Rotary Cathode Sputtering Target Design Consideration

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Target Design Considerations:

Selecting a target design that is compatible with the magnet bar selection and process parameters can have a substantial impact on the target utilization, process performance, and process safety. Incompatible target design selections can greatly reduce the target material utilization, increase arcing on the target surface or clamps, increase debris generation, decrease deposited film homogeneity, reduce film uniformity, and damage the target or backing tube.

The primary target design considerations are focused on the turnaround section design of the target tubes. The turnarounds are the sections on the target surface nearest the target clamps in which the plasma that is formed in a continuous loop makes a 180 degree turn and travels back toward the opposite turnaround. The two turnarounds separated by the two straightaway sections forms the racetrack shape of the plasma confinement. The target tube is constantly rotating while the plasma is generating ions to sputter the target surface so the width of the total target area covered by the plasma in the direction of rotation multiplied by the local plasma intensity determines the local sputter rate and target erosion rate. At the turnarounds, the plasma surface area increases and with it the target erosion rate usually increases. The increased erosion at the turnarounds can wear the target material away faster than anywhere else on the target thus limiting the lifetime of the target material to the turnaround erosion rate. If the turnaround erosion rate is significantly faster than the straightaway erosion the target can be eroded through which can damage the backing tube or in the worst case erode though far enough to breech the water cooling passages and or break off the target tube.

Reactive sputtering processes add another layer of complexity to the target erosion process. If running a reactive process in the transition mode between metal mode and fully poisoned oxide mode, the erosion rate (J_Y) becomes a function of the arriving reactive gas (J_R), the width of the plasma area in the direction of rotation (P_W), and the local plasma density ($\rho(B)$).

$$J_Y \approx \frac{P_W * \rho(B)}{J_R}$$

This erosion rate and reactive process relationship can thus accelerate the turnaround target erosion unless the reactive gas flux increase locally.

Target Designs:

When using SCI magnet bars, there are three primary target designs to consider based on the magnet bar selection.

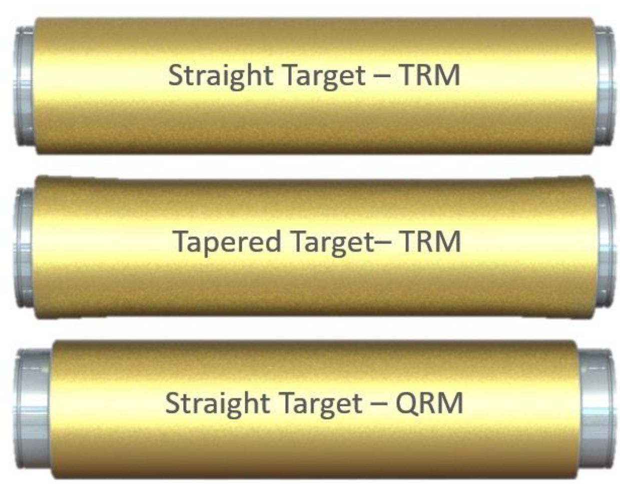

Figure 1: SCI target designs

The straight target for the TRM magnet bar is often used for metal mode deposition or with weaker turnaround magnets to improve the target utilization. The weaker turnaround magnets improve the target utilization but reduce the deposition uniformity. The tapered target design is used to increase the target utilization while minimizing the effects on deposition uniformity. This is done by increasing the diameter of the target at the location of the turnarounds with the taper design. The larger diameter increases the material inventory and simultaneously decreases the magnetic field strength above the target surface which decreases the plasma density. These changes result in a small decrease in the deposition uniformity and a large change in the radial erosion rate. The first order radial erosion rate is the derivative of the cross-section area of the target multiplied by the local plasma width and the change in the local magnetic field strength as a function of the target radius. The magnetic field strength is a third order polynomial with the constants a,b,c and d, a and c are negative coefficients, in the following equations:

Target cross sectional area:

$$A = \pi(r^2 - 132.5^2)$$

Target erosion rate:

$$J_y(r) = \frac{\partial A}{\partial r} * \frac{\partial B(r)}{\partial r} = P_W 2\pi r(r(3ar + 2b) + c)$$

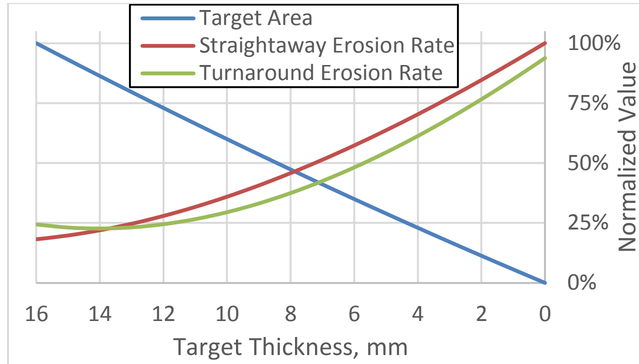

Figure 2: Normalized target cross-sectional area and erosion rate as a function of the target thickness for a straight target run in metal mode

With the TRM magnet bar on a straight target the turnaround plasma width is 142% wider than the straightaway plasma and the turnaround magnetic field strength in that location is around 70% of the straightaway. Multiply the two values and you find a result close to 100% or the value of the straightaway erosion rate. System and process based factors that can modify the plasma density or sputter yield such as distance to the anode and reactive gas flux account for the difference between these ratios and the actual erosion results.

The tapered targets with the TRM magnet bar provide a utilization advantage by starting the straightaway at 9mm thick and the turnarounds at 11mm thick. The taper has 148% the cross-sectional area of the straightaway cross sectional area and 97% of the straightaway erosion rate which results in 69% of the turnaround material being utilized at the end of the target life. The lower turnaround material utilization allows for operators for compensate for the plasma density and or sputter yield modification factors at the turnarounds that will increase the erosion rate.

The last standard target design option is the straight target for the QRM. The QRM magnet bar utilizes a turnaround design with multiple linearly offset curves to reduce the total plasma width and thus reduce the turnaround erosion further than the TRM magnet bar on straight targets.

The QRM magnet bar can be used with the TRM target design resulting in a band of un-sputtered material at each end of the target. The TRM cannot be used with the QRM magnet bar straight target because the turnarounds would extend past the ends of the target material and extend onto the QRM clamps. It is generally recommended to use the matching target design and magnet bars to prevent wasted target material, excess re-deposition onto un-sputtered target areas, debris generation, arcing, and damage to the clamps or target tube.

3rd Party Target Designs

Tapered targets not designed by SCI can become problematic if the target thickness decreases within the erosion area of the turnaround. The Soleras tapered target design shown in figure 3 has a chamfered end that the turnaround plasma from the TRM magnet bar will extend over. Depending on how far the turnaround plasma extends over this surface determines the starting thickness for a portion of the turnaround region. If the turnaround plasma confinement was to extend 50% onto this end chamfer, then the target material thickness would change from 14mm to 7mm and the corresponding target cross sectional area would change to 35% of the turnaround cross sectional area and start off with an erosion rate that is 2.26 times higher. This means that the target material in this section will burn through long before the straightaway target material is utilized.

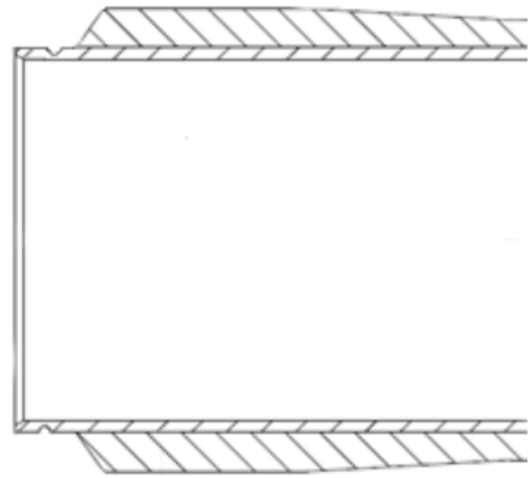

Figure 3: Soleras tapered target design with chamfered target end design

The Soleras tapered target design calls out for the end chamfer to extend into the target material along the axis of rotation by 10mm. If the magnet bar is centered to the target surface properly the plasma width at the maximum target thickness for the chamfer would be slightly larger than the plasma width of the straight away. If the magnet bar is shifted just a few millimeters in either direction about the target material, then the plasma width on the taper face will become significantly wider than the straightaway plasma width. The physical shape of the chamfer also causes problems since the magnetic field needs to be parallel to the target surface to enable magnetically confined sputtering. The turnaround magnets produce a magnetic field that is parallel to this tapered surface causing the plasma width to greatly increase and again reducing the target utilization. The last problem that this taper design creates for the TRM magnet bar is that the sputtered flux is directed toward the target clamps, end support, dark space shields, and chamber wall which can not only cause debris generation but can cause the clamps to heat up significantly. Repeated heating and cooling cycles can cause the clamps bolts to loosen or stretch and lots of debris to flake off the clamps surfaces.

To avoid problems with 3rd party target designs please review the target designs with SCI for before purchasing target materials.