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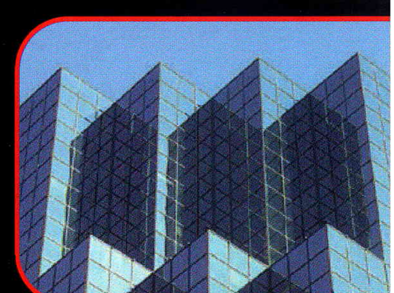
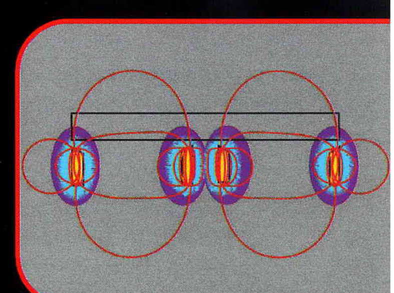
Magnetically Enhancing the Glass Coating Industry

A solutions article of the retrofit magnet designs produced by Angstrom Sciences, Inc. for glass coating operations.





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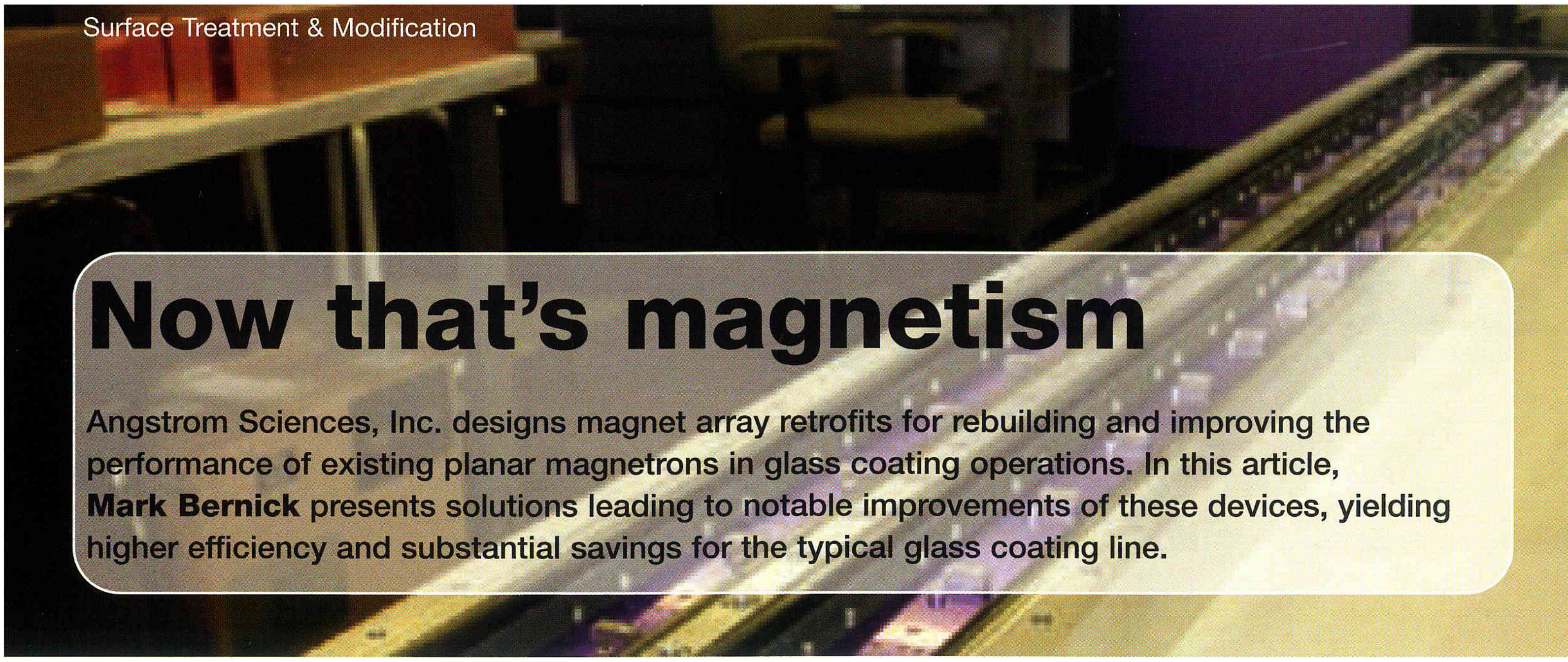


Now that's magnetism

Angstrom Sciences, Inc. designs magnet array retrofits for rebuilding and improving the performance of existing planar magnetrons in glass coating operations. In this article, Mark Bernick presents solutions leading to notable improvements of these devices, yielding higher efficiency and substantial savings for the typical glass coating line.

Do you have an old BOCCT style planar magnetron body lying around? Maybe the magnets have deteriorated to the point where the cathode is no longer in service. What do you do with a poorly performing cathode? Are you interested in a retrofit that would cut material cost and improve run times? This article may give you some ideas as to how to make the most of your repair budget by providing information on an effective way to retrofit existing planar cathode bodies with a new, modular magnet array.

There has been a steady rate of development in vacuum coating plant technologies. Much work has been done to improve gas distribution systems, reactive gas monitoring techniques, and power delivery systems to the planar magnetrons. Through all of these changes however, the planar sputtering cathode has remained essentially the same. Planar cathodes have been relegated to primarily sputter base metals while the rotating cylindrical style cathodes have been dominating the reactive sputtering processes. As such, very little effort is being put into improving the state of the planar magnetron.

Improved Magnet Array

How can a planar sputtering cathode be made to work more efficiently? The answer lies in the new materials available today for the heart of the sputtering gun – the magnet array. The use of newly developed high-energy product materials result in effective use of space behind the target by reducing the size of the magnets. Figure 1 shows a cross-section view of an original BOCCT magnet (top) and the improved Angstrom Sciences retrofit module (bottom). Note how the bulky original magnet structure is made of solid magnetic material. In comparison, the Angstrom Sciences retrofit module has two widely separated poles mounted on an anodized aluminum plate. This provides nearly 20mm of additional space in the coolant channel between the poles, resulting in greater cooling efficiency during the sputtering process. The difference, clearly seen in the side-by-side comparison of Figure 2. This separation of the magnetic poles in Angstrom Sciences patented design also provides a flatter magnetic field across the sputter target area, greatly improving target utilization. The theorem behind this is relatively well known. Electrons, following the Left Hand Rule, confine to a path that is at right angle to the E x B vectors. Essentially, the more magnetic field lines parallel to the face of the target, the wider area of electron capture. This leads to a wider area of ionization with the sputtering gas media and a wider erosion pattern through the target. Figure 3 shows the resultant target erosion improvement with comparative target cross-sections from the original magnet array (Top) and the Angstrom Sciences retrofit magnet array (Bottom). Both targets operated under the same conditions for the same length of time. Through measurements made with a three-axis Hall type probe, we can examine the relative shape of the magnetic field in both the original magnet assembly and the retrofit module. These measurements yield a predictive insight into the resultant shape of the target erosion in both cases. In Figure 4, we show a comparative plot $\tan^{-1}$ Bn/Bt of both magnet sections where Bn represents the magnetic field component that is perpendicular to the plane of the target; Bt represents the transverse component of the magnetic field that is parallel to the plane of the target going from magnetic pole to magnetic pole. Note that the retrofit has a much flatter profile. Increasing the distance between the two magnetic poles coupled with special profiled magnet poles, which is at the heart of Angstrom Sciences' magnet technology, yielded higher target utilisation.

To be fair, numerous magnet systems have been developed over the years by other companies expressly for flattening the Bt component of the magnetic field. Such magnet assemblies usually employ smaller pilot magnets to bend Bt in subtle ways. However, adding more mass to the magnet array incurs the potential liability for heat storage. In planar sputtering guns that see heavy-duty cycles and relatively high powers, it

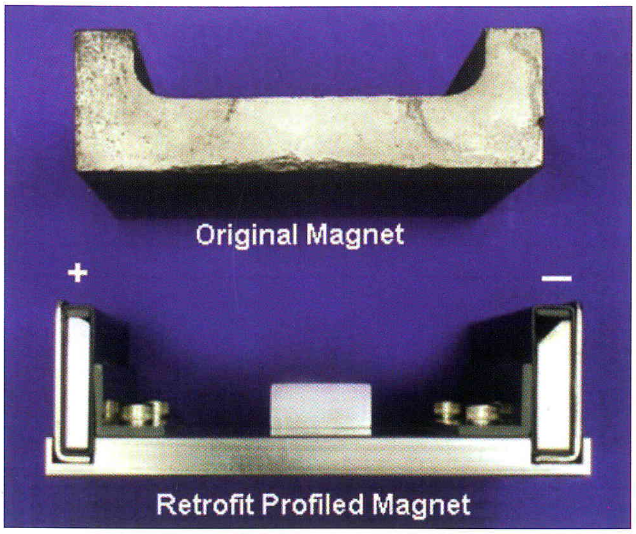


Figure 1: Cross section view of both an original magnet array section (top) and a retrofit (bottom)

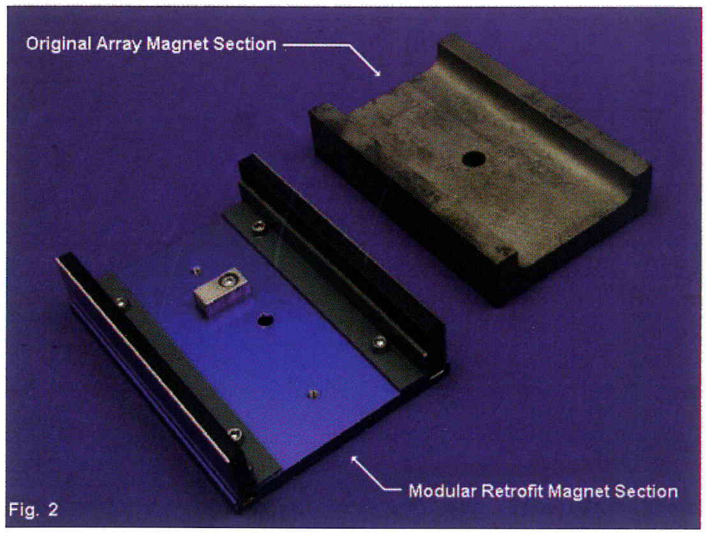


Figure 2: Comparison of a retrofit magnet array section (bottom left) to an original magnet section

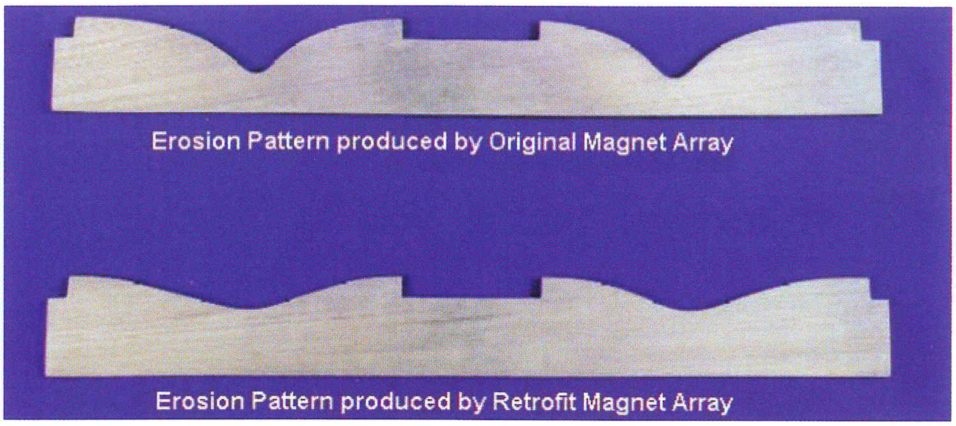


Figure 3: Cross-section view of target erosion using an original magnet array (top) and a retrofit array (bottom) for the Same kW-Hr usage

becomes important to keep the magnet mass low to allow as much heat to be liberated to the coolant as possible (we will get more into that shortly). Many smaller magnets can be a source of non-uniform magnetic fields as well.

The relationship of Bn and Bt is just one factor in how the magnet array will perform during actual sputtering. The magnitude of both Bn and Bt are also important. The magnet array must be capable of providing a magnetic field strong enough to result in effective electron confinement. By utilising higher energy product magnet material in the modular magnet array, it is possible to significantly reduce the magnet mass while boosting the magnetic field over the target.

It is true that higher energy product magnets are much more sensitive to heat. In production, long duty cycles and high powers tend to take their toll on any magnet material. The nearer a magnet material works to its Curie temperature (temperature above which the magnet will lose its magnetic properties) the more likely it will suffer irreversible damage. If the cathode has suffered an appreciable loss of magnetic field strength, it cannot efficiently confine electrons and sustain a plasma to sputter. This typically happens when a magnetron sputtering gun is run without coolant flowing to it. By increasing the size of the coolant channel around the magnets and reducing the thermal mass of the magnets themselves, Angstrom Sciences retrofits operate stably, even at the most demanding duty cycles.

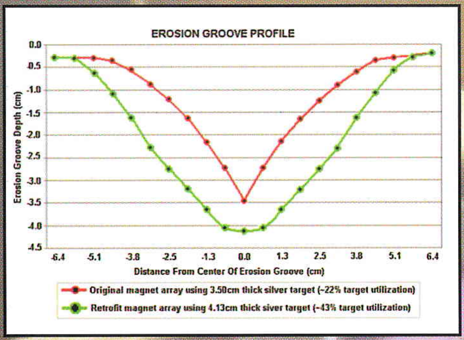
Benefits of increased target utilisation

With a rebuilt BOCCT type planar magnetron employing Angstrom Sciences patented magnet technology, we are able to increase typical target utilisations from 20% to 40%. Figure 5 shows actual erosion measurements from a customer's target using the original magnet array in a BOCCT style planar magnetron and the same cathode after an Angstrom Sciences rebuild. The cathode in both instances is running with a silver target sputtering low-e coatings. Target utilisation becomes a key issue when running semi-precious and precious metal targets. The more product run with one target, the lower the ultimate cost of the product and the more efficient the process becomes.

Modular approach

The modular approach to a magnet retrofit is also a great benefit. Changes in individual magnet sections in the array can be made. Such changes can make up for the uneven erosion noted in some target materials or system effects noted in the target wear patterns.

Figure 6 illustrates the broader erosion that can be obtained at the turn-around target section. This has a net effect of increasing the film uniformity in sputtering plants where uniformity is marginal. The modular sections also make a limited change out possible, should some parts of the magnet array become damaged. Another key advantage is that the magnets are not in direct contact with the coolant liquid. The individual magnets are plated and assembled in sections, which are encapsulated in a PVC sleeve. This system yields a magnet array that is guaranteed for two years.



Increased target life

When comparing target life between a BOCCT style planar magnetron with the original magnet array versus an Angstrom Sciences retrofit, customers have noted on average a 25% increase in target life. This is done through actual weight measurements of targets that have been run with the original magnet array and the retrofitted magnet array. In both instances, the targets were expended in production, sputtering low-e coatings.

Quick and affordable retrofit

The primary effort of the retrofit is to minimise expense to the customer by re-using as much of the planar cathode body as possible. In a BOCCT-style cathode, the primary aluminum cathode body undergoes several manufacturing steps to complete the retrofit. First, the old magnet array is machined out of the aluminum body to make room for the new magnet array. Second, the body undergoes minor machining operations to add tapped holes to hold the individual magnet modules. Last, the modules are assembled into the refurbished aluminum body. We employ a three-axis hall sensor to accurately map the finished array. The resulting retrofit is shown in Figure 7, ready to ship. The cost of the retrofit is approximately one third the price of a new planar magnetron. While retrofits are subject to our production schedule, generally all of this can happen within the time frame of one week.

Future Plans

Planar sputtering guns are just one aspect of the glass coating plant. Through continued research and development, Angstrom Sciences is experimenting with a potential retrofit for the cylindrical, rotating sputtering cathodes. Employing the same type of engineering and design we have used in the planar retrofits, we hope to offer a cost-effective and performance-enhancing solution to retrofitting your existing cylindrical cathodes.

It's simple

We have shown how a simple magnet array retrofit to a planar magnetron sputtering cathode can be cost effective, timely, and lead to improved performance. They have been exposed to the most demanding production applications and they have worked reliably. Angstrom Sciences is a recognised leader in the design, engineering, and manufacture of magnetron sputtering cathodes. Founded in 1988, the company supplies a broad range of standard products from research and development to production applications. They specialise in custom designs and will build to specific process requirements.

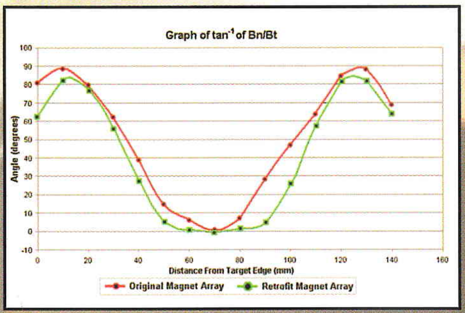


Figure 7: Completed retrofit ready to ship

Figure 6: Manipulating end erosion patterns to extend substrate uniformity

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