



Power Rating of a Sputtering Cathode Compared to a Target Materials **Power Limits and Finding the Ideal Operating Power for a Specific** **Application**

There are two power ratings that can be confusing when considering what power level can be utilized for a particular sputtering process.

The Magnetron Sputtering Cathode:

The maximum power a magnetron sputtering cathode can be run at is based on the, cathode construction, the power transmission line, the power connection and the cooling circuit. Low impedance materials such as copper and aluminum are typically used for the cathode body because they achieve excellent thermal and electrical conductivity. Provided that the cables and connectors are of adequate size, power levels for continuous Direct Current (DC) Sputtering power can reach levels of 250 watts per square inch (38 watts per square centimeter). The cooling circuit is also essential for attaining and running at maximum power. As a guide, one gallon per minute (3.78 liters per minute) is necessary to cool four kilowatts of power. Because the coolant is used to remove heat from the cathode and target, recommended inlet temperature should not exceed 68 degrees F (20 degrees C) and the outlet temperature should rise by no more than 22 degrees F (12 degrees C).

As an example, a sputtering cathode that uses a 5 inch wide by 40 inch long target would be rated at 50 kilowatts, (5 inch x 40 inch x 250 watts). The connectors and cables would have to support the current along with coolant flow in the 12.5 gallons per minute range.

The Sputtering Target:

The power rating of a sputtering target is based primarily upon a materials thermal and electrical property. Metallic materials that are highly conductive both thermally and electrically such as Copper (Cu) or Gold (Au) can be run at high current densities in the 250 watts per square inch (6.45 watts per square centimeter) range. Materials that have low thermal and electrical conductivity such as doped Silicon (Si) or reduced Indium Tin Oxide (ITO) will not conduct the current or thermal load and will run at much lower



power levels. Also, some refractory materials such as Niobium (Nb) and Tantalum (Ta) although electrically conductive can retain heat so they are limited by their thermal properties.

The main point is that a materials individual characteristics and properties will affect the power level that can be achieved.

Other Considerations:

The design of the sputtering cathode and the way a target is connected also has a great influence on the power levels at which a material can be run. In general, targets can be fastened to the cathode in three ways, Direct, Bonded, and Indirect.

Direct cooling uses a monolithic target that is attached directly to the cathode body and the coolant is in direct contact with the target material. This is the best method for conducting heat away from the target but the target must have enough strength to support the coolant and vacuum pressure, have good density to prevent leakage, and be able to withstand mechanical fastening.

A Bonded target and backing plate assembly can be used to provide the structural rigidity for materials that do not have enough strength or are brittle and prone to cracking. Bonding the target to a backing plate allows for direct contact with the coolant while providing superior thermal transfer of the heat in the target. Both Direct and Bonded designs can achieve power levels of 250 watts per square inch of target area.

Finally, Indirect cooling uses a membrane or wall between the cooling circuit and the sputtering target. This allows for the use of materials that will yield or crack under load however the contact and thermal transfer with the coolant is not ideal. Conductive pastes and foils can be used to promote conductivity between the cathode and target but they only provide marginal power increases. For indirect cooling, maximum recommended power levels for continuous DC operation are reduced to 100 watts per square inch (15 watts per square centimeter) of target area for materials that are both highly conductive thermally and electrically. Further power rating reduction will be necessary as the thermal and electrical properties decrease.

Finding the Maximum Power for a Specific Process:

There is no easy answer for finding the maximum power level for a given process and many variables must be considered. One method to find the maximum DC power is to slowly ramp up the power and monitor the voltage while operating in constant power mode. The voltage should increase as the power increases but will start to decrease over time as the target erodes. If the voltage goes down you can increase the power level in a controlled step. At the next level, if the voltage also goes down over time then you can once again increase to the next level. If at the next power level the voltage starts to increase and then further increases at a high rate this indicates that the target is becoming resistive and you have reached maximum power. Log and decrease power to a level where the voltage was stable and decreasing over time.

Coolant temperature will also affect the power and voltage level. Monitor the inlet and outlet temperature of the coolant. Maximum input should not exceed 68°F (20°C) and the outlet should not exceed 90F (32°C).

There are other considerations which will affect the power level of a process such as the type of power used, duty cycle, run times and operating pressure.

Also remember that running at high power levels may provide the highest rates but the film properties may not be ideal for the application. Additional substrate heating, high ion energies, process gas inclusions and the resultant microstructure all need to be considered.

The power levels and process information above are using a Direct Current (DC) power supply and a non-reactive process gas, Argon (Ar).

Conclusion:

In conclusion, when trying to determine the best power rating for an application several factors must be considered. These include the cathode rating, the sputtering target properties, the cooling circuit and the power transmission. In the end, only through trial and testing can the optimum power level for a specific process be established.