Rotary Cathodes Basics – Sputtering Target Materials and Process

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Introduction:

Sputtering targets are the material that is transferred from the magnetron to the substrate during a sputtering process. Figure 1 below shows two SM cathodes with ceramic targets installed on them. For rotary cathodes, the sputtering targets are comprised of anywhere from 1 up to 3 distinct parts as shown in figure 2. The backing tube, a bonding layer, and the target material. The use of separate backing tube and bonding layers depends primarily on the type of materials required for the process and the manufacturing techniques that are available to produce the target. The length of the targets and the distance from the substrate, known as the TTS (target to substrate distance), determine the coating uniformity.

Figure 1: Two SM cathodes with ceramic targets

Sputtering Target Construction:

The target Material required for the sputtering application can vary anywhere from pure metals to conductive ceramics. Many pure metals can be made into single piece or monolithic targets that are machined from thick tubing or billet, if they are compatible with the cooling water that runs inside the targets and are not porous which can cause leaks into the vacuum system. Ceramic targets usually require the three-layer construction technique because they are not strong enough to support their own weight and the 5 to 7 bar water pressure inside the tube. Ceramic target materials are bonded to a titanium or stainless steel backing tube because these metals are non-magnetic and have a very low coefficient of thermal expansion. Differences in the thermal expansion of the backing tube material and the target material can lead to large stress concentrations in the target material during the bonding process and or sputtering process that can cause the ceramic materials to crack and break off. Indium is usually used as a bonding material between the target material and the backing tube because it has a very low melting point, good thermal conductivity, low chemical reactivity, and good adhesion to most materials. The low melting point of indium keeps the differential stresses due to the different thermal expansion rates low but also becomes the limiting factor for the sputtering power density that can be safely used on targets.

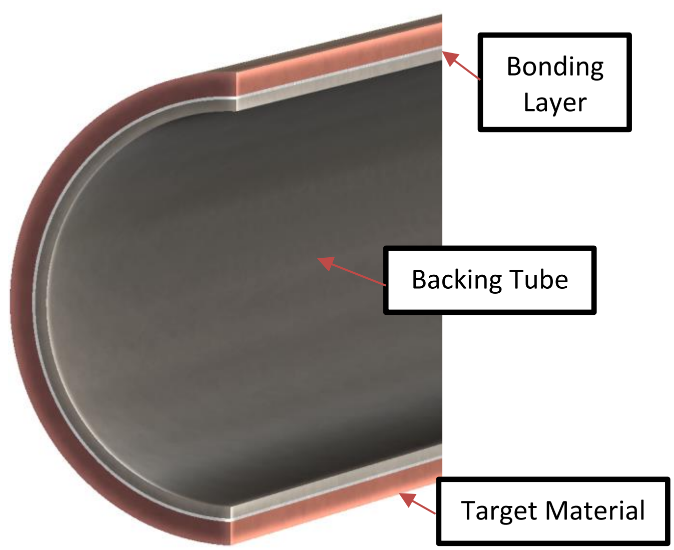

Figure 2: Target Material Cross Section

To maximize the sputtering power density for some ceramic materials or pure metals that cannot be made into monolithic backing tube a 2-layer structure can be formed using manufacturing techniques that either spray the material or press a powder into a solid on the surface of the backing tube. Eliminating the indium bonding material can greatly increase the maximum operating temperature of a target material assuming the coefficient of thermal expansion difference between the target material and backing tube is small enough to keep the target stresses low. Two-layer targets can also have drawbacks such as reduced target material density and inclusion of gas species in material that are released during the sputtering process which can cause some process contamination or stability issues.

The length of the target also dictates the construction techniques that can be used. Ceramic materials with coefficients of thermal expansion significantly different than the backing tubes may require the target material to be broken up into multiple sections on a backing tube to reduce the stresses that could cause the target material to break. The length of certain monolithic targets must be considered depending on the orientation of the targets and how much weight the target flanges can support without plastically deforming or breaking which can occur for brittle materials. The length of the target is a critical factor for the achievable uniformity and thus must be carefully considered during the process requirements planning phase.

TTS and Uniformity:

The TTS (target to substrate distance) and target length are used to define the achievable uniformity that a process can have from the start of the sputtering process all the way to the end of the target lifetime. The target length is typically the length of the substrate plus a multiplication factor for the TTS that ranges from 3 to 5, with the relationship shown in figure 3. Since the distance between the target surface and the substrate increases as the target material erodes away the TTS is constantly changing during the life of the target. The larger the TTS the poorer the achievable uniformity on the substrate thus the worst process uniformity occurs at the end of the target lifetime. Due to the mathematical simplicity, the TTS is usually measured from the target OD which will produce good initial results but the uniformity at the end of target life may be out of the uniformity specification depending on the initial target thickness.

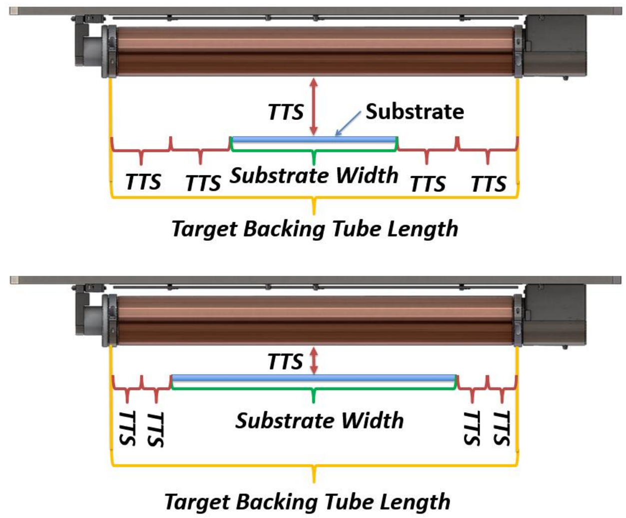

Figure 3: TTS, Target, and Substrate Length Relationship

To keep the uniformity from drifting out of the required specification the uniformity should be calculated for the initial and end of target lifetime TTS. This can easily be done with the online uniformity calculator in the process tools section of the sputteringcomponents.com website as shown in figure 4.

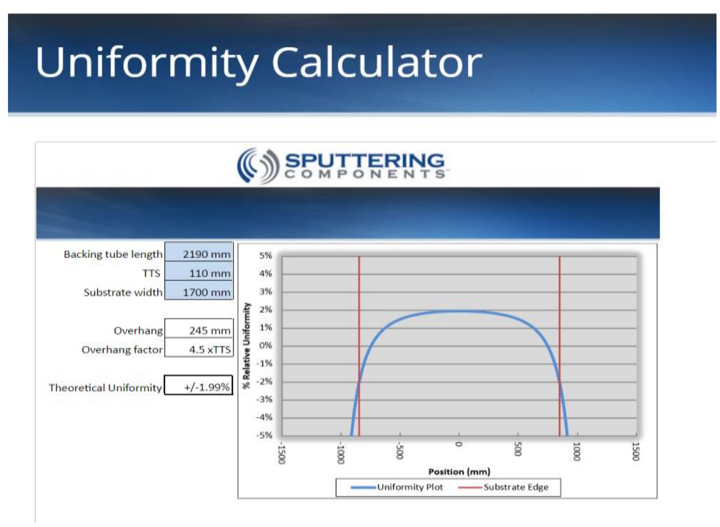

Figure 4: Online Uniformity Calculator