System geometry tuning

Improving uniformity with Gencoa simulation tool

Tuning the system geometry can improve uniformity of circular magnetrons and result in coating requirements being met for a specific application.

Coating uniformity simulation

For circular magnetrons, the uniformity on a substrate is determined by the coating flux distribution from the target surface. Geometry is also a major factor as the target diameter relative to the substrate size, and target to substrate separation will have major influences.

Generally for static coating of substrates the target needs to be much larger than the substrate. So, for example, a 10-12" target is typically required in order to coat a 6" substrate with good uniformity as long as the target to substrate separation is set at the optimum level.

For static deposition the magnetic field can also be tuned to manipulate the flux distribution to improve the coating uniformity. There are two types of magnetic concepts for circular magnetrons – a fixed magnetic array and a rotating magnetic array (FFE). This document will confine itself to the fixed type of magnetic system and a future technical paper will cover the FFE types in more detail.

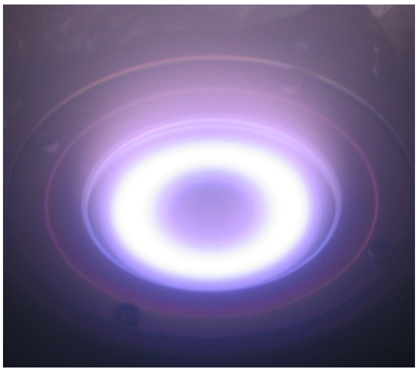

Figure 1 – single plasma trap

For target sizes of 6” or smaller the magnetic system will usually just contain one plasma trap (figure 1). For target sizes of 8” and over the magnetron can utilize a multi-ring magnetic design which enhances the uniformity tuning options (figure 2).

Figure 2 –Multi-ring plasma.

For the smaller single ring plasma the diameter and shape of the race-track will define the shape of the coating flux. As mentioned above, this basic magnetic field shape can be tuned to improve the uniformity for a given situation.

The flux distribution from a small circular magnetron provides a very limited area of good uniformity if the substrate is static and the target to substrate separation is small. Moving the substrate to a high separation will improve uniformity greatly from a small target, but the coating rate is much reduced (figure 3).

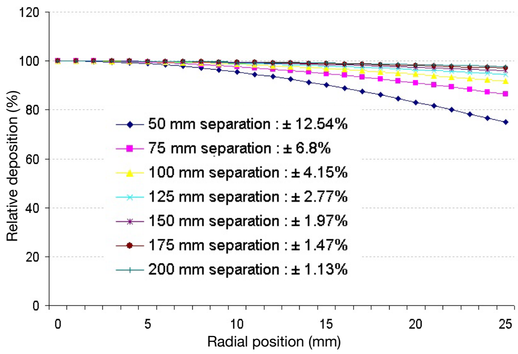

Figure 3 – SW50 uniformity at 50mm-200mm separation

Due to the modest area of uniformity from small sources, the off-axis and rotation of the substrate method is commonly used to improve uniformity over larger areas. This involves positioning the magnetron head away from the centre of the substrate and then rotating the substrate (figure 4).

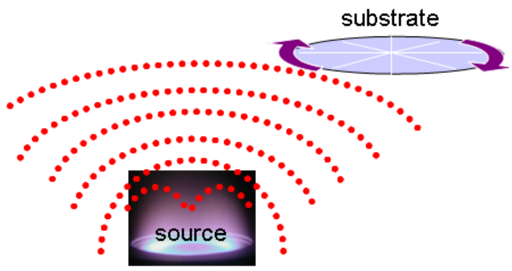

Figure 4 –Combined action of the vapour flux distribution with the substrate rotation can create high uniformity

Uniformity can be improved via the geometry of this arrangement as the shape of the coating flux works with the rotational effect of the substrate to equalize the rate of material arrival over the whole area. This arrangement is also low rate as the coating flux is distributed over a large area, but it allows multiple sources to be positioned around the centrally rotating substrate and hence opens up the possibility of multi-layer or co-deposition methods.

The success of the off-axis and rotation method will be determined by good lateral positioning of the magnetron head, the angle of the head relative to the substrate, the size of the target and substrate and the vertical separation of the substrate from the magnetron. This introduces five variables to the geometry, hence experimental determination of the best arrangement is a lengthy process.

Uniformity simulator software

Gencoa have developed a program that can predict the coating uniformity on a substrate. The uniformity simulation software calculates the sputtering probability across the substrate and hence a model of the coating flux from the target material can be generated.

The software can be used for improving target use or uniformity in an existing machine, or to help in overall process and system design prior to manufacture.

Correction factors can be added to the model to account for different target materials, since the angular sputtering dependance varies for each material.

There can therefore be some error which can be corrected by physical measurements and the subsequent introduction of a correction factor to the software model.

The program uses data from the finite element magnetic field modelling, and can consider many factors including whether substrates are on or off axis, and the required height of the substrate from the source. Also, for a given uniformity requirement, the optimum position of the substrate can be advised. Once the optimum position is found, the deposition rate in this position may be low, especially if offset distances are large. One method of increasing the rate is to tilt the magnetron in that position.

If the uniformity cannot be achieved, then some manipulation of the magnetic field may be required. By using the simulation software it is possible to predict the corresponding change in uniformity. In this way the uniformity can be tuned to a specific application requirement.

The uniformity simulator tool for geometric positioning of magnetrons (figure 5 and 6) is available free of charge to Gencoa circular magnetron customers. Please contact your local sales representataive to request a copy. If magnetic field adjustments are needed to drive the uniformity away from the standard, the Gencoa development team can assist as a contracted service.

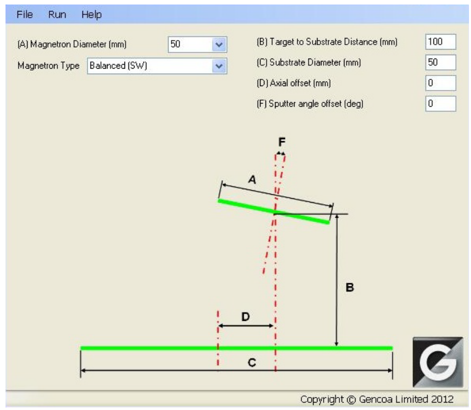

Figure 5 – Uniformity simulator

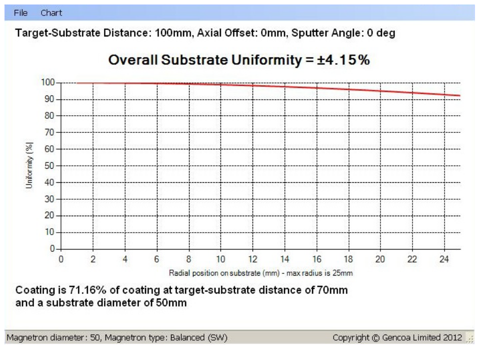

Figure 6 – Uniformity simulator

Redesigning the magnetic model

The application example shown to the left is for the sputtering of carbon across a 3.5" diameter static substrate, with a target diameter of 6" and target to substrate separation of 2".

In the example, a uniformity of ±4% is given. However, the requirement is for the uniformity to be ±2.5%.

Using the uniformity simulator, the magnetic field model was redesigned. The new magnetic field model resulted in an improvement of uniformity from ±4% to <±1.5%.

This is shown in the graph (figure 7, bottom right), which illustrates how the adjusted magnetic field model produces a uniformity which meets the application requirements.

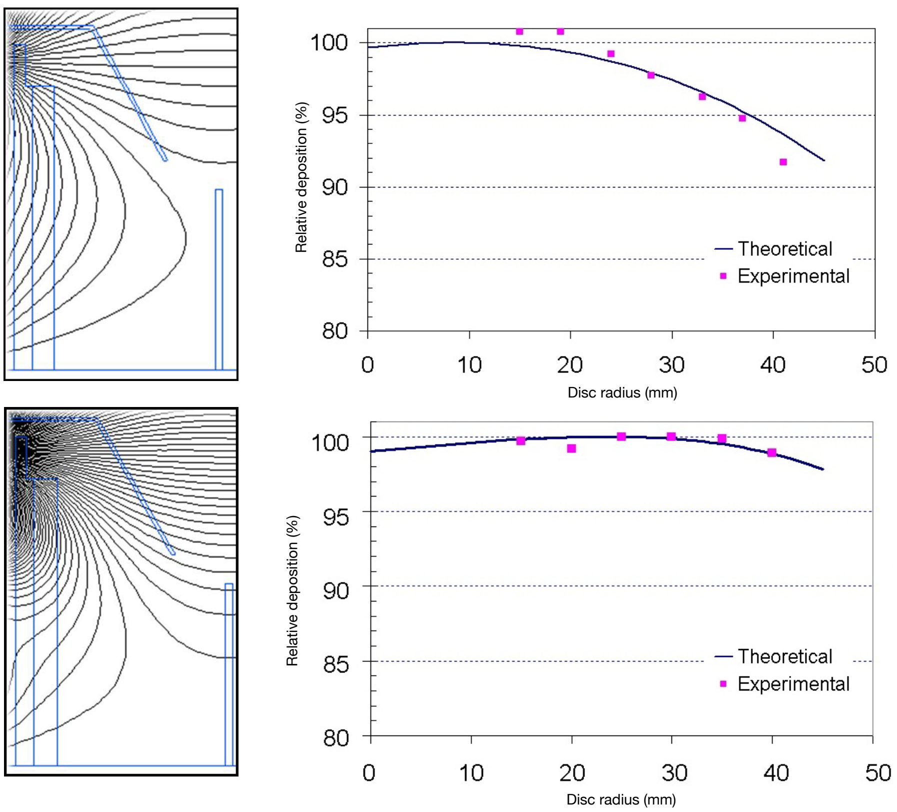

Figure 7 – Coating distribution on a hard disc. The graph shown on the top right shows the uniformity generated from the original magnetic model, while the images below show the redesigned magnetic field model, and the resulting uniformity improvement.