditions are optimized, the shadow mask shapes can then be calculated to improve the uniformity for planetary fixtures. Additional modeling is planned.

References

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