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USING THE RPG GENERATOR

By Jeff Sellers, Senior Principal Engineer, ENI

ENI RPG Generators are the first to harness the power of Asymmetric Bipolar Pulsed DC technology, enabling you to produce low-defect, dielectric insulating films with existing PVD tools. With this technology, a variety of unique films have been produced at high rates; typical films in production include Al_2O_3, BST, PZT, Ta_2O_5, TaN, TiN, ITO, SiO_2 and SiN.

This document includes sections on initial setup, troubleshooting, noise control and process optimization. Setting up the RPG for your application is quite simple, and need only be done once for each type of cathode (magnetron). The RPG Generator is designed to make your transition to sputtered insulators as painless and successful as possible.

Initial Setup

To set up your RPG for the first time, it is necessary to observe the voltage and current waveforms at your cathode. ENI recommends the use of a Tektronix P5200 differential voltage probe, a Tektronix AM503 amplifier and matching Tektronix P6303 current probe, as well as a high-quality digital storage scope such as the Tektronix THS720 or Tektronix 2232A.

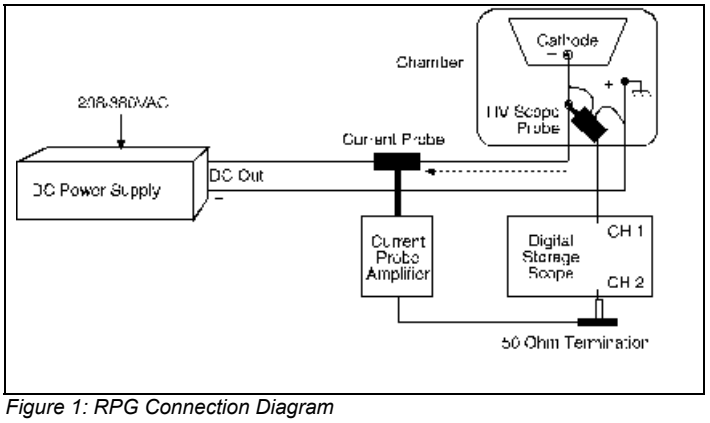


Figure 1: RPG Connection Diagram

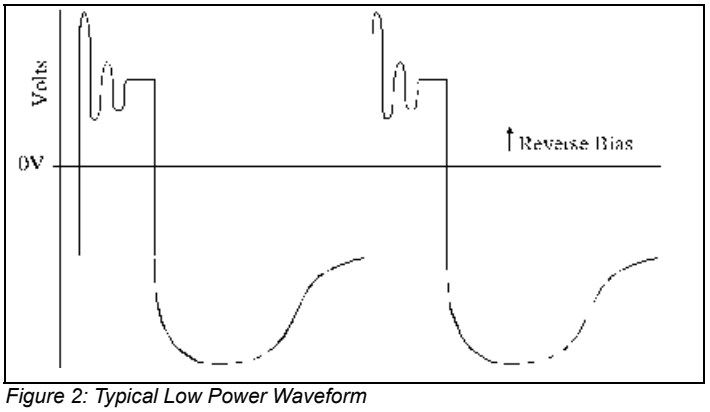


Figure 2: Typical Low Power Waveform

First, connect the scope probes as shown in the connection diagram, Fig. #1. Be certain that the probes are connected directly at the cathode. Next, set up the plasma system to the approximate values of pressure you expect to be using, and run only the sputter gas (typically argon). Then turn on the RPG at a low power (such as 50 Watts), and observe the waveforms. They should resemble the waveforms in Fig. #2. Pay particular attention to the reverse bias portion of the waveform; it is critical to set a wide enough pulse width to form a definite flat area after the initial ringing dies out (see Fig. #3).

Next, confirm that there is no backsputtering by carefully observing the leading edge of the current waveform and comparing it to Fig. #4. Also, look at the plasma through a window if at all possible – localized, extremely bright areas indicate possible backsputtering. Typically, the area between the target and the shields is the most prone to backsputtering. If backsputtering is suspected, reduce the sputter pressure or reduce the reverse bias voltage. Next, step up the power to the range you expect to be using and confirm that the reverse pulse is still wide enough to maintain a small flat at the higher power level. Note the required pulse width – this is the minimum pulse width for this magnetron. Wider pulses can be used, but there is the potential to

reduce the deposition rate. Remember, there is no deposition during the reverse bias pulse, so it is desirable to keep it short.

Conversely, there are situations when it is beneficial to use the maximum pulse width. Working with carbon (or other materials with a low sputter yield) is one example. In some cases, the improvement in sputter yield gained by the increased voltage (due to the excess pulse width) will compensate for the reduced deposition time (duty cycle); see Fig. #5.

Setting up frequency is much more to your discretion, but remember to keep the frequency high enough to do the job (maintain the target through preferential sputtering). To check this, simply run the process and monitor the arc count. If the arc counts increase over time, then your frequency is a bit low. If the counts stay low or remain at zero, you can probably reduce the frequency a bit. If the plasma impedance goes up (more voltage, less current), this can also imply an increase in target poisoning and a need for a higher frequency. It is important to monitor your arc counts closely for the first few runs, so you have a basis for comparison. The trade offs are that low frequency tends to increase deposition rate (more like DC) while a higher frequency improves plasma chemistry, providing uniformity, resistivity or composition enhancement (more like RF). Typical values are 100kHz and 2.8µs pulse width.

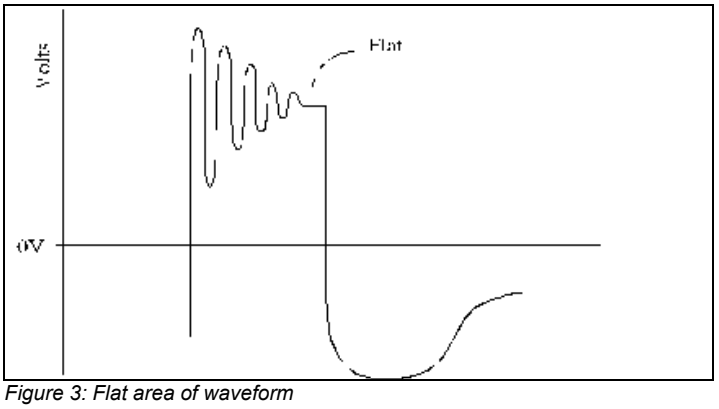
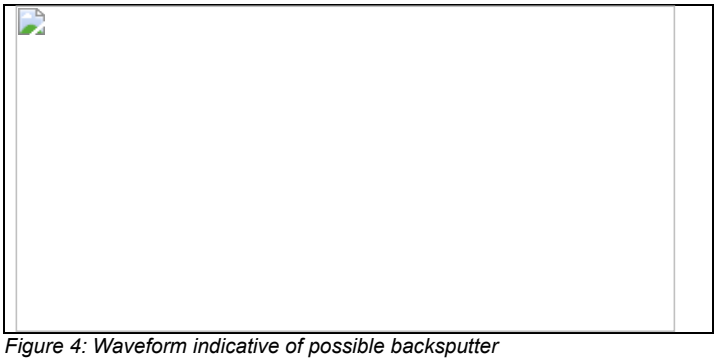


Figure 3: Flat area of waveform


Figure 4: Waveform indicative of possible backsputter

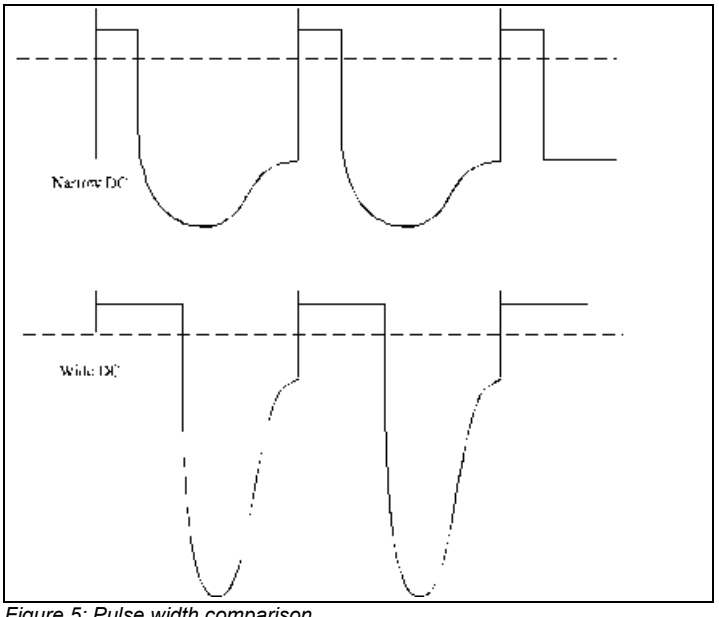


Figure 5: Pulse width comparison

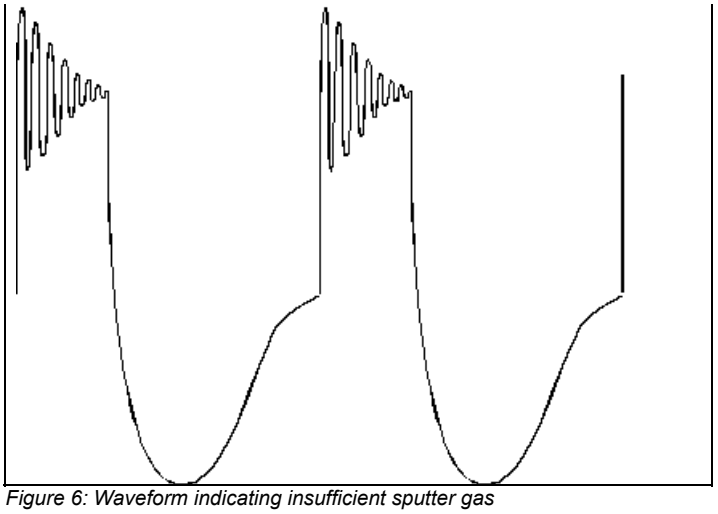


Figure 6: Waveform indicating insufficient sputter gas

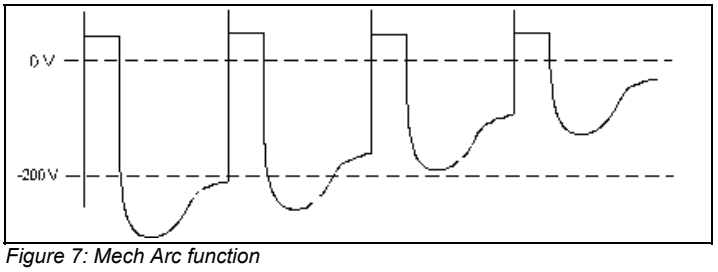


Figure 7: Mech Arc function

Troubleshooting

Since your RPG is a new and different machine, you may experience some difficulties as you climb the learning curve. Don't panic – it isn't difficult, just different!

For starters, make sure that the unit is properly hooked up (see your DCG manual for instructions), and that no fault messages are on the screen. If there are any active faults, they must be cleared before continuing. Be sure the output cover is installed to clear the output safety interlock. Refer to your DCG manual for assistance with fault messages.

If you still have difficulty, try turning off the pulse and Mech Arc functions (Mech Arc stands for Mechanical Arc, a catchall term for arcs that are not caused by dielectric breakdown or target poisening. An example would be flakes falling off the shields and shorting the cathode. Mech Arcs have unique charcteristics and need to be resolved using a different methodology). Now you are dealing with a regular DC supply. So, if the plasma does not light, check for gas flow, correct gas pressure, correct unit connection to the target, correct polarity, DC power on, etc. Make no assumptions, actually measure at the cathode. After you have confirmed all these points, you should be making plasma. If the plasma voltage is below 200 volts, confirm that the Mech Arc function is turned off.

Next, turn on the pulser while running plasma. Tune to your cathode according to the instructions. Note the output voltage; if the unit's output power dropped when you went to pulse mode, then the unit is likely to be in an overvoltage condition. This can be confirmed by observing the overvoltage LED on the back panel, or by looking in the arc menu (press menu button once). The overvoltage condition occurs at about 1600 volts peak-to-peak. To correct this condition, increase the gas flow to raise the base sputtering pressure, or bring in some reactive gas.

A waveform resembling Fig. #6 indicates that there is insufficient sputter gas available. If the output voltage is above 200 volts, turn on the Mech Arc function; if the voltage is less than 200 volts, leave Mech Arc off. The Mech Arc function seeks about 200 volts peak-to-peak across the output (see Fig. #7). There is a Mech Arc fault LED on the back panel to assist you. The Overvoltage and Mech Arc LEDs will flash each time the protection circuits are activated. If there appears to be a continuous fault (either Overvoltage or Mech Arc), then check the arc parameters and insure that the arc type is set to "max." and the arc delay is at least 400µs. The condition may also clear if Mech Arc is turned off. If all else fails turn off the pulse function and check with plain DC.

Noise Control

Due to the high frequency components of the pulsed waveforms, there is a much greater opportunity for interference from the plasma and output cabling affecting the vacuum system. Usually, these effects are easily stopped by simply ensuring that the output cabling is not run next to sensitive, low-level control wiring. In most cases where there is a problem, however, the problem is more direct, and involves electrical connections in the plasma. For example, exposed thermocouples in the chamber can pick up the full plasma voltage, and then radiate it to the control system. A similar effect can be found on systems that have low-level motion sensors with

good coupling to the plasma. Open heaters in the chamber may also be affected by the increased ionization of the RPG plasma as this tends to increase plasma conductance substantially. These problems can manifest themselves as bizarre readings on thermocouples, pressure gauges, or cryo-controllers, motion system resets, heater shutdowns, etc. They are usually easy to fix, but they can be surprising if you are not expecting them. Remember that your RPG is, in many ways, an RF supply and needs to be treated with forethought.

It is also important that the system be well-grounded. A copper water pipe on the fourth floor does not intrinsically make a good ground connection for a plasma system! As with any plasma system a solid (local ground) is needed for trouble-free operation. These system problems are easily corrected using well-known methods, as long as you don't overlook the obvious. There is no magic; but remember, electrons really do know where ground is – even if you don't!

Optimization

The ideal settings for your RPG will vary depending on the particular issues you are trying to resolve. But one thing is clear – frequencies of 100kHz and above have shown benefits for every process with which we have worked. Usually, the RPG tends to open up the process window and desensitize the process to minor parameter changes. However, it is also important to realize that fairly small changes can have significant effects on the film characteristics. We have occasionally seen films that were quite sensitive to incremental changes in pulse width and frequency. In one case a change from 100kHz and 1.6µs to 110kHz and 3µs measurably changed the film quality.

There are also some adjustments you can make to your chamber to optimize performance. First, it is important to insure that the shields are well-grounded, and that the grounding is symmetrical. It is not good practice to use a single, long, thin ground connection. Remember, there are significant high frequency components in the pulsed waveform. Due to these same HF components, the pulsed waveforms need a solid RF ground to avoid self-biasing the shields. The positive aspect of the HF frequency components is that they generate significantly higher levels of plasma ionization. This increased ionization may permit the use of lower pressures or a reduction in the magnetic field intensity of the magnetron cathode (which can broaden the race track and improve both uniformity and target utilization). Further, the Peak-to-Average Power ratio can be adjusted to increase deposition uniformity. The higher this ratio, the more uniform the deposition pattern. This is adjusted with the pulse width (see Fig. #5).

The final key item to optimize in your system is the anode. When you sputter insulators they tend to cover the chamber walls. As the insulators build up over time, the plasma will lose its anode, or ground path, due to the insulating film. It is therefore important to provide a defined anode for the system that will not be degraded by normal deposition. This can be as simple as a flat, line of sight shield to a complex, recessed driven ring. Exact form does not matter, but it is an important consideration. One easily implemented anode structure simply places the anode below the target, allowing the target to shield the anode. The lack of a well thought-out anode structure may cause a wide variety of odd problems. The clear indication of impending anode problems is a change of impedance and plasma stability over time, as the plasma seeks out a new anode location. Again, a well-placed window may simplify development by allowing you to see the changes in the plasma.

Conclusion

Hopefully you have found this information to be pertinent and helpful in setting up your first pulsed DC process. If you have any additional problems (or helpful hints), please contact the nearest ENI office for additional application assistance.

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