

## You're Grounded: Practical Instructions for Proper Grounding

Improper grounding puts your manufacturing operation and personnel at risk. Its possible effects include interference with neighboring electrical systems, such as the circuits powering your offices. There are actual cases in which such interference has caused overhead lights to blink on and off. Likewise, incorrect grounding can underlie such phenomena as EMI and erroneous instrument readings, which can negatively impact your process and film quality. Most important to note is that improper grounding puts personnel at risk of electric shock. With such potential costs, it's important to be fully informed about proper grounding practices.

The Q1 2008 edition of Sputter Spotlight<sup>®</sup> offers straightforward, hands-on advice for the proper grounding of the electrical systems involved with your vacuum processing operation, including your power supplies. These principles, photos, diagrams, and explanations provide steps you can take to improve system performance and factory safety.

Please note that grounding is a complex topic. While the information here is designed to provide essential principles and guidance, it is in no way an exhaustive discussion. Please [contact Doug](#) for advice on your particular situation.

**Grounding must be done in accordance with local codes and regulations. Before working on your systems, refer to applicable standards for your location and take all necessary safety precautions. Improper grounding poses serious hazards to personnel and equipment.**

## General Principles

*When using copper straps for grounding, make sure they are sufficiently wide. Commonly referred to as the "skin effect," high-frequency power and [AC](#) low-frequency power travel only on the surface of the strap. Therefore, your grounding strap should have as much surface area as possible. Figure 1 shows a ground strap of recommended width.*

Other materials that may be used for grounding are litz wire and flat wire braid. The material you choose depends upon your particular equipment/system requirements. Please [contact](#)

[Doug](#) for advice on your particular situation.

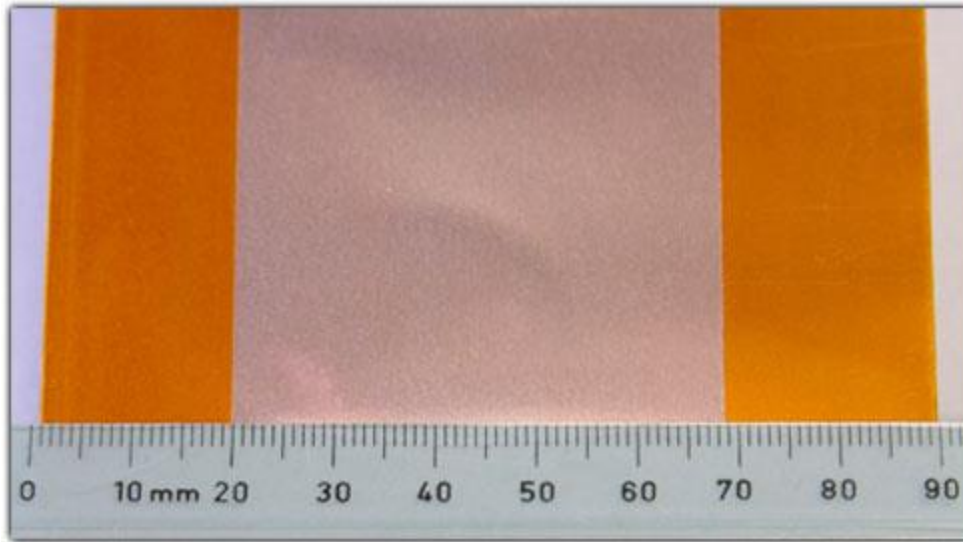


Figure 1. A copper ground strip of recommended width

*Crimp and solder your grounds.* Crimping alone is not adequate for output cables because copper tends to oxidize. This oxidation compromises your ground connection so that eventually, without both soldering and crimping, the connection may break completely. Figure 2 below shows a flat braid crimped and soldered to a ring lug, creating a secure connection to the ground stud on the [DC power supply](#).

*Make metal-to-metal ground connections.* Do not allow paint or any other insulating material to come between one side of your ground connection and the other. Either make your connection to an unpainted surface (Figure 2), connect your ground before painting (Figure 3), or remove paint or other insulating coatings before grounding to metal beams, poles, or pipes (Figure 4). Please note that painting over a proper ground connection helps prevent oxidation and therefore protects the connection.

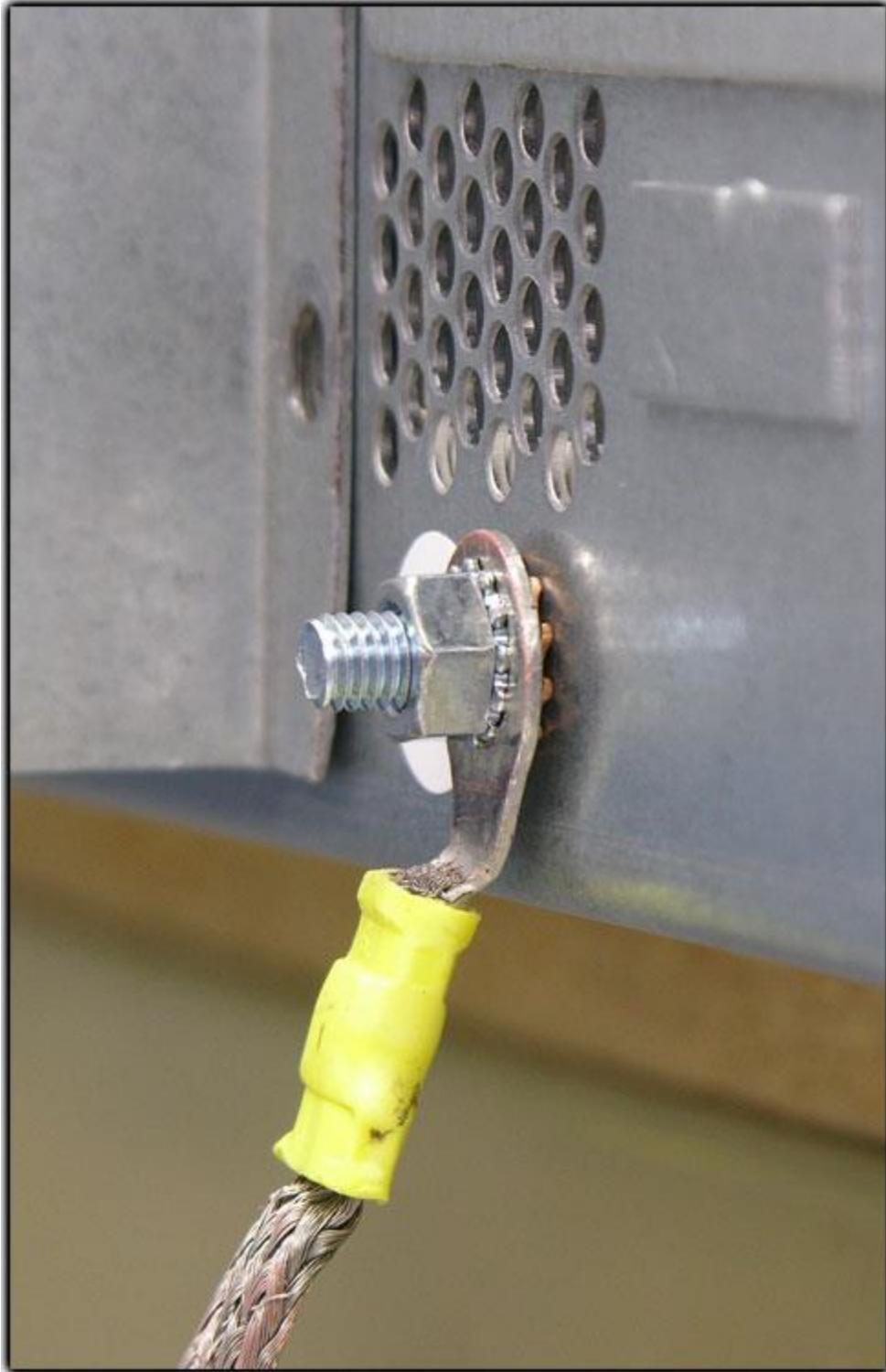


Figure 2. Ground connection made to unpainted surface



Figure 3. Ground connection made to metal beam before painting

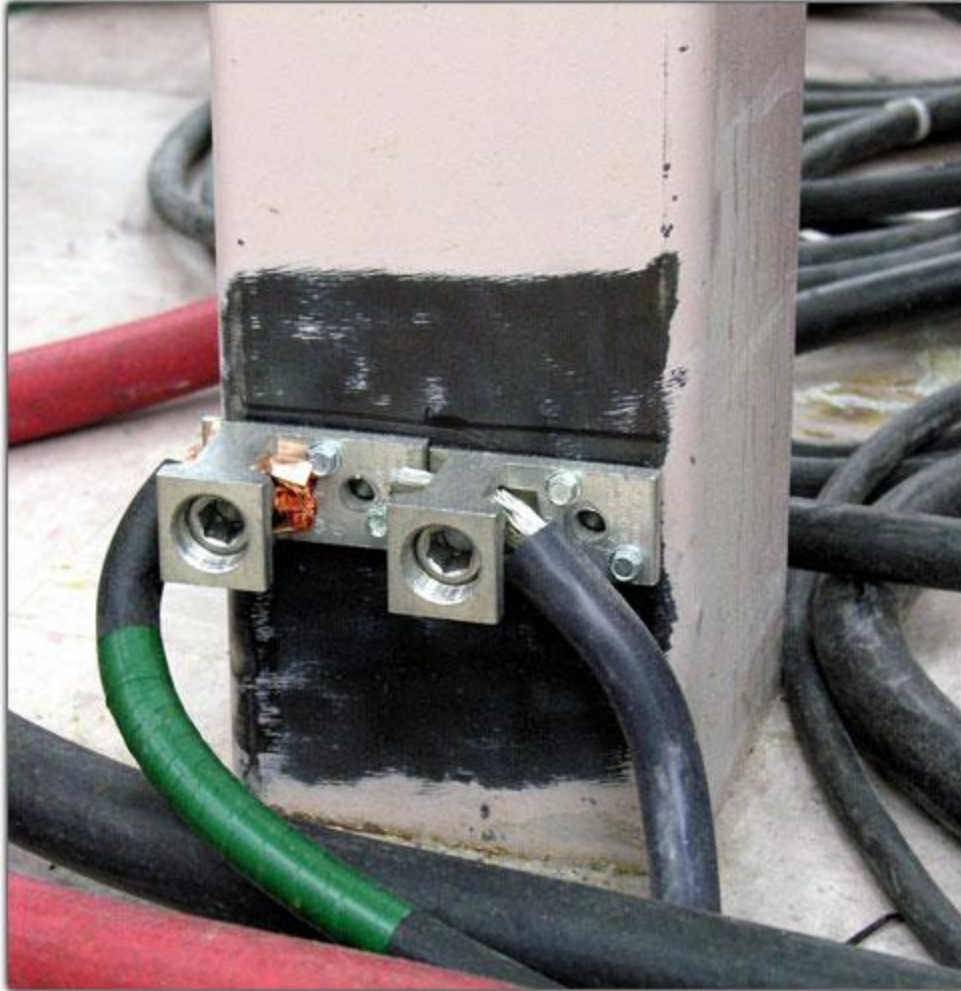


Figure 4. Ground connection made after paint removed from metal beam

*Always ground your power supply chassis.* This particular connection is often overlooked or deemed unnecessary. However, it is always an important connection to make to your power supply.

*Assemble your ground connection correctly at the power supply chassis.* Figure 5 shows a correctly assembled power supply ground connection. The star washer between the end of the flat braid and the power supply chassis resists oxidation and therefore helps maintain the ground connection over the long term.

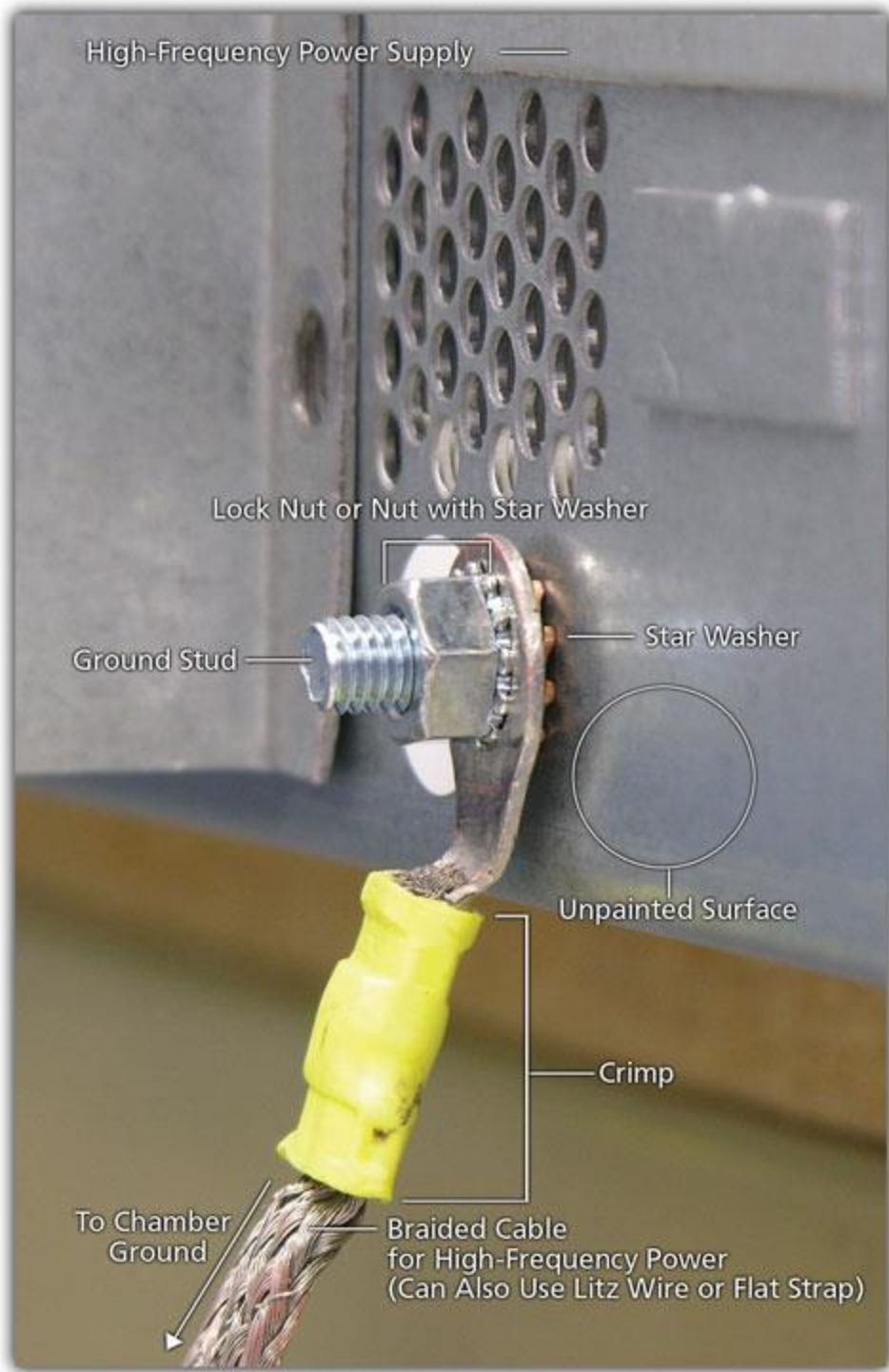


Figure 5. Close-up view of correct assembly of ground connection to [Pinnacle®](#) chassis

*Connect your AC power supply's output cables to ground at both ends.* For power usage of the magnitude used in [industrial sputtering applications](#), grounding at one end is not sufficient. A length of cable has a certain amount of resistance that will allow a possibly high amount of voltage at the ungrounded end, putting equipment and personnel at risk.

*Connect grounds from the chamber to the power supply and ultimately to the building.* This ensures that your system ground terminates securely in the earth. An earth ground is more effective than a reference ground, and greatly helps prevent EMI, noise, electric shock to personnel, and all of the other problems associated with improper grounding. Figure 5 (above) shows a flat braid ground cable leading from the power supply to the vacuum chamber. Figures 6 and 7 (below) show a flat copper strap connected to the chamber and power supply.

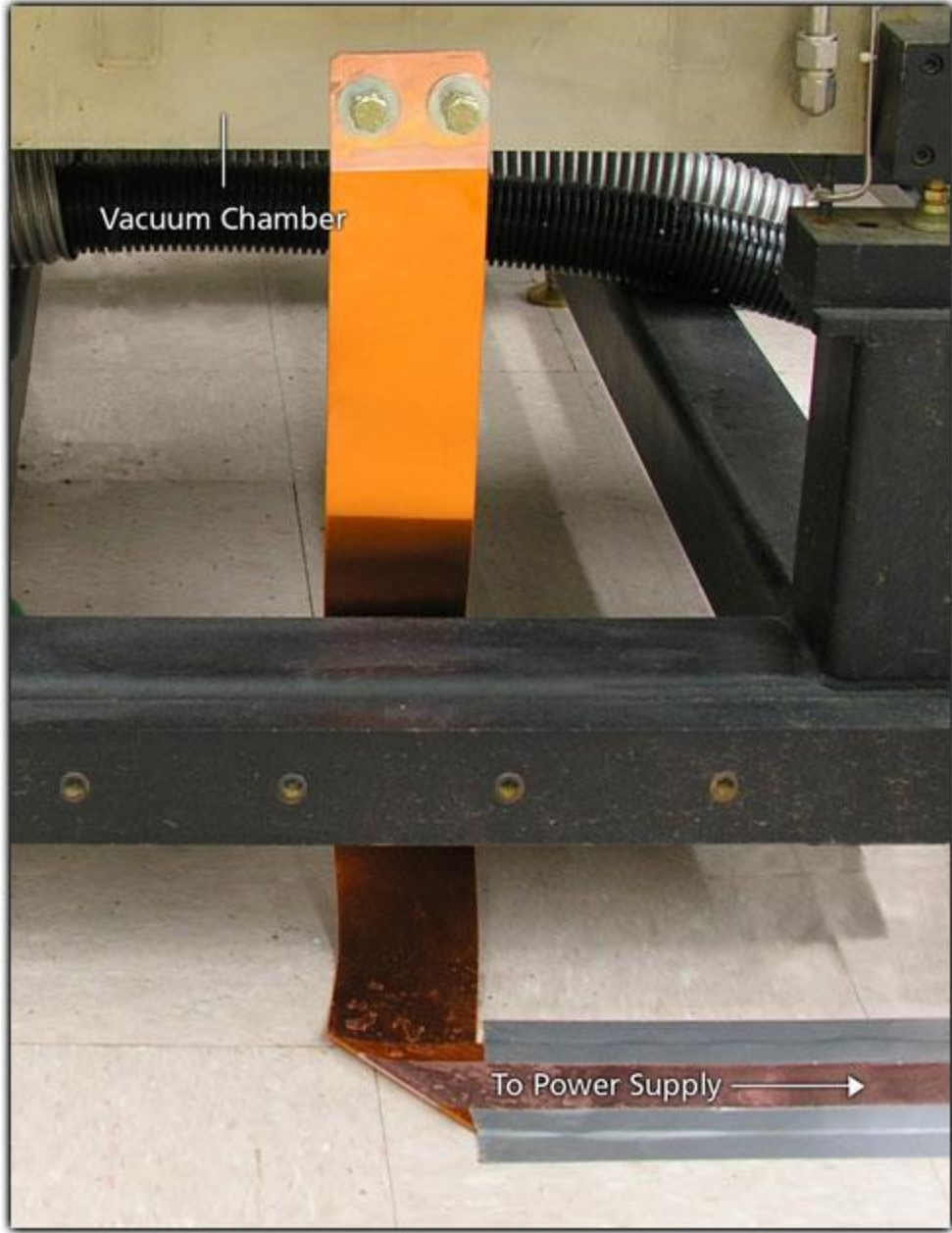


Figure 6. Flat copper ground strap connected to the chamber from the power supply





Figure 7. Copper ground strap leading to the power supply from the vacuum chamber

# System Grounding

Good system grounding starts in the very foundations of your buildings. The following diagrams show a properly grounded industrial coating system inside a room constructed with grounding in mind. The ground wire, ground rods, and other structural elements allow the coater to be grounded properly.

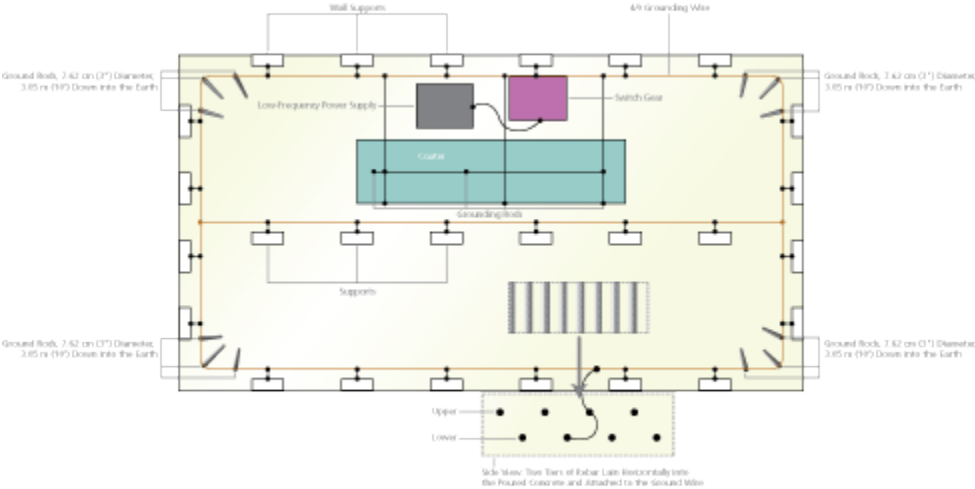


Figure 8. Proper system and factory grounding for an industrial coating operation

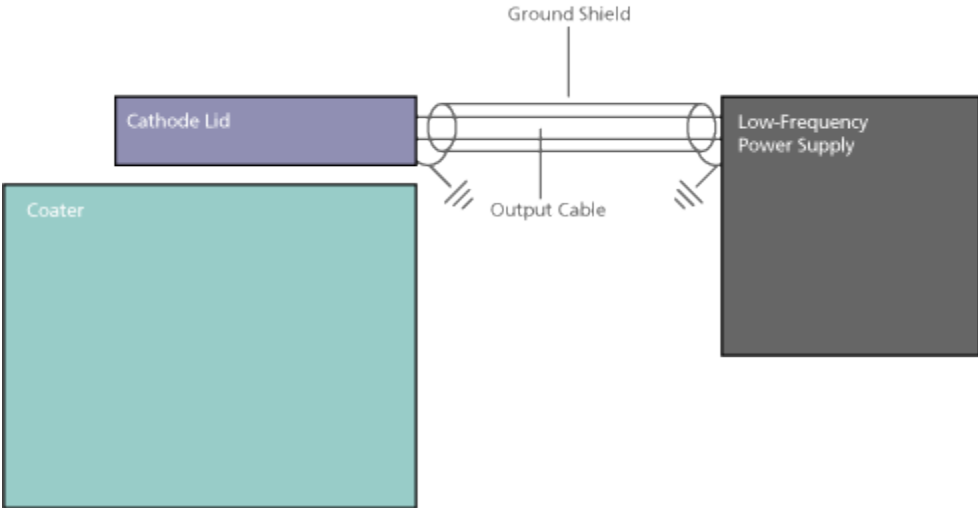


Figure 9. Detailed illustration of properly grounded power lines between the low-frequency power supply and cathodes in the coater; The power supply output cable is surrounded by a ground shield that is itself grounded at both ends

The following photos show a factory under construction that will house an industrial coating system. In this phase, we can clearly see the built-in hardware that will enable proper grounding once the system is installed and operating.



Figure 10. Proper ground connection to wall support



Figure 11. Cables connecting room grounding wire to grounding rods at corners of room



Rebar Inside Wall

4/0 Grounding Wire Inside Room



Figures 12 and 13. Room grounding wire connections to rebar inside wall



Figures 14 and 15. Properly crimped cable connections

## Ask Doug!



[Doug Pelleymounter](#), AE's senior application engineer for industrial sputtering, has more than 33 years, or 231 dog-years, of hands-on experience working with all kinds of challenging sputtering applications. In this column, Doug helps you answer some of your difficult application questions. Submit your question or comment to [sputtering@aei.com](mailto:sputtering@aei.com).

1. [I am setting up a process and have a question regarding an RF power supply. What are the advantages and disadvantages of running a process in voltage or power mode? Will I get the same film properties running the process in fixed power that I will get running it in fixed voltage mode?](#)
2. [We are researching TiO<sub>2</sub> films for an optical application using a single magnetron cathode. The target would be TiO<sub>2</sub> using a pulsed-DC power supply. The substrate would be heated up to 350°C max, and we would use O<sub>2</sub> and Ar as process gases. Can you recommend a pulsed-DC power supply and the best process parameters to get a good, dense film and high deposition rate? What is the maximum deposition rate possible for TiO<sub>2</sub>? Give me the same information for SiO<sub>2</sub>.](#)
3. [I don't have enough space in my chamber to use DC in my dual-magnetron system. Are there any good alternatives?](#)
4. [I've heard that setup for RF superimposed DC is complicated. What are the main pitfalls to avoid?](#)

1. I am setting up a process and have a question regarding an **RF** power supply. What are the advantages and disadvantages of running a process in voltage or power mode? Will I get the same film properties running the process in fixed power that I will get running it in fixed voltage mode?—*Anonymous*

**Answer:** I personally would run your supplies in power control mode. The supply will "see" the load and adjust the V and I accordingly so there is room on both for any anomalies in the process. If the supply is run in voltage control mode, then it will adjust the P and I accordingly. This is OK *if* you have strict control of your load. If the load changes any, the P and I will also change; therefore the process can go out of spec quite easily. Good luck!

2. We are researching TiO<sub>2</sub> films for an optical application using a single magnetron cathode. The target would be TiO<sub>2</sub> using a pulsed-DC power supply. The substrate would be heated up to 350°C max, and we would use O<sub>2</sub> and Ar as process gases. Can you recommend a **pulsed-DC** power supply and the best process parameters to get a good, dense film and high deposition rate? What is the maximum deposition rate possible for TiO<sub>2</sub>? Give me the same information for SiO<sub>2</sub>.—*Atul*



Nagras

**Answer:** I would use a [Pinnacle® Plus](#) DC/Pulsed DC Power Supply. AE offers 5 kW and 10 kW versions. The version you choose would depend on the size of your target. My general rule is 100 W per in<sup>2</sup> inch max, 70 W per in<sup>2</sup> nominal for decent cooling overhead. This is for continuous operation.

TiO<sub>2</sub> in the fully oxide mode is quite slow. The rate will depend on lots of things in your chamber: distance from target to substrate, pressure, magnet strength, etc.—you know the drill. A good guess would be 3 to 5 Å per sec. SiO<sub>2</sub> would use the same supply and you will probably get 5 to 8 Å per sec.

Please see [What sputtering rates can I achieve?](#) from the [Q1 2007 Sputter Spotlight newsletter](#) and [How can I optimize my sputter rate?](#) from the [Q3 2007 edition](#) for more information about the factors involved in sputter rate. And feel free to [contact me at sputtering@aei.com](mailto:contact_me_at_sputtering@aei.com) for further advice.

3. I don't have enough space in my chamber to use [DC](#) in my dual-magnetron system. Are there any good alternatives?

**Answer:** There are two main choices: RAS or RF superimposed DC (RF/DC). I wouldn't recommend using RAS in this case because it would require drilling holes in the vacuum chamber in order to add high-voltage anodes, which is extremely complicated and labor intensive. On the other hand, RF/DC is less complicated to add than RAS and requires less space than plain DC, since only one cathode is required. Cost-wise, there is a bit of a tradeoff. RF/DC is more expensive initially because you have to buy two power supplies (an RF unit and a DC or pulsed-DC unit), but you'll save on consumables because you have only one cathode to buy.

4. I've heard that setup for RF superimposed DC is complicated. What are the main pitfalls to avoid?

**Answer:** Proper arc handling setup is key to success with RF/DC because two different types of power are working simultaneously.

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.

There are additional issues to keep in mind when setting up RF/DC, such as cabling and the use of a filter/combiner. For more information, please see our [Arc Handling in RF-Superimposed DC Processes application note](#).

