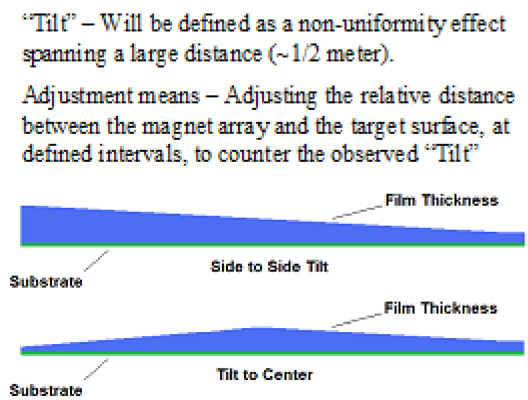
Uniformity Control for Rotating Cylindrical Magnetrons

Optimizing production sputtered thin film throughput and yield is not always synonymous with maximizing target material utilization. To achieve tight uniformity of films from rotating cylindrical magnetrons, the fabricator may have to buy oversized or shaped targets which increases material costs, install trim-shields which may reduced product throughput, or suffer a reduction of product yield due to uniformity drifting in and out of specification. Often these deficiencies are combined with a magnetic field design for the magnetron that causes “end-grooving” and allows the user to achieve target utilization of less than 70%

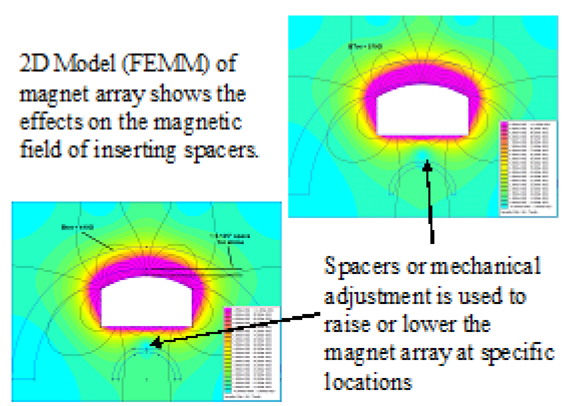
Angstrom Sciences has developed a magnet array which allows the rotating cylindrical magnetron user to achieve high target utilization with no end-grooving and to shape the magnetic field to maximize sputtered thin film uniformity. These innovations allow the user to maximize both product yield and throughput while helping to minimize target material costs.

This presentation will cover the major contributions of the magnet array for rotating cylindrical magnetrons. The first section will discuss methods and results for tuning a rotatable cylindrical magnetron – in order to meet a uniformity specification

The 2nd section will discuss some of the criteria which should be understood prior to implementing a rotating cylindrical magnetron.

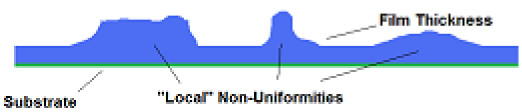


To eliminate tilt is a sputtering profile it is necessary to adjust the magnet array proximity to the target surface. The following models show the relative intensity of the magnetic fields when the magnet array is fully spaced or not spaced at all!



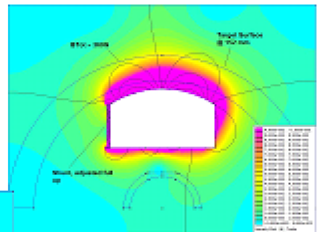
"Local" – Will be defined as a non-uniformity effect spanning a distance from ~ 2-40 cm.

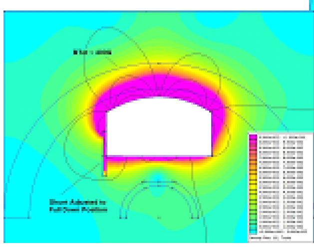
Adjustment means – Change the intensity of the magnetic field in the position directly aligned with the non-uniformity



The major differentiation between a "tilt" effect and a "local" effect is the length of the perturbation in your data. A local effect is much smaller in length and adding or removing spacers to the assembly will not address this problem.

To eliminate "local" uniformity effects, 1 or more shunts may be cut to length and used for tuning over the magnet array length





Depending on the size of the uniformity anomaly, shunts may be used on one or both sides of the magnet array.

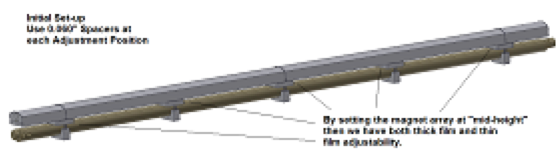
To eliminate local effects it is required to address the non-uniformity on the magnet array, directly correlating to where the anomaly occurs. The 2D plots show that the relative intensity changes for applying the shunt full-up or full-down.

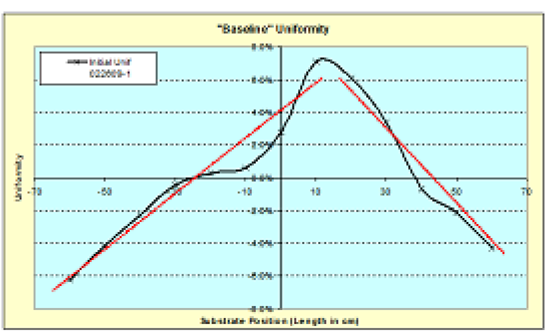
All magnet array adjustments are based on the basic correlation:

Deposition Rate α Magnetic Field Strength

With some tools available now to address uniformity discrepancies, we can now work on a "real-world" problem using the follwing sequences and results.

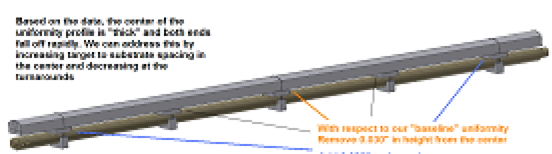
Step #1: Establish a baseline uniformity from which we will begin to shape the magnet array in order to achieve film thickness uniformity.

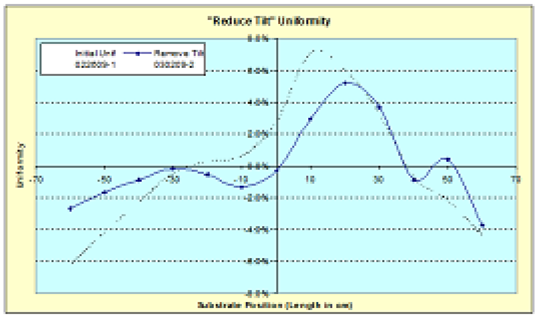




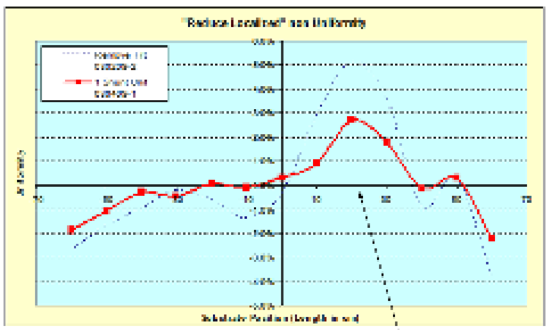
The dashed red lines show we have 2 slopes over the entire length. Both towards the center of the magnet array. We will add spacers and retest!

Step #2: Remove "tilt" over a long length by adding/removing spacers along the length of the array.

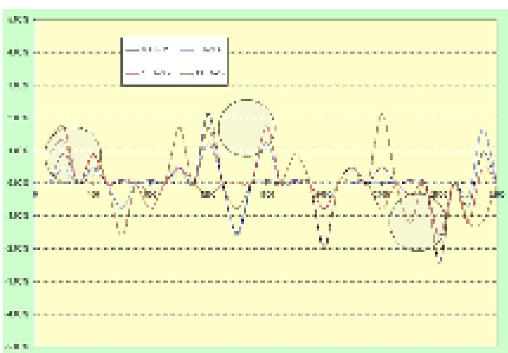




At this point we can either try further adjustment to the tilt, or, try to remove the "local" non-uniformity

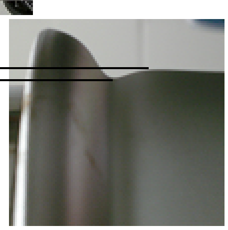


In addition of a single shunt brought the [illegible] uniformity [illegible] the correct direction but was not strong enough. Add 2nd shunt to other side of magnet array!



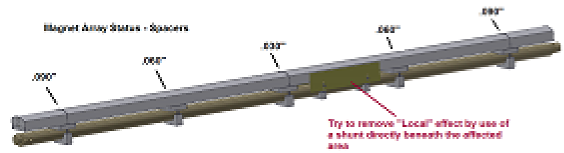
Applying the same procedures for a single 3.5m magnet array on a 3.2m Substrate

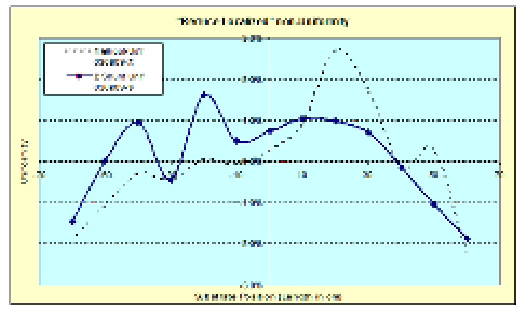
End Grooving refers to the target erosion at the racetrack turnarounds



This effect causes a loss in target utilization and changing uniformity effects

Step #3: Begin to focus on localized non-uniformities by use of shunts.

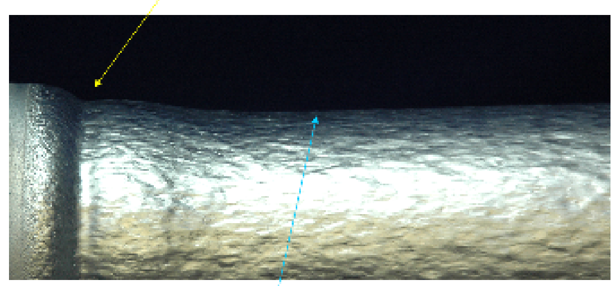




Uniformity Criteria is met!

This last section will discuss some of the other effects the magnet array has on your process and productivity. Specifically we will look at "end-grooving" and its ill-effects as well as the magnetic angle which defines the position of the racetrack.

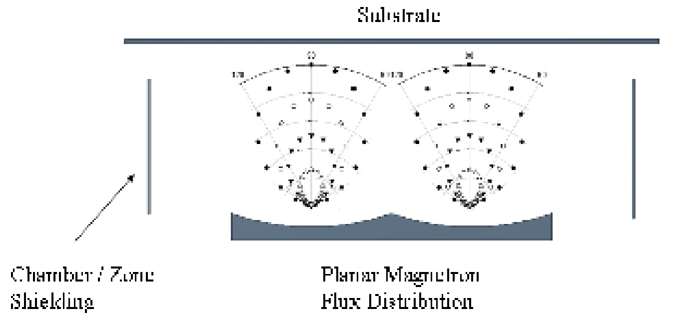
No End-Grooving!



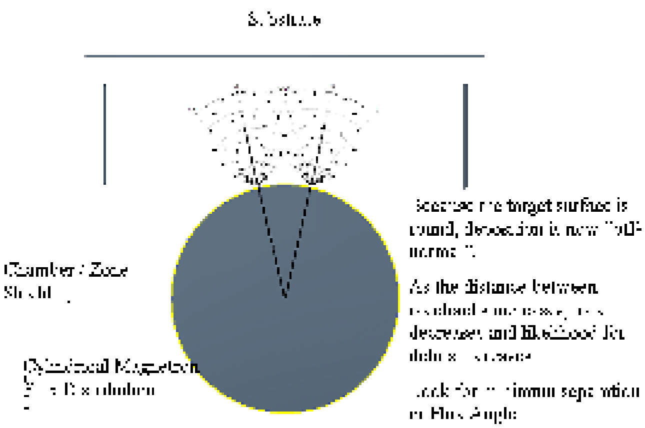
Deepest Erosion is along the length of the target surface

The angular flux of the racetrack is important to take note of with cylindrical magnetrons. Because the target surface is round, unlike the planar, the sputtered flux is much more “off angle” from normal.

Depending on this angle, it now brings shields into play with respect to film uniformity and the amount of time which the user can operate before debris is a problem.



The “normal” orientation of the material flux to the substrate helps to minimize the amount of debris migrating to the sputter shields



In Summary:

1. Rotatable Cylindrical Magnet Arrays can be tuned for thin film layers in uniformities of +/-2% or better
    - Look for ability to use spacers
    - Look for ability to use shims

1. Rotatable Cylindrical Magnet Arrays also have a large influence on uniformity stability and Rate or Throughput
    - Look for elimination of “End-Grooving”
    - Minimize the Angular Flux Between Racetracks