Rotatable sputter targets and advanced rotatable magnetrons will further transform the coating marketplace through increased material efficiency and cost reductions.

**Steven Luys**  
*Bekaert Advanced Coatings N.V.*  
*Deinze, Belgium*

**Magnetron sputtering** is a vacuum coating process for depositing thin films on glass. Since their invention in the late 1960s, sputtering electrodes have undergone a developmental revolution. The most significant technological advances are rotating cylindrical magnetrons (Fig. 1) and advanced rotating cylindrical sputter targets (Fig. 2). These two parallel developments have enabled manufacturers to boost coating throughput and reduce cost, while maintaining layer quality and thickness consistency.

This article shows that rotatable magnetron sputtering is the most economical and results-driven process available today because of remarkable R&D advancements in technology, process, and engineering. The many shortcomings of planar magnetron sputtering techniques can be overcome by the adoption and implementation of rotating cylindrical technology. There are three significant advantages to adopting the rotating cylindrical magnetron sputtering method, they include: superior material inventory, a higher degree of utilization, and the possibility to triple the power density, resulting in much faster sputter rates or in more complex stacks.

**Rotatable sputter targets**

As the market interest in vacuum coating by magnetron sputtering grows, target manufacturing is consequently expanding. Thermal spray is the preferred technology to manufacture sputtering targets, because it offers a broad range of capabilities to meet these very complex manufacturing demands. Three parameters directly impact total cost of ownership:

- **Material composition:** Doped materials can be produced in both stoichiometric and non-stoichiometric compositions without the limits of phase diagrams, allowing operators to develop specific coatings that cannot be made via classic target casting technologies. Thermal spraying does not need to take possible restrictions of limited solubility into account with thermal spraying: Any mixture of two materials can be processed by simply mixing the appropriate fractions together before spraying.
- **Expanded coverage:** Nearly all materials can be sprayed, from low-melting point metals to high-melting point ceramics.
- **Target flexibility:** Long-life (dog-bone shaped) targets increase thickness of the material at both ends. As a result, high target material utilization is possible with most materials and for different target lengths (up to 152 inches), and are easily produced.
- **Film composition:** Typical thin films and coating stacks, such as SnO₂, TiO₂, SiO₂, and Si₃N₄, can be made via advanced cylindrical target tubes.

**Silicon aluminum targets**

Thin films of SiO₂ and Si₃N₄ are sputtered from Si(Al) targets. The successful production of Si(Al) targets by thermal spray takes advantage of key
spray process features. Its inherent flexibility for target geometry allows a wide range of target diameter, length, and straight or dog-bone target ends, while maximizing target sputter capacity by increasing the target layer thickness up to 9 mm. Aluminum dopant levels can range from 0 wt% to 19 wt%, with strict controls over the final chemical composition. By changing from standard 6 mm thick targets to the new 9 mm targets (containing 50% more material), coating cost can be reduced by up to 3%, and uptime can be raised by 5% because of fewer target swaps.

High-density tin
Standard thermal-sprayed tin targets have 90% of the required theoretical density, with an estimated oxygen content of 2000 ppm. However, advances in thermal-spray technology have resulted in a new high-density tin target, reaching more than 98% of the required theoretical density, combined with oxygen content below 250 ppm. This advance combines the benefits of thermal spray technology with high-density structures.

Defined in terms of arc rate, burn-in behavior, deposition rate, and current/voltage characteristics, the sputter behavior of the high-density tin target demonstrates superior performance. In addition, advanced thermal spraying allows for precise tuning of the grain morphology, grain orientation, and material density. These flexible adjustments optimize performance to provide specific sputter or coating characteristics, resulting in significant cost savings.

Titanium oxide
A perfect illustration of how thermal spraying results in a value-added target product is the production of TiOx targets. First, the high process temperatures allow the ceramic titanium oxide to melt. Simultaneously, the titanium oxide undergoes partial reduction with the process gases, transforming it into an electrically conductive phase. At high cooling rates, it remains conductive at room temperature. This material greatly enhances stability during reactive processes, without requiring a feedback loop process control system, yet it still improves sputter deposition speed.

Indium tin oxide
Indium tin oxide is one of the top performing transparent conductive oxides available to the display market. Applications include flat panel displays, such as LCD, PDP, and OLED, in which the indium tin oxide layer serves as a transparent electrode.

Planar ceramic targets consist of one or more tiles bonded to a metallic backing plate. Today, reactive DC magnetron sputter deposition from a planar ceramic target is the most widely deployed technique for deposition of indium-tin-oxide (ITO) coatings on glass and plastic substrates. In spite of their popularity, planar targets have several intrinsic restrictions because of their planar structure.

Rotating cylindrical ITO targets resolve many of the limitations of planar ceramic ITO targets. Some of its inherent advantages include:
- Larger useful target inventory and increased target material utilization, both of which lead to reduced machine downtime.
- Increased process stability for reactive deposition.
- Improved target cooling, which increases power density and raises the deposition rate.
- Preliminary field tests have shown that total cost of ownership can be reduced by more than 40% per square meter while doubling the utilization of targets.

Three magnetic effects
Control of the magnetic field is important because it affects three key characteristics of the sputtered coating: thickness uniformity, high deposition rate, and maximized target utilization.

More-demanding sputter applications necessitate stricter thickness uniformity. The accepted standard is usually a few percentage points for a substrate width over three meters. Magnetic field strength is the most effective way (next to gas tuning) to adjust the deposition profile to provide ideal coating uniformity.

The magnetic field at the target surface must be carefully controlled in order to combine the highest possible deposition rate, optimized thickness uniformity, and maximized target material consumption.

To answer these three magnetic technical challenges, Bekaert has introduced a new Adjustable Magnet Bar designed for large area rotating cylindrical magnetron sputtering. Incorporating recent magnetic and mechanical enhancements, the complete magnet bar is essentially a combination of magnets on a pole piece attached to a water conduction tube. The bar is robust, easy to handle, and qualified for an off-line measurement setup. The new design is suitable for horizontal as well as vertical applications, and offers enhanced and
more flexible tuning of the magnetic field while optimizing target utilization. The magnet bar is critical for high-performance glass coaters operating at high coating levels.

**Rotatable magnetron end blocks**
Rotatable magnetron technology is featured in a new generation of hardware that integrates two advanced techniques. These two technologies combine to resolve the complex challenges of high-power AC sputtering, thus improving technical performance under a wide variety of operating conditions.

- **Improved current transfer:** This innovation has been incorporated into the Bekaert ACV3 End Block (Fig. 3) through a drum-type slip ring, which was specifically designed to maximize potential current density while minimizing brush wear. This allows extended service intervals while reaching currents up to 400 amperes.
- **Advanced water sealing:** This improvement has been achieved by replacing the lip seal with a mechanical seal that is resistant to small water-pressure shocks. The mechanical seal is self-lubricating and wear-resistant.

These two new features complement the double dynamic vacuum seal that is designed for both water-atmosphere and atmosphere-vacuum conditions, augmented by intermediate leak-checking capabilities. This important feature enables users to avoid catastrophic failures by proactively detecting seal breakdowns before they happen, without interrupting a running coating campaign.

Magnetron sputtering is the most economical and results-driven process available today because of remarkable R&D advancements in technology, process, and engineering.

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For more information: Steven Luys, Bekaert Advanced Coatings N. V., E3 Laan 75 – 79, BE 9800, Belgium; tel: 32 9 381 6161; e-mail: info@bac.com; website: www.bekaert.com/bac.