New Sputtering Targets: to Test or Not to Test?

J.O. McGeever, Technology Assessment International, Cranberry Township, PA

Key Words: Sputtering target; Sputter deposition; Sputtering materials; Reactive deposition

ABSTRACT

When a vendor approaches you to try a new sputtering target, this usually means changes to your established process and the risk associated with any change. How do you assess whether or not the benefits promised by the vendor justify the risk of a trial? How do you do this if you have no performance data? Fortunately, it is possible to make such an assessment with a little sensitivity analysis applied to a simple spreadsheet, as long as you have some qualitative information about how the new target differs from your existing targets. This paper will outline the method behind such an approach and analyze several examples to illustrate it, including silicon-aluminum. This is a method anyone can use.

JUSTIFYING A TEST

"It takes time to persuade men to do even what is for their own good."

Thomas Jefferson

If the performance data were available, an economic assessment of the value of the product could be conducted and a buying decision made. The key to obtaining reliable performance data is to conduct a test, but whether it is done in a lab or on a production line, there are associated costs and risks.

Potential benefits from the change generally fall into five categories: new markets, quality, reliability, productivity and enabling other productivity gains. The last one occurs when the process/technology being considered for replacement is a bottleneck. I will ignore the first one as that is a topic worthy of another discussion. For the other four, a comparison is most easily made by assessing all four on the same scale: the "bottom line".

MEASURING ALL BENEFITS ON THE SAME SCALE: THE BOTTOM LINE

Making a rational decision on whether to test or not to test involves speculating on the performance and constructing a cost analysis comparing operating costs per unit of output under current conditions to cost per unit with the new target. The basic information required is shown in Table 1. Entries in bold characters are the inputs to the spreadsheet. Other values are calculated from those.

Table 1

OPERATING PARAMETERS	**Current**
Cost of the Line/hour	**$5,000**
Number of hrs Between Target Changes	**252**
Number of hrs of Shutdown per Change	**8**
Duration of a Production Cycle	260
# of Production Cycles per Year	33.69
Current # of Productive Hrs per Year	8490

Let us take an example. The target currently being used is a rotary silicon-aluminum target produced by plasma spraying elemental powder (aluminum powder blended with silicon powder). The rotary target being considered is made by hot isostatic pressing (HIP) of pre-alloyed powder. In this process, a powder of the desired alloy is first made by melting the alloy and inert gas atomizing it. In a second step, the powder is consolidated by HIP, an inert gas forging process that results in high density. Figures 1 and 2 illustrate the microstructures of the two targets.

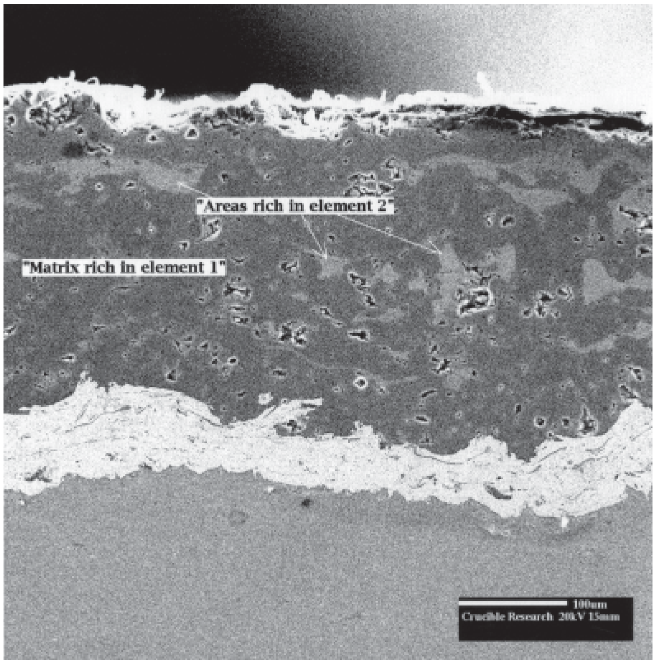

Figure 1: Microstructure of plasma sprayed silicon-aluminum. *Photo courtesy of Crucible Research, Pittsburgh, PA.*

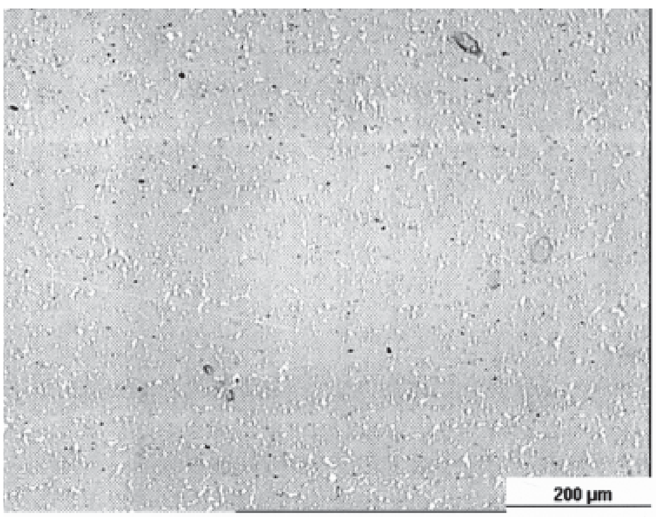

Figure 2: Microstructure of HIP pre-alloyed silicon aluminum. *Photo courtesy of Crucible Research, Pittsburgh, PA.*

HIP has no limitation on the thickness of the target, so the target can be twice as thick as what is currently used. The impact on the process is that the time between target changes would be twice as long and a smaller number of hours would be spent on downtime. Table 2 shows the impact on productivity.

Table 2

OPERATING PARAMETERS	**Current**	**After Change**
Cost of the Line/ hour	**$5,000**	
Number of hrs Between Target Changes	**252**	504
Number of hrs of Shutdown per Change	**8**	8
Duration of a Production Cycle	260	512
# of Production Cycles per Year	33.69	17.11
Current # of Productive Hrs per Year	8490	8623
BENEFIT OF THICKER TARGET		
% increase in target thickness		**100.00%**
% Increase in Productive Hrs		1.56%

In this case, doubling the thickness could lead to a 1.56% increase in productivity. We will see later in this paper how to convert this to a dollar value. When we do, it will become apparent that this small number, seemingly too small to possibly even detect, represents savings in the millions.

DEALING WITH ABSENCE OF DATA

It is generally perceived that there is no reliable information unless the product has been tested in a facility similar to yours. However, such is not the case. You have quantified information such as your operating costs, your operating parameters (output, rates, reject rates, downtime, etc.) and the vendor has quantitative information about its product (price, physical characteristics, etc.). Your understanding of your process should allow you to consider the characteristics of the new target and decide if it would improve or worsen productivity, rejection rate, etc.

The current target is porous but the new target is essentially non-porous. It might reduce particulate ejection and allow the use of a higher power input. This could permit speeding up the line and result in a productivity increase. Let us speculate on a 5% increase in line speed (Table 3).

The less porous target might also reduce the rejection rate. Let us suppose that the rejection rate, now 2%, is reduced to 1.6%. This reduction can be regarded as an increase in productivity since more salable product will be produced in the same time interval (Table 3).

Table 3

INCREASE IN LINE SPEED	**Current**	**After Change**
The targets are denser. The power input might be increased without increasing spitting. This would increase the line speed.		
Increase in Speed Due to High Density		**5.00%**
REDUCTION IN REJECTION RATE		
Uniform chemistry and reduced spitting could increase yield.		
Percentage of Rejection	**2.00%**	**1.60%**
% Increase in Productivity from Lower Rejection		0.41%

Before we convert the increased productivity into cost savings, we need to evaluate the impact of the higher price of the new target on operating costs. As can be expected, these new targets bring value, but at a higher price than those currently purchased. Table 4 below illustrates the change in target cost.

Table 4

TARGET COST	Current	After Change
Target Price	**$6,000**	**$18,000**
Number of Si-Al Targets in the unit	**12**	**12**
Cost of Targets per Year	$2,425,846	$3,695,625
Change in Cost of Targets per Year	0	$1,269,779

When making these calculations, the numbers used should be those that would be experienced in production. For example, no matter what the cost of a current single target might be, the price used should be the price that would be experienced for the size used in production, when ordered in production quantity. If not, the evaluation will be misleading. It is sometimes difficult to get a handle on this number, and if the manufacturer is at the beginning of its learning curve, it may be difficult to pinpoint what price you can expect in production. The best you may be able to get is a range. Then, the price of the target becomes one of the variables as well.

ADDING THE VALUE OF ALL IMPROVEMENTS

Using the information in Table I, we can calculate the current operating cost for one year:

$5000 x 24 hrs/day x 365 days = $43,800,000.

To estimate the operating cost after change, we only need to add to this number the additional cost of targets:

$43,800,000 + $1,269,779 = $45,069,779.

The combined increase in productivity is obtained by multiplying the effects described above:

1.0156 x 1.05 x 1.0041 = 1.0708 or a 7.08% total increase in productivity.

There are two ways to value the increase in productivity. The first method is to divide the yearly cost of production by 1 + the percentage of increased productivity, conveying that more has been produced for the same cost, and subtracting this new cost of production from the current one. This method introduces an artificial "saving" which represents that less of the production capacity was used to produce the same output. This method is illustrated in Table 5.

Table 5

YEARLY COST COMPARISON		
This section compares the costs of producing what is currently produced in one year.		
Cost of Production	$43,800,000	$45,069,779
% Increase in Units Produced		7.08%
Cost of Current Year of Production	$43,800,000	$42,091,434
SAVINGS FOR CURRENT YEAR		**$1,708,566**

It is interesting to note that in the fictitious case used here, an additional annual expense of $1,269,779 might produce a net saving of $1,708,566.

ESTIMATING THE REAL VALUE OF ADDITIONAL CAPACITY

This is not the most realistic way of accounting for an increase in productivity because this extra capacity requires no additional investment or overhead. It only costs the marginal production cost, not the average production cost. Therefore, the impact on profit is much greater by this method than by the method illustrated in the table above. For example, if the marginal cost is only 50% of the average cost, the additional profit is not $1,708,566, but $3,417,132.

SENSITIVITY ANALYSIS

It is generally easy to decide if a feature of the product is likely to be positive or negative. It is more difficult to predict to what extent, for a theoretical benefit might in practice be negligible.

The speculative cost analysis, however, can be done with different values to give a sense of the effect. In the case presented above, for example, the only benefit that is unquestionably quantified is the thickness of the target. One question that could be asked is whether or not that is enough to justify a test. The 1.56% in productivity gain, by itself, as shown in Table 6, would result in a net cost increase of $576,398.

Table 6

YEARLY COST COMPARISON		
This section compares the costs of producing what is currently produced in one year.		
Cost of Production	$43,800,000	$45,069,779
% Increase in Units Produced		1.56%
Cost of Current Year of Production	$43,800,000	$44,376,398
SAVINGS FOR CURRENT YEAR		**-$576,398**

If the manufacturer, however, can provide the target for $12,000 instead of $18,000, the net annual savings would be $636,525. This number would certainly argue in favor of a test, at the very least to see if more benefits can be obtained by using the new target.

Similarly, we can return to the original case presented here and see what minimum increase in line speed, in addition to the increase in target thickness, would produce savings. Table 7 shows that less than 2% increase in line speed would be sufficient to produce a net saving.

Table 7

INCREASE IN LINE SPEED	**Current**	**After Change**
The targets are denser. The power input might be increased without increasing spitting. This would increase the line speed.		
Increase in Speed Due to High Density		**2.00%**
REDUCTION IN REJECTION RATE		
Uniform chemistry and reduced spitting could increase yield.		
Percentage of Rejection	**2.00%**	**2.00%**
% Increase in Productivity from Lower Rejection		0.00%
YEARLY COST COMPARISON		
This section compares the costs of producing what is currently produced in one year.		
Cost of Production	$43,800,000	$45,069,779
% Increase in Units Produced		3.59%
Cost of Current Year of Production	$43,800,000	$43,506,272
SAVINGS FOR CURRENT YEAR		**$293,728**

Perhaps the most startling observation that comes out of this example is that paying several times the current price for targets could produce an increase in profit of several millions. It is a counterintuitive finding worth noting.

One might think that a cheaper target is a "no-brainer", but as the examples above illustrate in reverse, a very small change can have a very large impact in productivity. Just as a 6% improvement in line speed might justify a doubling in target price, a 30% saving on targets might be a very bad deal if its changed features result in a decrease of productivity of only 2%. The key to a good decision is to understand how the new item differs from the one being replaced.

GENERAL GUIDELINES

In general, if the change requires only a 2% improvement to justify itself, this argues in favor of a test. If the improvement required is 10%, it is still a moderate expectation. An improvement of 30% is of course less likely to be achieved, but you must remember that your vendor has invested in a technology in hopes of providing a significant improvement. In all likelihood, if he could not hope for more than a few percentage points of improvement, he would not be introducing the product.

What if the product requires a several fold improvement? Should you exclude the possibility of a test? That is where your judgment becomes particularly important. Such improvements are not unknown, but they are few and far between. You must decide, based on your knowledge of the characteristics of the product and of your process, what is the most likely outcome. Perhaps there is a smaller, less expensive test, or published research on a similar subject, that will allow you to make a better guess.

COST OF TESTING

If the cost comparison looks promising, there are two approaches to dealing with the costs and risks of a trial: you can either use the production figures as a "go-no go" criteria regardless of the cost of testing, or you can estimate the cost of testing and treat it as an investment and submit it to the same ROI standards as any other investment.

CONCLUSION

The absence of data is not an absence of knowledge. By combining knowledge of your supplier and knowledge of your process, it is possible to make a rational decision about whether or not to test a new technology. The process involves quantifying the impact of potential benefits on the bottom line.