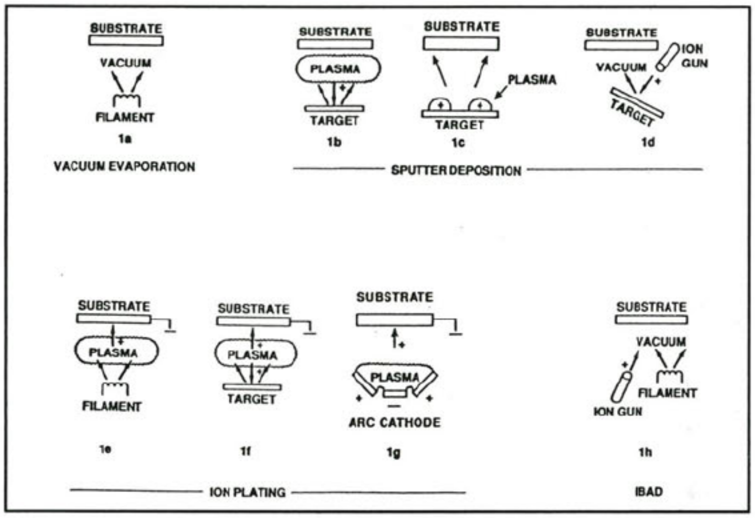
HANDBOOK OF PHYSICAL VAPOR DEPOSITION (PVD) PROCESSING

Film Formation, Adhesion, Surface Preparation and Contamination Control



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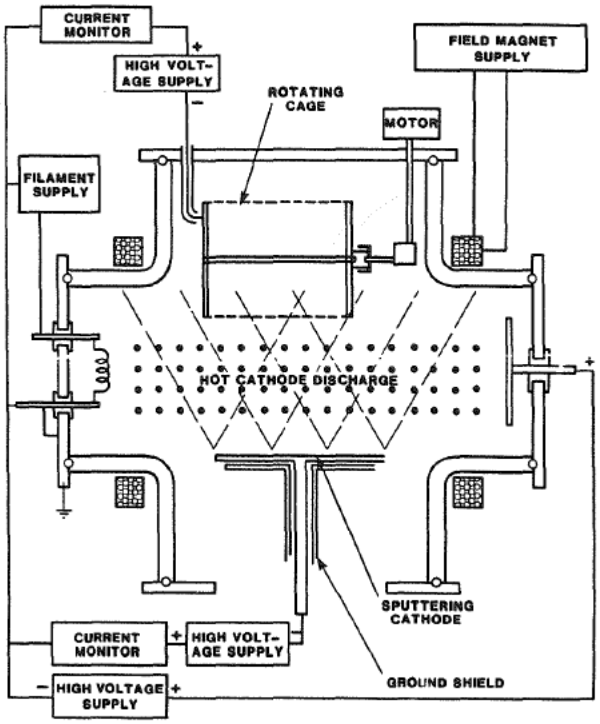

Figure 4-6. Barrel ion plating system configuration with a triode DC discharge.

The DC diode discharge cannot be used to sputter dielectric target materials, since charge buildup on the cathode surface will prevent bombardment of the surface. If there are reactive gases in the plasma their reaction with the target surface can lead to the formation of a surface that has a different chemical composition than the original surface. This change in composition leads to "poisoning" of the cathode surface and thus changes the plasma parameters. In the extreme, poisoning will cause bombardment of the cathode to cease due to surface charge buildup. If an insulating surface forms on the DC cathode, charge buildup will cause arcing over the surface.

The suppression of arcs generated in the DC discharge (arc suppression) are important to obtaining stable performance of the DC power supplies particularly when reactively sputter depositing dielectric films.[46] Arcing can occur anytime a hot (thermoelectron emitting) spot is formed or when surface charging is different over surfaces in contact with the plasma. Arc suppression is obtained by momentarily turning off the power supply or by applying a positive bias when an arc is detected.

Pulsed DC

When a continuous DC potential is applied to a metal electrode completely covered with a dielectric material, the surface of the dielectric is polarized to the polarity, and nearly the voltage, of the metal electrode. If the surface potential is negative, ions are accelerated out of the plasma to bombard the surface giving sputtering, secondary electron emission, "atomic peening," and heating. However, since the secondary electron emission coefficient is less than one the surface will buildup a positive surface charge and the bombardment energy will decrease then bombardment will crease. This problem can be overcome by using a pulsed DC rather than a continuous DC.

Pulsed DC uses a potential operating in the range 50–250 kHz where the voltage, pulse width, off time (if used), and pulse polarity can be varied.[47] The voltage rise and fall is very rapid during the pulse. The pulse can be unipolar, where the voltage is typically negative with a no-voltage (off) time, or bipolar where the voltage polarity alternates between negative and positive perhaps with an off time. The bipolar pulse can be symmetric, where the positive and negative pulse heights are equal and the pulse duration can be varied or asymmetric with the relative voltages being variable as well as the duration time.[48] Figure 4-7 shows some DC waveforms. Generally in asymmetric pulse DC sputter deposition, the negative pulse (e.g., -400 V) is greater than the positive pulse (e.g,. +100 V) and the negative pulse time is 80–90% of the voltage cycle and the positive pulse is 20–10% of the voltage cycle.

In pulse DC sputtering, during the positive bias (and off-time), electrons can move to the surface from the plasma and neutralize any charge build-up generated during the negative portion of the cycle. During the negative portion of the cycle, energetic ion bombardment can sputter dielectric surfaces.

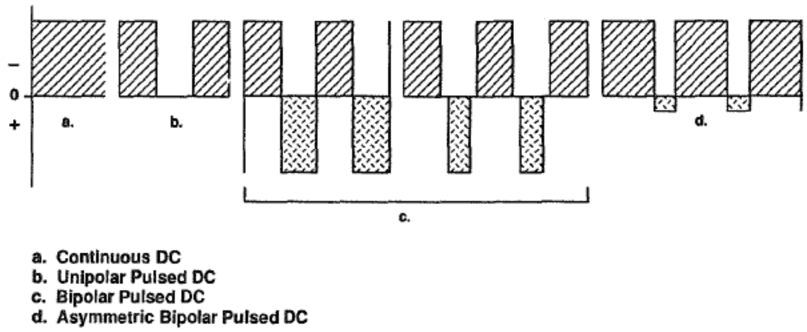

Figure 4-7. DC waveforms.

Pulsed DC power can be obtained by switching a continuous DC or sinewave power supply with auxiliary electronics[49] or can be obtained from a specially designed pulsed power supply that generally allows more flexibility as to waveform. The pulsed power supply generally incorporates arc suppression that operates by turning off the voltage or by applying a positive voltage when the arc initiates. Pulsed plasmas are also of interest in plasma etching and plasma enhanced CVD (PECVD).[50]

4.4.4 Magnetically Confined Plasmas

Balanced Magnetrons

In surface magnetron plasma configurations the electric (**E**) (vector) and magnetic (**B**) (vector) fields are used to confine the electron path to be near the cathode (electron emitting) surface. An electron moving with a component of velocity normal to the magnetic field will spiral around the magnetic field lines and its direction will be confined by the magnetic field. The frequency of the spiraling motion and the radius of the spiral will depend on the magnetic field strength. The interaction of an electron with the electric and magnetic fields depends on the magnitude and vector orientation of the fields (**E x B**). For example, if the magnetic field is parallel to a surface and the electric field is normal to the surface an electron leaving the surface will be accelerated away from the surface and will spiral around the magnetic field. There will also be a resulting motion

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