The Art of Choosing the Right Power Supply

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Wise decision-making regarding process power helps you meet your particular goals for sputtering rate, film quality, and setup cost and complexity. Each power method offers a unique set of benefits and drawbacks. Therefore, there are no clear-cut answers. Your selection must be based on the recommendations presented here, as well as your individual process priorities.

Power Supply Selection Overview

Table 1 lists the primary factors involved in power supply selection, with ratings for each power method. Find the factors that are most important to your process in the leftmost column, and then choose the highest-rated power supply methods for these parameters. Consult the table further for information on your chosen methods' performance along all important criteria. Then, read on for more factors to take into consideration before making a final decision.

Table 1. Power supply selection matrix

	DC	AC	Pulsed DC	RF	Pulsed DC with RF	DC with RF
Sputtering Type	Magnetron only	Magnetron only	Magnetron only	Magnetron or Diode	Magnetron only	Magnetron only
Appropriate Target Materials	Conductive only	Conductive only	Conductive only	All targets	Conductive only	Conductive only
Typical Sputtering Rate (% of DC)	100%	70 to 85%	70 to 85%	20%[1]	70 to 90%	70 to 95%
Cost and Complexity	◉	●	●	◒	○	○
Campaign Length (Loss of Anode)	○	●	◒	●	◉[2]	◉[2]
Film Quality						
Optical Transmission	◒	●	●	◉	◉	◉
Flatness	◒	●	●	◉	◉	◉
Pinholes	◒	●	●	◉	◉	◉
Packing Density	◒	●	●	◉	◉	◉

[1] No magnetron
[2] No loss of anode even when using only one cathode

LEGEND ◉ Best ● Excellent ◒ Very Good ○ Good

Process Setup Specifics

The following information addresses common issues in sputtering process setup. It resolves questions left unanswered by the reference table above and offers power supply setup advice.

Choosing RF for Maximum Film Quality

If film quality is your one and only priority, RF power is the clear choice for process power. RF energy causes the electrons to become exceedingly energized in the plasma, creating a "hammer effect" in which the ions bring themselves down into the substrate with great force. This enables them to pack down tight to create very flat, uniform films, with low pinhole incidence.

The main drawback of RF power is its very low speed. Its sputtering rate is just 20%, while all other methods have rates of 70% or higher, up to 100%. However, for critical applications, such as antennae arrays and solar panels for use in outer space, this low speed may be tolerable. It depends on your priorities.

Setting Up RF

For processes using relatively small cathodes (1 to 1.5 m, 3.3 to 4.9′), matching network placement is key to correct RF setup. To maximize power transfer to the load, place the matching network as close to the cathode as possible. This decreases the length of the output cable from the matching network, which acts as part of the load. A shorter cable thus increases power transfer and process repeatability.

Grounding is another critical element in RF setup with small cathodes. The grounding strap must be wide to maximize surface area, as well as short. Also, all connections must be extremely clean to prevent resistance.

Unfortunately, there are no easy guidelines for processes using larger cathodes due to wavelength modes. Compared to small-cathode RF processes, setup is inherently more complicated and involves more trial and error.

Rotatable cathodes are not compatible with RF power. Generally, they are best used in AC, DC, or pulsed-DC powered processes, in which they can increase target utilization by 80 to 90%.

Choosing Between AC and RF

The choice between AC and RF is determined by the target materials and/or the desired film quality. If the length of the cathode is more than a quarter wave of 13.56 MHz, you can encounter film thickness variations.

Choosing Between AC and Pulsed DC

The choice between AC and pulsed DC depends on the number of cathodes in your system. For any batch system, pulsed DC may be the better choice. For a new inline system with more than one cathode, AC is a better choice than pulsed DC. It will give you a significant return on investment for very little money by enabling cleaner, longer-lasting processes that result in better film quality.

For retrofits:

- *If you are retrofitting a system already equipped with AC, stay with AC.*
- *If you are retrofitting a system equipped with DC and you have only one cathode, switch to pulsed DC.*
- *If you are retrofitting a system equipped with DC and it is at all possible to add a cathode, switch to AC because of the ROI benefits of AC described above.*

Choosing Between DC and Pulsed DC

Pulsed DC is almost always a better choice than straight DC because it enables better film quality and longer manufacturing campaigns. Most systems that are equipped with DC simply were set up before pulsing technology became available.

The addition of low-frequency pulsing makes for more energized electrons, enabling a "hammering-down" effect. This improves film flatness, packing density, and transmission, and reduces the occurrence of pinholes. Pulsed-DC-powered processes also require shorter, less-frequent chamber cleaning steps than straight DC. This dramatically increases process productivity and yield.

Cost is not a significant deciding factor between straight and pulsed DC. Pulsed DC enables the use of much less expensive target materials than straight DC. Please read further for details.

Saving on Target Cost by Choosing Pulsed DC or AC Over Straight DC

In general, AC and pulsed-DC power produce better film quality than straight DC methods. This enables processes using AC or pulsed DC to save on cost significantly by using lower-grade target materials. Any DC sputtering process will create "fingers" that can protrude into and through the adjacent layers. DC-powered processes therefore must use expensive, high-grade aluminum targets, while AC and pulsed-DC processes can use much more affordable target materials, with no negative effects on film quality.

Adding a Pulsed-DC Accessory for Better Film Quality, Campaign Length, and Cost Savings

DC pulsing accessories, such as AE's Pulsar® accessory, increase film quality and campaign length without significant cost. Pulsing accessories are easily installed on all types of DC sputtering power supplies to create pulsed-DC power. This results in flatter films due to higher electron energy. It also dramatically increases your return on investment by reducing chamber cleaning requirements. This significantly improves manufacturing campaign length. As described above, pulsing also enables the use of less costly target materials, for notable savings.

Choosing Between DC with RF and Pulsed DC with RF

Generally, pulsed DC with RF is a better choice than straight DC with RF. The same film quality, productivity, and cost considerations described in *Choosing Between DC and Pulsed DC* apply here.

Process Setup for DC with RF or Pulsed DC with RF

Combining RF with DC or RF with pulsed DC adds a certain amount of complexity and cost to process setup. Arc handling particularly presents a challenge when two different types of power are working simultaneously.

In these configurations, the DC or pulsed-DC power supply can more accurately identify and respond to arcs than the RF power supply. Therefore, your DC power supply must be able to control your RF unit to shut off both DC and RF power when an arc occurs. It must also be able to quickly return power once the arc is extinguished. DC power supplies on the market today vary in this regard. While some offer no built-in DC/RF control method whatsoever, others offer powerful control. For example, Arc-Sync™ technology enables Pinnacle® Plus+ DC power supplies to easily and effectively control a connected, Cesar® RF unit in order to handle arcs.

Choosing Between Diode and Magnetron Sputtering

Your priorities for sputtering speed, film quality, and target utilization determine the best choice between diode and magnetron sputtering. Diode sputtering applications produce better film uniformity, as well as 100% target usage. However, the sputtering rate is much slower than magnetron methods. Magnetron sputtering applications have a high rate, but use a maximum of only 50% of the target. Following the shape of the magnetron, the target material is consumed in an oval shape (called a racetrack), leaving the remaining material untouched.

To view AE's comprehensive power systems portfolio, visit:
www.advanced-energy.com/en/Power_Systems.html

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