BALANCING TARGET CONSUMPTION IN PULSED DUAL MAGNETRON SPUTTERING PROCESSES

Ascent® DMS Accessory: Independent Control of Power Delivered to Each Magnetron

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The Ascent® DMS dual magnetron sputtering (DMS) component independently controls the application of power at each magnetron, and also provides measurements of voltages at each magnetron. One or more actuators control the voltages using measurements provided by the Ascent DMS component. These capabilities enable users to balance target material consumption.

Background

During reactive sputtering in a magnetron sputtering system, material sputtered from the magnetron is combined with a reactive gas at the substrate (item being coated) to form a compound at its surface. The reactive gas also reacts with the target surface, forming a compound there. These systems can operate open-loop in either the metallic mode, where a small fraction of the target is covered with the compound, or in the poisoned mode, where a large fraction of the target is covered with the compound.

In some cases, the compound's sputtering yield is much lower than that of the native target material. In fact, the sputtering yield for a target completely covered with reactive compound (poisoned) can be as low as 10% (or even less) of the sputtering yield for the native target material. Typically, the transition mode is inherently unstable, so feedback control is usually required to stabilize the process there. Examples of feedback control modes include process voltage, reactive gas partial pressure, and optical emission from

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the target.

A common implementation of reactive sputtering is dual magnetron sputtering; an example is shown in Figure 1. A key advantage is the absence of explicit anodes and the challenges that come with them. The two magnetrons alternate roles as cathode and anode. When a purpose-built bipolar pulsed supply is used to drive the process, the power to each magnetron can be regulated individually. Users can monitor and control the process with fast readbacks of power, voltage, and current. In DMS systems, uneven target consumption may result from differences in reactive sputtering working point and differences in power delivered to each magnetron of the pair.

Figure 1. Dual magnetron sputtering arrangement, with rotatable magnetrons

Introduction

The Ascent DMS component independently controls the application of power to each magnetron in a dual magnetron sputtering system. To balance target material consumption, users can control the power and voltage applied to each magnetron independently, via the DMS component.

The component's switching elements receive DC power and apply pulsed-DC power to the dual magnetron system, controlling the power delivered to each magnetron independently. Using voltage measurements supplied by the DMS component, actuators adjust voltage at each magnetron. The actuators may include gas-flow controllers and/or motor drives that control magnetron rotation. To balance voltage, users can modify the flow of reactive gas to one magnetron relative to the other magnetron, and/or adjust rotation speed of one or both of the magnetrons.

Balancing Target Consumption

In order to achieve fully balanced target consumption, both targets must be at substantially the same working point, and equal power must be delivered to each target. As a consequence, in the highest-performance embodiments, both the working point of the two targets and the power delivered to each target is balanced.

In a pulsed dual magnetron system, it is possible to control the power delivered to each of the targets independently. For many practical reactively sputtered compounds, voltage is an excellent indicator of the fraction of the target surface covered with the reactive compound, and can be used as a feedback signal to control the process.

In a pulsed dual magnetron system, it is possible to control the power delivered to each of the targets independently. For many practical reactively sputtered compounds, voltage is an excellent indicator of the fraction of the target surface covered with the reactive compound, and can be used as a feedback signal to control the process. Figure 2 shows the voltage versus reactive gas flow control space of a dual magnetron system. A key point is that each magnetron has its own control curve, and they are different due to inevitable asymmetries in the hardware. Example asymmetries include magnetic field strength and profile, target thickness, and gas flow. For a given reactive gas flow, and with identical power delivered to each magnetron, the voltage is different. This indicates a different fraction of the target covered with compound, and a different target material removal rate for each target.

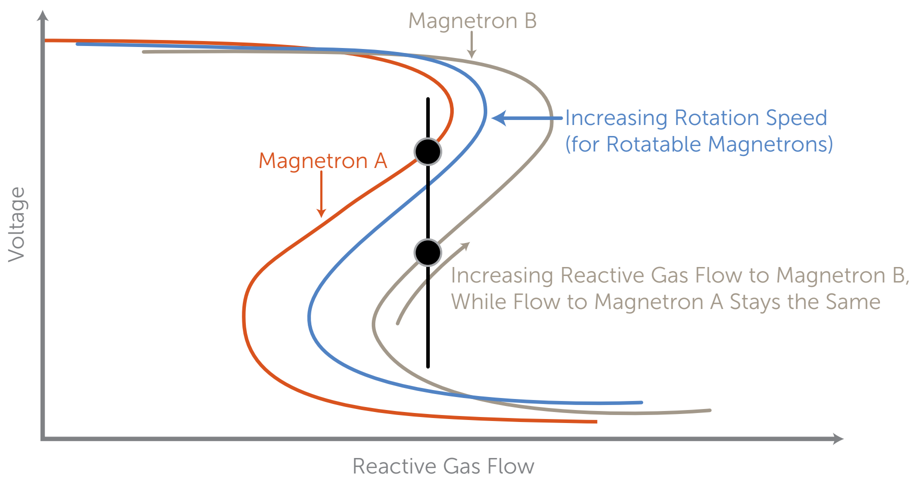

Figure 2. Voltage versus reactive gas flow control space of a dual magnetron system

The highest-performance strategy to match the target material removal rate for each magnetron would match the quasi-DC discharge voltage of each magnetron and the power to each magnetron. In this case, there are two things to be controlled, so two actuators are required. Power balance can be achieved explicitly by the pulsed power supply. Voltage balance can be achieved by modifying the flow of reactive gas to one magnetron relative to the other, by using a secondary gas manifold and means of controlling gas flow. When rotatable magnetrons are used, it is also possible to move the transition curve to the left by increasing the rotation speed, as shown in Figure 2 [1].

In cases where a second actuator is not available, there are two clear possibilities. The first is to simply balance the power delivered to each magnetron. The second is to match the voltage of the two magnetrons and accept the power imbalance. This may actually result in the minimum difference in target material removal rate, since it can be such a strong function of voltage. With a fast readback of the power delivered to each magnetron, it is possible to monitor the power imbalance, and predict the mismatch in target consumption.

Figure 3 shows a waveform for driving pulsed DMS arrangements. This graphic defines the waveform interval to be averaged for fast voltage feedback. The voltage in this interval reflects the quasi-DC discharge voltage of the magnetron. As such, it is a good indicator of the fraction of the target surface covered with the reactive compound, and therefore, the sputtering yield of the target surface.

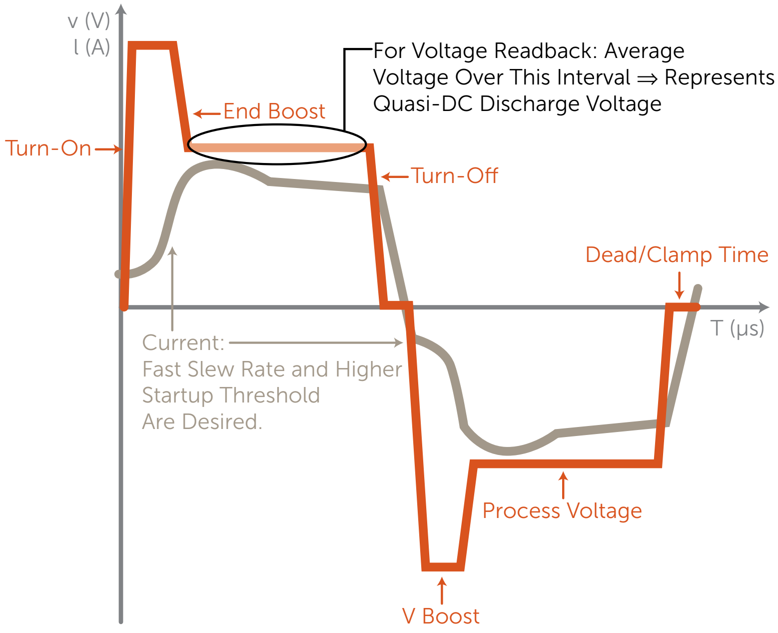

Figure 3. Baseline output waveform, showing region for sputtering voltage measurement

The DMS component

From a system design perspective, modularity is important. Here, modularity was implemented in two dimensions. First, the DC power source was separated from the pulsing module. Second, DC power supplies can be master-slaved (M/S) to achieve higher power. The pulsing section is also designed for M/S connection. This allows systems to be constructed with just the power required for the process, with powers from 30 kW to over 200 kW and a granularity as small as 10 kW. Both DC supplies and pulsing modules are rack mountable. The pulsing module, Advanced Energy®'s DMS component, is shown in Figure 4. Their compact size, rack mounted, allows for efficient use of space and enables industrial systems to be implemented with modern aesthetic sensibilities. Systems driving adjacent magnetron pairs can be synchronized to eliminate crosstalk and coordinate arc handling with common exciter (CEX) functionality.

Maintenance is another benefit of modularity. Typical pulsed and AC supplies in the 100 kW and up class are large and heavy. When service is required, service personnel usually visit the factory to do the maintenance or repair. By contrast, modular components, such as those shown in Figure 4, can be easily shipped to a service depot for maintenance or repair. Spare units can be kept on hand by the user and swapped into the system as required.

Figure 4. Ascent® DMS dual magnetron pulsing module

Reference

[1] Diederik Depla and Stijn Mahieu, eds., *Reactive Sputter Deposition*, Springer (2008) p. 191.

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