

Precious Metal Target Enhancements

Abstract

Sputtering is used in a variety of commercial applications. Cost is a major concern for thin film manufacturing, and it can be addressed by the deposition equipment or by the target design. A number of improvements to magnetron design have enabled higher target utilization, but these are not always practical when it comes to the use of precious metals. Precious metal target enhancements, such as the X-tended™ Life, HR™ Targets and Modular IBD Targets, are a way to offer improved precious metal utilization, reduced target costs and increased cycle times without any change to the magnetron.

Introduction

To a factory manager, the most important considerations in thin film manufacturing are throughput and cost. Of course, thin film properties and yield are important, but to the factory manager, these things are a given, and the problem of the product and process engineering teams.

Regardless of the industry, from semiconductor to solar, and LEDs to architectural glass coating, there is a constant drive to increase the throughput of capital equipment and reduce the cost of sputtered films. The requirements in terms of product performance and yield must not be compromised in this exercise. The requirements to improve throughput and reduce costs have driven a number of innovations in process equipment, magnetron and target design. Increasing throughput is fairly straightforward, though not necessarily easy or cheap to implement. Larger substrates can equate to higher throughputs, but the capital required for new equipment can be quite significant. Target enhancements enable one to increase throughput and lower costs through longer target lifetimes, minimized refining and reduced downtime, and can be implemented on both new and existing equipment.

Scaling in Thin Film Manufacturing

The capital equipment approach to achieving these goals has varied over time and by industry, but falls into a few general categories. In the semiconductor industry, batch processing was common in the 1980's, but gave way to single-wafer processing tools in the 1990's. The use of single wafer processing has remained the rule up to 300mm. The approach as the industry transitions to 450mm remains to be seen, but it is very likely that single wafer processing will continue to dominate.

The general trend in increasing substrate size and faster tact times has also been seen in the glass coating industry, for both sputtered coatings on architectural glass and transparent conducting oxides on LCD panels. Architectural glass is processed in sizes up to 3m x 6m, and the gen10 size in LCD glass is approximately 3m by 3m in size. Where throughput in the semiconductor industry is measured in wafers per hour, the glass industry measures it in meters per minute. The glass coating industry has adopted the use of large, in-line coaters to meet throughput and cost needs.

In the LED industry, where the use of relatively small wafers is common, batch processing tools are still used. The crystalline silicon segment of the solar industry uses mostly batch processing equipment, while the thin film segment of the solar industry uses mostly in-line processing tools.

What Types of Magnetrons are Used?

Another consideration in thin film manufacturing is cost – how much does it cost to deposit a layer of a given thickness on a substrate? The two main considerations for this are the cost of the target material and the target utilization. Target utilization is simply how much of the material is sputtered over the lifetime of the target, and is largely a function of the magnetron design.

In terms of magnetron design, the first types of magnetron to see widespread use were stationary planar magnetrons. Depending on the magnetron design and deposition geometry, stationary planar magnetrons typically have target utilizations in the range of 15% to 25%. Some of the earliest deposition platforms, such as the MRC 900 series, translated substrates underneath the target to improve uniformity.

In order to improve film uniformity, deposition rates and target utilization, two general approaches have been taken. The semiconductor industry has tended towards rotary planar magnetrons, where a magnet array is rotated, improving both film uniformity and target utilization. With rotary planar magnetrons, target utilizations in the range of 40% to 50% are typical. The Endura platform from Applied Materials was the most successful metallization system in the semiconductor industry. The Endura's success was due, in part, to its rotary planar magnetrons with full-face erosion, which featured excellent film uniformity, superior particle performance and long target lifetimes.

The architectural glass and display coating industries have tended towards cylindrical magnetrons, where the magnet array is held fixed and the target is rotated. With cylindrical magnetrons, target utilizations of up to 80% are commonly achieved in manufacturing. Cylindrical magnetrons are mostly used in in-line sputter coaters in a range of processes from transparent conducting oxide films in the solar and display industries to low-e coatings on architectural glass. While the target utilization performance of cylindrical magnetrons is very impressive, adopting the use of these magnetrons in semiconductor manufacturing has not been practical. They are very well suited for large in-line sputter coaters, but not so much for single-wafer cluster tools.

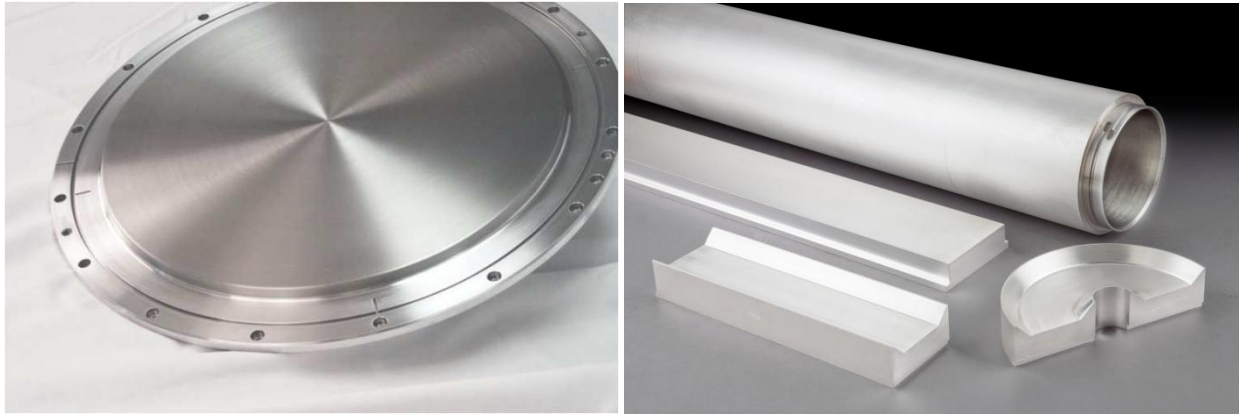


Figure 1: Image of a target for a rotary planar target (left) and cylindrical and planar targets (right).

Why are Targets Important?

There have also been a number of innovations in target design and manufacturing that have had an impact on system uptime, performance and cost, regardless of the sputter platform or magnetron type. These innovations address performance issues such as target lifetime, burn-in time, and film uniformity. These innovations are particularly important for precious metal targets. Precious metal target enhancements are relevant in many commercial settings, and with both new and existing magnetron sputter equipment.

Precious Metal Targets

The use of precious metals adds another dimension to the cost equation in thin film manufacturing. Precious metals are used in many market segments in thin film manufacturing. Precious metals used in thin film manufacturing include high purity gold, high purity silver, platinum, platinum alloys, gold-tin and gold-germanium alloys.

Pure gold is used in LCD driver chips, and gold alloys are used in die attach processes. Silver is used in applications ranging from the disk industry to solar and large area architectural coatings. Platinum is also used in the disk drive industry, as well as in medical applications such as blood glucose sensors.

Over the past year, with gold and platinum prices reaching the \$1750-\$2000 range, it has become even more important to make as efficient use of the target materials as possible. In general, thicker target designs allow for longer time between preventative maintenance cycles, which increases system uptime and improve cost of ownership. However, magnetron designers define the specific target thickness that can be used, which is based on the strength of the magnets used and the magnet array design. One cannot just arbitrarily increase the thickness of a sputter target.

X-tended™ Life Targets from Materion

Materion has created improved target designs, called X-tended™ life targets, which can be used to increase lifetime without making any changes to the magnetron design. With this approach, material is added to the target, but often only in the area of the erosion groove. This approach works with all types

of magnetrons, from stationary and rotary planar magnetrons to cylindrical magnetrons. An example of this can be seen in the Figure 2, which shows an X-tended gold target. This method is particularly well-suited for manufacturers with existing equipment, who may not have the capital or schedule to upgrade their system with new magnetrons.

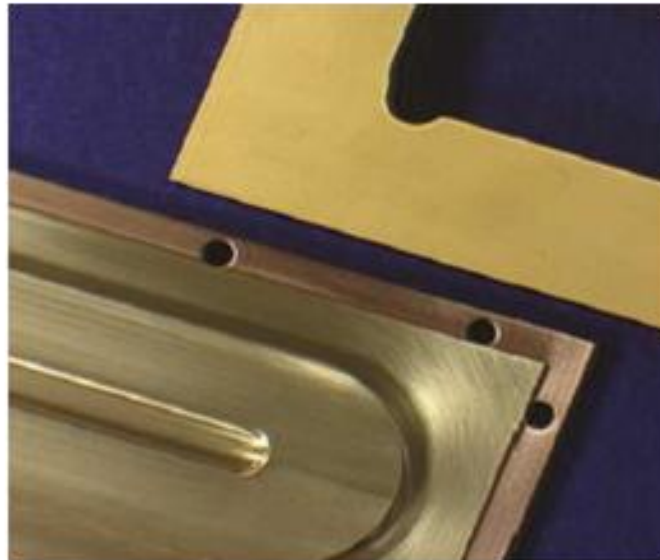


Figure 2: X-tended™ life gold target

Gold sputtering is commonly used in LCD driver chips, or the “gold bump” process. Gold bump manufacturers use deposition platforms with either stationary planar magnetrons, or rotary planar magnetrons. Another precious metal application is the die-attach process, in which AuSn alloys are commonly used. The X-tended target is particularly well-suited for precious metal applications such as these. Using this method, lifetime can be improved by as much as 50%, with cost of ownership savings as high as 35%.

X-tended™ life targets have been designed for a number of commonly used magnetrons and material combinations. If an X-tended™ life target does not already exist, there is a standard procedure to generate one. First, the customer sends a spent standard target to Materion to measure its erosion profile. It is measured at very high resolution with a coordinate measuring machine (CMM) to map the erosion profile. It is recommended to send several spent targets, particularly if the customer has

multiple deposition systems. Figure 3 shows an image of a spent target with the erosion profile measured using this method.

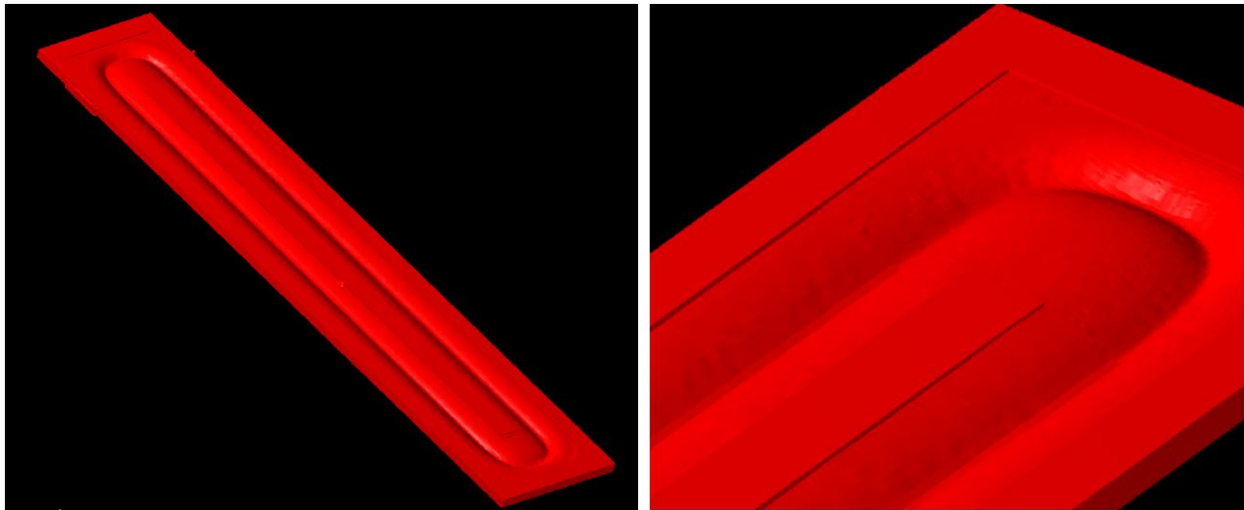


Figure 3: Spent target with erosion profile measured using CMM

With the erosion profile measured, Materion generates a proposal for an enhanced target design, with an estimate of the improved target lifetime. Targets can be designed to maintain the same starting weight or reduced to maintain the same number of runs with a reduced target weight. The cost of ownership can be addressed using either approach. The enhancements are provided without any change in grain structure, thus target performance will be consistent throughout the life of the target. With a choice made, the customer can purchase and test the target to verify its lifetime. Another iteration of the procedure may be required to achieve the best possible lifetime for the enhanced target since the target flux may change slightly.

This method is particularly useful for customers with a large installed base of equipment, with no capital to upgrade or buy new equipment. With this approach, no changes are made to the magnetron, so there are no changes to the process, which makes it very low risk for implementation in manufacturing. With the X-tended™ life target design from Materion, the customer gets a longer target lifetime, higher target utilization and a longer time between preventive maintenance cycles without any expensive equipment upgrades.

HR™ Targets from Materion

Another area of improvement in precious metal targets is in the amount of time it takes to burn in the target. Metallic targets typically have surface damage from the target fabrication process that must be sputtered away before the film properties stabilize. The burn-in time can vary, depending on the target material, fabrication techniques and surface quality of the target. By optimizing the target fabrication and surface quality, the target burn-in time can be reduced.

In the case of platinum, gold and silver sputtering, a “hot-roll” process can be used to fabricate the target. This process leads to targets with much finer grain sizes compared to standard techniques.

Figure 4 shows a gold target fabricated using standard techniques on the left, and HR™ target on the right, created using a hot roll process. The HR™ process results in targets with shorter target burn-in times and improved film uniformity. The shorter burn-in time and improved uniformity can be attributed to the smaller grain size for the HR target.

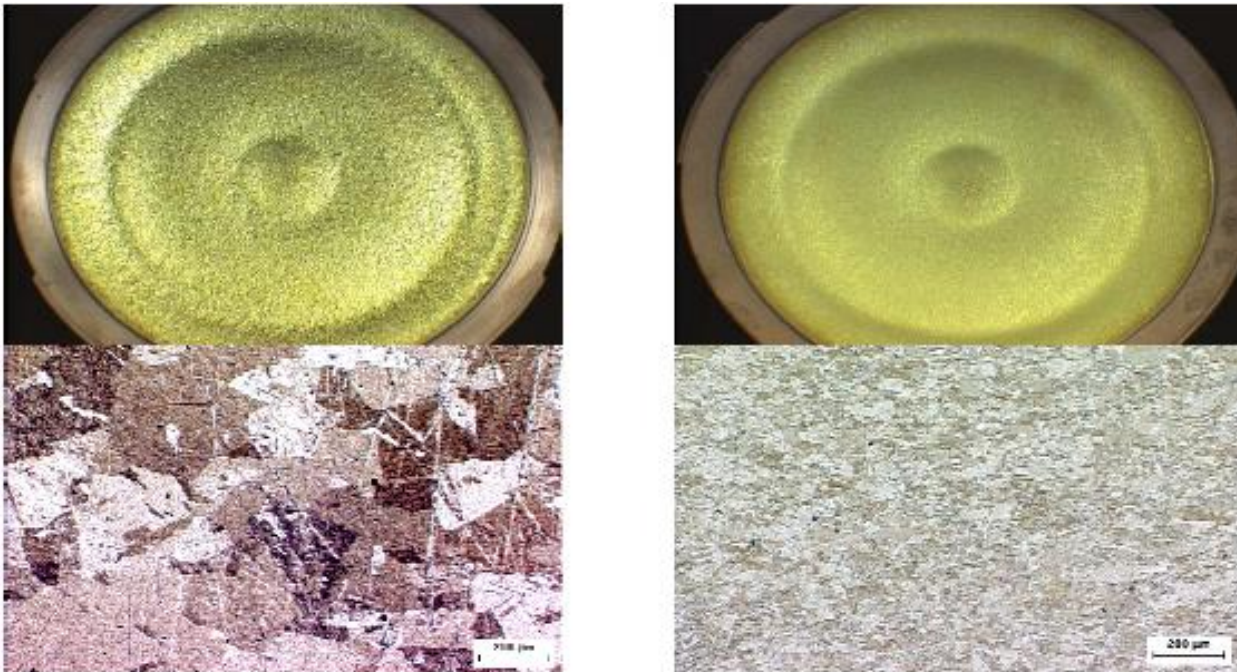


Figure 4: Standard gold target with large grain structure (left) HR™ gold target with small grain structure (left)

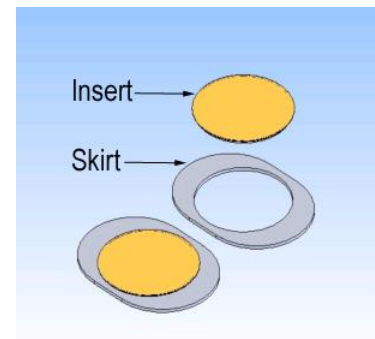
Modular Design Targets for IBD

Ion Beam Deposition (IBD) systems provide many advantages when depositing certain films. Among them are high-energy film growth, precise thickness control and high purity films. However, target utilization is not one its strong points.

In some cases the ion beam only covers a scant 40% of the target surface and when accounting for a safety factor to prevent a burn through, less than 10% of the target's weight is used before changing the target. This is not considered a major issue when non-precious metal targets are used, but this can create high costs for materials when semi-precious metals like Ta are used. Even higher costs are incurred for refining fees when precious metals are deposited by IBD.

Materion engineers have designed a solution to this costly problem - a two-piece modular target design.

This patented design keeps the large area target (skirt), which is needed in case of beam "wander", but uses a small, replaceable "insert" in the center of the target where 99% of the beam is concentrated. Therefore, when the target gets to the end of its life, only the insert needs replacement and sent out for refining.



Consider this case. A user is depositing ruthenium by IBD and the standard target size is such where it uses 255 troy ounces of Ru. Normally the "spent" target weighs around 240 troy ounces. So that 240 ounce target would need to be sent out for refining so it can be reused for future targets. The cost to refine that target would be almost \$6,500. With a Materion modular target, the new insert would weigh a mere 100 troy ounces and the spent insert 85 ounces. Instead of sending 240 troy ounces for refining, you're only sending out 85 troy ounces at a cost of less than \$2,300 for a savings of \$4,200 on every target change.

The patented Materion modular target design has been proven in rigorous production applications for over seven years. Modular target materials used in production include: CoCrPt, Cr, WTi, Ta, Rh, and CoPt. If you are using precious or semi-precious materials in an Ion Beam Deposition system, contact Materion to see if the modular design is right for you.