Chapter

Sputtering Deposition

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Abstract

Hundreds of research papers on various elements of sputtering have been published. The goal of this chapter is to present different aspects of sputtering that have been observed when materials are exposed to intense ion beams. Sputtering deposition is a common physical vapor deposition technology that has benefits over the molecular beam epitaxy and pulsed laser deposition in order to produce films of large area for a variety of industrial applications. Sputtering deposition has a reputation for producing high-quality epitaxial coatings and complicated oxide super-lattices at a cheaper cost than other methods, and the resulting films have proven to be essential enablers of scientific advancement. The sputtering process is discussed in detail, as well as the design and basic operations of the sputtering system, the effects of low and high energy sputtering, and changes in sputtering performance as a function of both the sputtering gas composition and the incident ion mass, dose, energy and angle. Sputtering deposition's benefits, limits, and future trends are also discussed. Sputtering deposition is an important green technology for material production.

Keywords: sputtering, deposition, physical vapor deposition, ion bombardment, film coating, emission

1. Introduction

Greene, J. E. [1] reported that the sputter deposition, described in the early 1800s, had already controlled the optical-coating industry by 1880. In 1891, radio frequency (rf) glow discharges were recorded. The term "magnetron" first appeared in literature in 1921, and the first magnetron sputtering experiments were reported in the late 1930s. In the early 1960s, capacitively-coupled rf sputtering devices were conceived and modeled. The first reactive sputtering kinetic models appeared in the 1960s. Parallel-plate magnetron was described in 1962. In 1975, a patent was submitted that led to pulsed dc and mid- frequency-ac sputtering. In the early 1980s, rotatable magnetrons were introduced. During the 1990s, two new types of magnetron sputtering emerged, both with the purpose of effectively ionizing sputter-ejected metal atoms. In 1992, tunable "unbalanced" magnetron sputtering was invented [1]. Historical flowchart is represented by **Figure 1**.

2. Sputtering deposition

Sputtering is a physical vapor deposition process (PVD) and was firstly coined by M. Blocher. This process is initiated by the bombardment of positive ions, usually Ar^+ gas

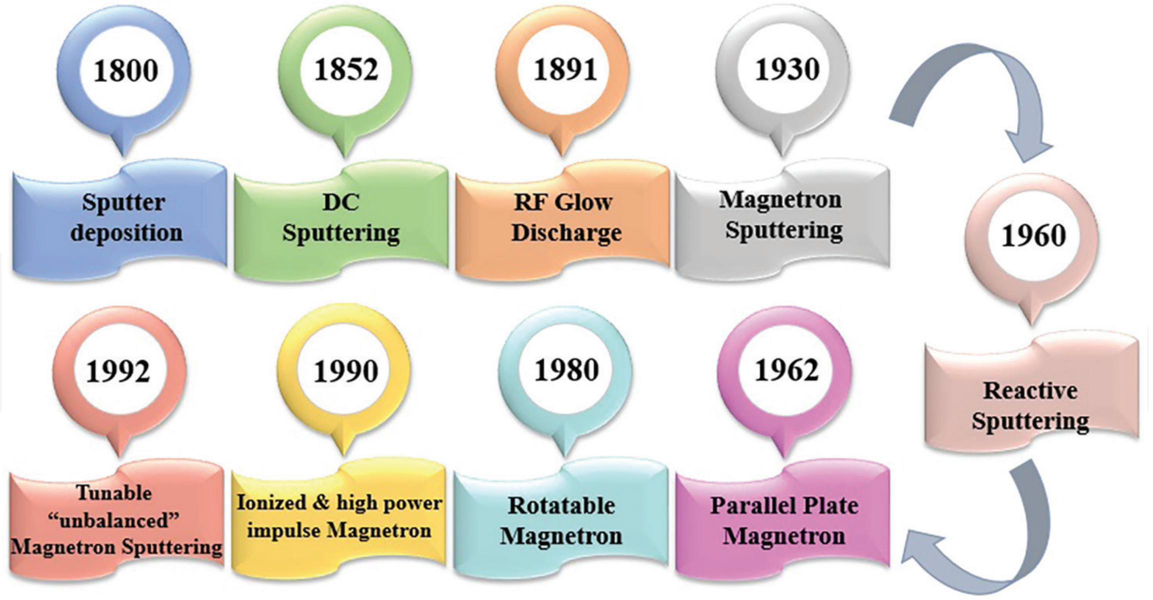

Figure 1.
Historical flowchart.

is used due to its low cost, chemical inertness and high sputtering yield provider ability. It is the process of directing high-energy ions to a target in a vacuum and remove target atoms**.** The deposition of these emitted atoms on the surface of substrate is called Sputter deposition.

Sputter deposition takes place in an evacuated chamber with a low pressure of a rare gas such as argon backfilled in, as shown in **Figure 2**. The film is then formed on a substrate with a dc voltage applied between a metal target (the source of the film atoms) and substrate upon which the film is deposited. The voltage causes the gas to break down into Ar + ions and electrons, forming a glow discharge. Positively charged

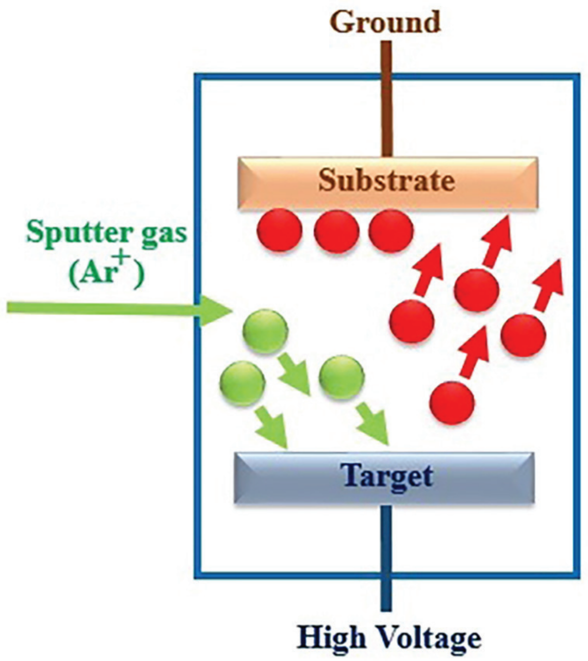

Figure 2.
Sputtering tube.

ions are accelerated and collide with the target, to sputter the target atom through momentum transfer. Some of it deposits on the substrate or sample [1].

There are some requirements for sputtering deposition as given below:

- Ion beams and potentials
  Ion beams and potentials extract ions from a plasma by means of a potential applied to the sputtering target. This sprayed plasma can be free when it occupies the entire processing volume.

- Low Pressure (less than 5 m torr)
  The pressure in the system must be low enough to prevent the sputtered particles from being subjected to excessive gas phase collisions.

- Good vacuum
  In order to maintain clean surfaces and prevent contamination from residual gas molecules, especially on the substrate, a good vacuum is required (< 10^{-5} Torr).

Sputtering can also be induced by electronegative elements like oxygen and fluorine as negative ions. Reflection of high-energy ions from a sputtered surface produce high-energy neutrals [2, 3].

The energy of incident ions influences the sputtering effect. With energy less than 10 eV, the ions can also adsorb to the surface and provide that energy to phonon. At energies over around 10 keV, the ion enters the substance, passes through multiple atomic layers, transmitting the majority of its energy in the form of heat deeply into the material and altering the target materials' configuration [4].

The **Figure 3** predicts a series of collisions that occur when an ion hits the surface of a target. When the surface is bombarded with the high energy ions, emitted electrons from the metal surface are known as secondary electron. Under this ionic interaction between atoms of the substrate, ions might be neutralized or reflected.

2.1 Ionic interaction with superficial atoms

The specific methods by which atoms are ejected from a surface under ionic impact are unknown, but details of the associated interactions can be inferred. Because an ion is about the same size as an atom, when it collides with a surface, it first collides with a surface atom. The sputtering process depends on the value of the energy interchange between an incident ion and a superficial atom; it also depends on the difference in size of the incoming ion and the superficial atom. The detailed description is given below [5].

The energy exchange between a surface atom and incoming ion is substantially greater than the binding energies of the lattice atoms, hence ions impact the bombarded surface in the normal parallel direction of the surface.

As a result, the primary collision is strictly binary, with the incident particle delivering a considerable portion of its core energy to the damaged atom and keeping the rest. If the incident ion's mass is less than the mass of the surface atom it collides with, and the collision occurs in front or close, the incident ion must bounce off the surface, as seen in **Figure 4** (Event-I).

If the mass of incident ion is greater than the affected atom, both the ion and the atom will leave the collision point following inward paths from the surface, regardless of whether the collision is frontal or lateral as seen in **Figure 4** (Event-II). So we have at least

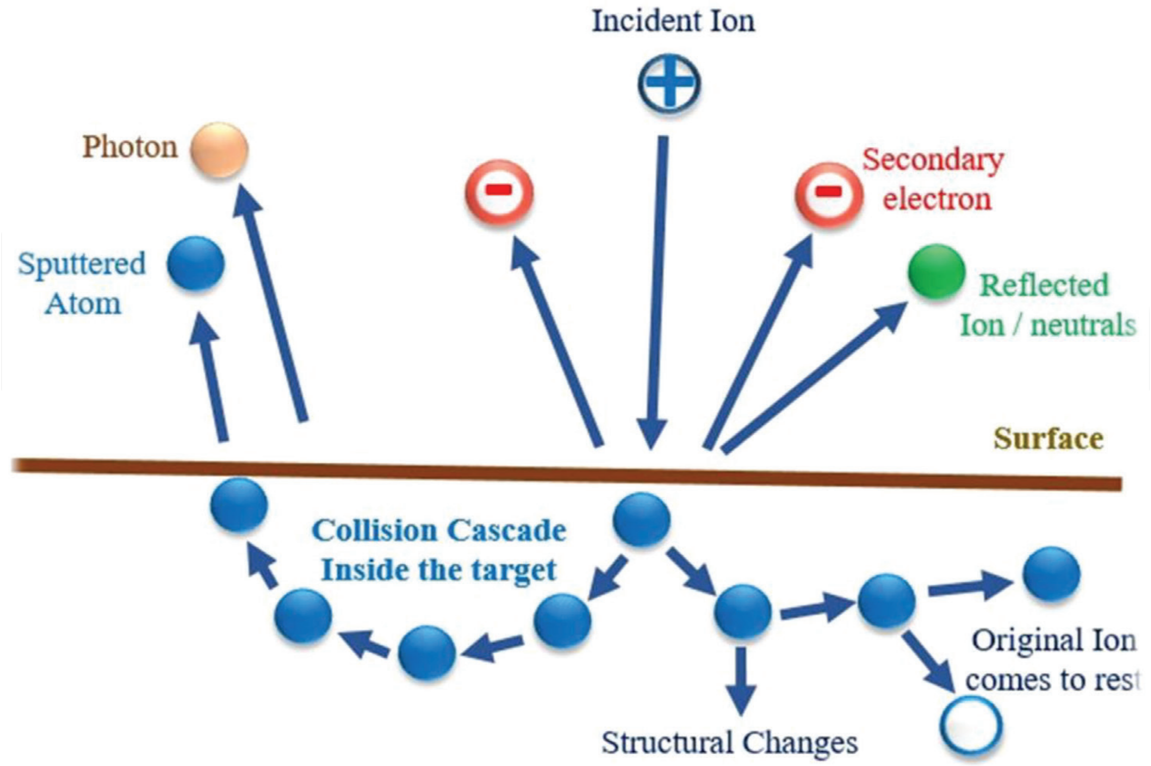

Figure 3.
Series of collisions under the ionic impact between atoms of substrate.

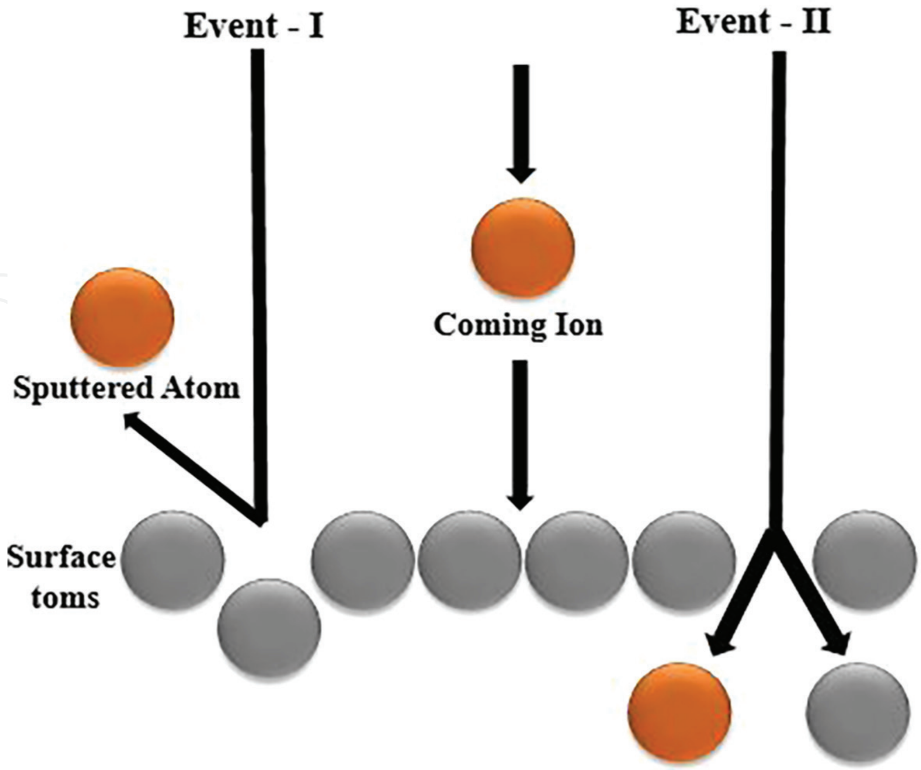

Figure 4.
Ionic interaction with superficial atoms at normal incidence.

one and usually two particles traveling to the surface with energies lower than the impacting ion's fundamental energy but still much greater than the energies of the lattice.

2.2 The impact of primary & secondary collisions on the surface

As a direct result of the primary collision, no atoms are emitted from the surface. For an atom to be emitted from the surface, it must have a velocity component in the opposite direction of the incident ion's actual velocity.

2.2.1 When the angle between ionic and damaged atomic momentum vector is 90°

As indicated by event C in **Figure 5**, the maximum feasible angle between the ion's actual momentum vector and the subsequent momentum vector of the affected/damaged atom is 90°, and the momentum vector of the hit atom is zero. In this instance, as a direct outcome of the basic collision, surface atoms cannot acquire the velocity components in the direction away from the surface. A primary collision will result in at least one and usually two secondary collisions, all of which will be close to the surface.

2.2.2 When the angle between ionic and damaged atomic momentum vector is greater than 45° (less than 90°)

We see that atoms can emerge from the surface as a direct result of the second series of binary collisions. Looking at event B in **Figure 5**, we can see that the affected ion or atom must be able to depart the collision point at an angle greater than 45°

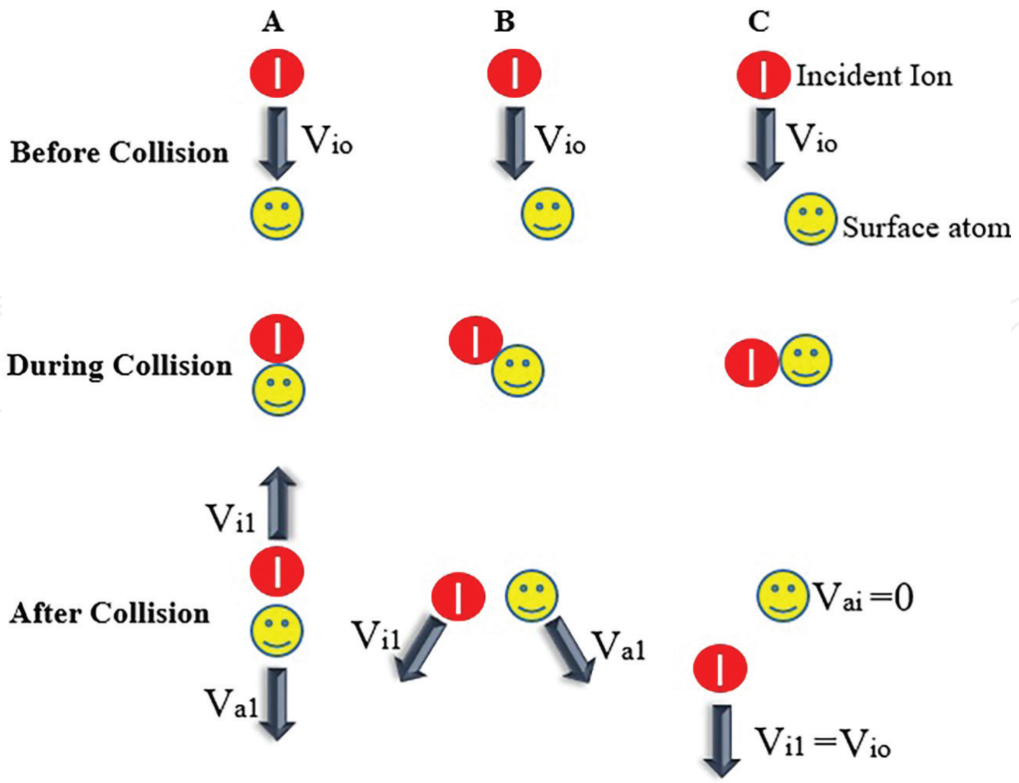

Figure 5.
Three types of collisions between ions and superficial atoms.

(relative to the actual direction of movement of the ion). As a result of the secondary impact on the same plane of motion, it should be possible for the lattice atoms to leave the secondary impact point at angles greater than 45°. Since two angles greater than 45° intersect at an angle greater than 90°, this lattice atom has an outward component of motion from the surface and can therefore be emitted.

Further consideration reveals that atoms cannot be pulled out parallel to the surface normal. Such atoms cannot be pulled in the opposite direction of the incident ion. This necessitates two 90° reflections, at least one of which moves the atom 90° in the grid/lattice while acquiring the zero velocity. Atoms with zero velocity cannot be created or ejected. Atomized atoms can be pulled towards the surface with greater force than usual, but this is not the case.

It has been determined that when ions are normally generated at the energy of interest, the sputtered atoms are removed off the surface essentially with a cosine distribution, similar to the evaporated atoms.

This is significant because the most likely emission direction is the exact opposite to the direction of the incident ion. Obviously, the incident ion's energy provided by the incident ion is so arbitrarily dispersed by the multiple collisions before the atom's emission that the incident momentum vector vanishes completely and has no effect on the emission. Note that this result applies only to the regular sputtering events [5].

2.2.3 Interaction at oblique angles

Bombarding ions can collide with the surface at oblique angles in some instances. In this instance, a basic/fundamental collision between the incident ion and the surface atom is very likely to result from a collision that occurred earlier in time. In the case of diagonal events, the incident momentum vector is found to have a significant

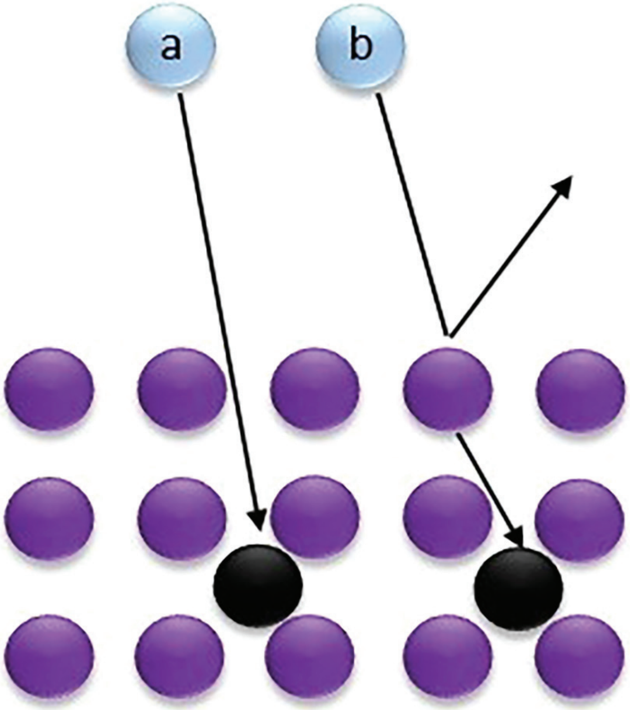

Figure 6.
(a) Direct and (b) indirect penetration by ions.

influence in the emission pattern, with the sprayed atoms being expelled extremely powerfully in the forward direction.

2.3 Direct and indirect penetration by ions

The large-angle knockout process can be broadly divided into direct and indirect as shown in **Figure 6**. “Direct” means that the surface atoms are knocked out directly by the incident ions and “indirect” means knockoff of surface atoms by incident ions just before scattering from other target atoms near the surface. Only indirect incidence works if the angle of incidence is not very oblique, but direct incidence plays a major role if the angle of incidence is grazing [6].

3. Sputtering yield

Sputter yield Y is the average number of sputtered atoms ejected by incident ions from a solid’s surface per incident ion. It is represented by

$$\text{Sputtering Yield}(\text{Y}) = \frac{\textit{No.}\text{of sputtered atoms ejected from the solid}^{\prime}\text{s surface}\,\textit{by}\,\text{incident ions}}{\text{number of incident ions}} \quad (1)$$

In 1923, A. Hull discovered that the yield of sputtering was proportional to the mass of impact ions, and increased with the mass of the impact ions.

Sputtering yield increases when energy of the ion exceeds a particular threshold, regardless of substrate temperature. For smooth target faces, sputtering yield rises with increasing oblique angle bombardment up to a point, then falls as the angle of bombardment rises, resulting in increased bombarding particle reflection. The impact of changing the morphology of surface on sputtering yield have been examined by researchers. Because a large portion of the energy from high bombarding energies is deposited below the region right near the surface, energy does not directly enhance the sputtering yield.

In 1973, Attention was paid to the change in sputtering yield due to the amount of target impact on the pure metal surface. This phenomenon could be caused by bombarding species being incorporated into the region near the surface, recoil interstitials straining the near the surface region, and/or ion bombardment generating a highly defective film near the region of the surface [2].

3.1 Elements influencing the sputter yield

The interactions of incident ions with target surface atoms create sputtering. The following elements/factors will influence the sputter yield: *1) The bombarding particle’s angle of incidence:* The angle of Ar atoms from the target metal’s surface affects the sputter yield as well. As the incident angle increases, sputter yield rises. Between 60° and 80° angles, the sputter yield achieves the highest, the deposition rate will also be highest, resulting in a thicker coating. Further increasing the angle will cause the sputtering yield and film thickness to decrease rapidly. *2) Sputtering Voltage through which the ion is accelerated:* The applied voltage regulates the maximum energy that the atoms that are expelled from the target can have. Ions’ Kinetic energy (KE) that collide with the target surface is controlled by the applied voltage. The energy of the ions will be greater due to the higher cathode voltage, which will cause a greater number of atoms to sputter from the target. The more atoms that are sputtered, the more material will be deposited and sputter yield will rise as a result. The term "Threshold Voltage" refers to the required minimum voltage for the sputtering process. Ions do not have enough energy to knock out the target's binding energy atoms below this voltage. Its value ranges from 0 to 100 eV. To have an appropriate film thickness, the normal voltage range is between 100 and 1000 V. Unfortunately, raising power or voltage has a lot of negative consequences such as any energy used to operate the gun will eventually be lost, about 75% of it goes up heating the cooling water for the gun. Thermal conductivity, melting point, thermal coefficient of expansion and mechanical strength properties of the target are undoubtedly important factors. *3) Sputter Gas Pressure:* The mean free path will be shorter and there will be more collisions before the sputtered atoms deposit on the substrate as the gas pressure rises. A low deposition rate brought on by increasing number of collisions will result in a reduction in film thickness. As a result, modest/low pressures between 10^{-5} and 10 torr are used during the sputtering process. A small increase in deposition rate is produced by lowering the sputter gas pressure through two mechanisms: I- There will be fewer thermal collisions for sputtered atoms that are leaving the target. They are more likely to propagate to the substrate, less likely to scatter laterally and enhancing the deposition rates slightly. II- The plasma-to-target voltage will slightly rise in power control mode when using RF or DC power. As a result, the energy of the ions that collide with the target will be higher, somewhat increasing the sputter. A change in film homogeneity is one potential adverse effect of lowering the gas pressure. Deterioration is usually unpredictable because many factors play a role. The quantity of thermalizing impacts is lessened, though, and this is an obvious aspect. Arcs are more likely to form close to the target as a result of the combination of lower gas pressure or higher plasma to target voltage. According to the experimental results described by Chargui A, et al. [7], higher pressure results in thinner and less crystallinity in the tungsten films produced. Tungsten foil exhibit the best electrical and elastic properties at low pressures.

4. Increasing Target Size: The sputter rate increases with target diameter. This can be explained easily. For a given power density, a bigger target diameter results in a larger sputter trench area, and a larger trench area results in a higher sputter rate. *5. Number of Guns:* Most R and D deposition systems are equipped with multiple sputter guns. The user often installs several target materials in each pistol. The sputter rate and subsequent deposition rate can be doubled, tripled, etc. when the identical target material is added into two or more guns and they are all fired at the same time. The disadvantage is that many multi-gun systems only have one power source and were not designed for simultaneous deposition operations. This method could be more expensive if additional supplies are needed for concurrent operation. *6. Atomic number of element:* By reducing the target element's atomic number, the spatter yield is increased. *7. Reducing the target-to-substrate distance:* A quick, easy technique to boost deposition rate is to shorten the throw distance—the distance between the target and the substrate. The flux distribution of a sputtered material is described by terminology like over-cosine and under-cosine. Material is ejected from a circular 'trench' around the target. For these remarks, the arrival rate of the sputtered particles (per unit area of the substrate) varies as the inverse square of the throw distance. This means that halving the throw distance will quadruple the rate at which the material arrives at the substrate and the layer thickness will be four times the previous rate.

It is crucial to take into account how the shorter throw distance would affect the uniformity of the film's (thickness). The number of thermalizing collisions between sputtered atoms and sputter gas atoms increases with throw distance, for example, if material departs the target in an approximately cosine distribution pattern. The cosine distribution tends to "flatten out" as a result of these encounters, which makes the deposition more uniform across the substrate. Film homogeneity may be worse at shorter distances because there are fewer impacts at shorter throw distances. Additionally, substrates may experience greater energy sputter particles, more stray electrons, more plasma ions and "hot" neutrals, as well as increased thermal radiation heat transfer from the plasma and target surface, when throw distances are shorter. Excessive outgassing of the substrate, an increased compressive stress of the growing membrane/film, substrate melting, substrate films/membranes under the film destroyed by electron bombardment and other negative effects are caused by shorter throw distances. There are also advantageous effects of shorter throw distances (higher substrate temperatures) such as tensile stress of film may be lowered, the high energy of the incoming atoms improves the adhesion of the film and the membrane can be "densified" by colliding high-energy plasma ions with "high temperature" neutral particles. *8. Temperature:* The system's temperature has an impact on the thickness of the film as well. The atoms on the surface will be more mobile as the temperature rises. The larger particle size and smoother film will result from this higher mobility. The larger the particle size, the thicker the film and greater the sputter rate. The substrate is often placed on a heating stage for the higher temperature because of this. However, the act of sputtering itself generates heat as a result of collision between the atom and the surface. The deposited film might be harmed by excessive heating. As a result, cooling is required in cases of severe heat [8–10].

3.2 Cosine sputtering law

The angular distribution of the sputtered particles ejected from the target surface can often be estimated by a cosine distribution as shown in **Figure 7** in circumstances of normal incidence of the projectile atoms on the surface of the target.

$$J\Omega(\theta) = Y\Phi\left[\frac{cos\theta}{\pi}\right] \quad (2)$$

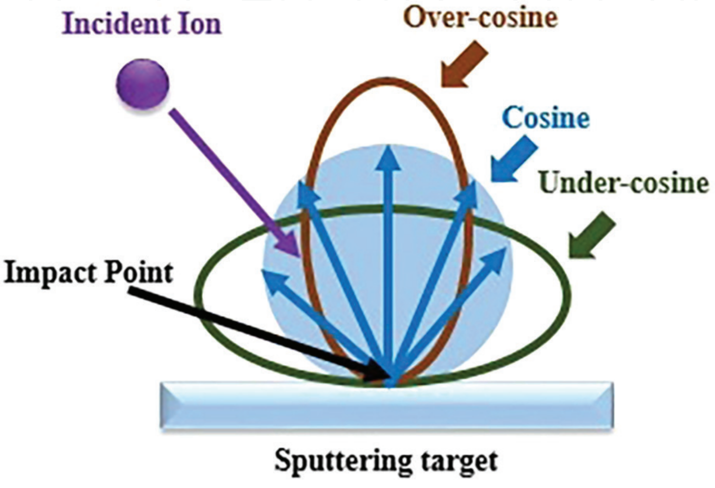

Figure 7.
Cosine law angular distribution.

Here, $j_\Omega \phi$ is the angular distribution of the emission flux as a function of the angle Θ into the differential solid angle $d_\Omega(\phi)$, Y is the sputter yield, and ϕ is the local ion flux incident on the surface.

If the recoil velocities of the sputtered atoms are considered to be isotropic, this conclusion can be calculated analytically. Low sputter-ion energies (undercosine) and high ion energies (overcosine) show deviations from the ideal cosine distribution. Undercosine means the flatter distribution and overcosine means the sharp forward-peak distribution [11].

4. Types of sputtering deposition

There are many sputtering deposition processes like Gas flow sputtering/Glow discharge sputtering deposition, Ion beam sputter deposition (IBSD), Reactive sputter deposition, Ion-assisted deposition, Magneton sputter deposition and Radio frequency (RF) sputter deposition etc.

Few mechanisms of sputtering deposition are explained in detail.

4.1 Ion beam sputtering deposition (IBSD)

Ion beam sputter deposition (IBSD) can solve a variety of problems. IBSD, unlike other PVD processes, provides a unique desirable ability to modify properties of thin film such as dense film, fewer flaws, higher purity, greater adhesion etc.

A setup is depicted in the **Figure 8**. An ion beam source, target, and substrate holder make up the ion beam sputter deposition setup. To sputter a target, IBSD uses a wide beam ion source with low energy ions. A film forms when the powder (emitted particles) condenses on a sample. Primary particles also disperse on target to provide aid in the formation of a thin coating. Dispersed primary particles as well as the sputtered target particles, both play an important role in the film formation process. The essential process parameters are geometric parameters and ion beam parameters, such

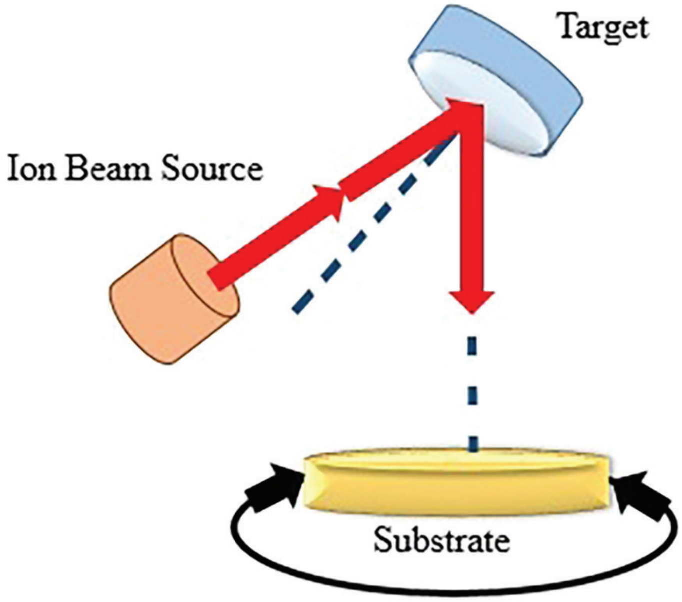

Figure 8.
Ion beam sputtering.

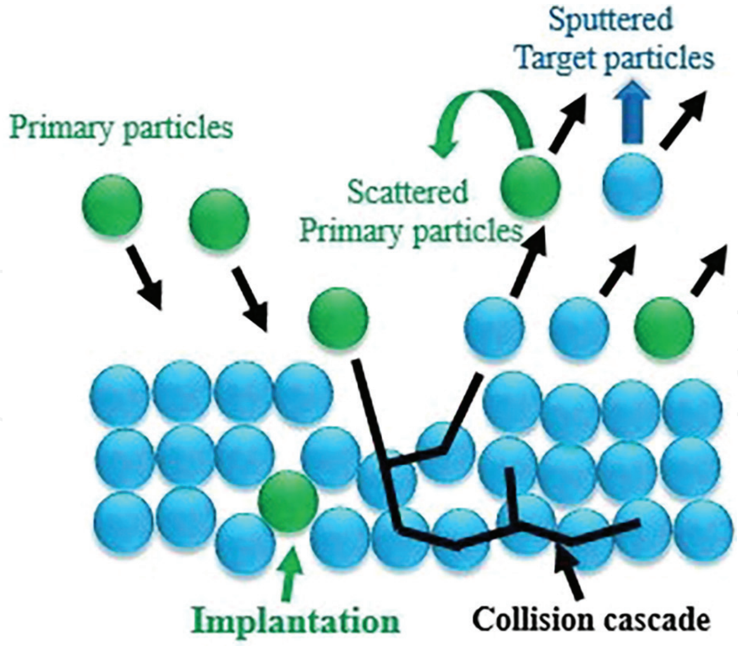

Figure 9.
Schematic diagram of ion surface interaction and resulting implantation, scattering and sputtering process.

as ion's angle of incidence, polar emission angle, angle of scattering and ion energy E_{Ion} etc. When these parameters are changed, energy distributions of the particles that make up film are also changed.

When an energetic particle collides with a target, the momentum and energy are transmitted from primary to the target particle. Sputtering, dispersion, and implantation are all significant processes in IBSD as in **Figure 9**. The retreating target particles and the scattered primary particles can collide further, creating a collision cascade or leaving the target. If target particles at the surface have acquired enough energy to overcome the binding energy of the surface, they can escape the target. The dispersed primary particles can either scatter or stay on the target. The dispersed particles are known as scattered particles.

Two particle collision is shown in **Figure 10**. Here, α is the Ion Incident angle, β is the Polar emission angle and γ is Scattering angle γ. Angle of incident plays an important role to decide either the resulting process will be scattering or sputtering.

Additional features must be addressed in order to fully utilize IBSD's potential. To begin with, the ion beam is always slightly divergent. As a result, the primary particles will collide with the chamber's components and walls. The forming film can be contaminated by eroded particles, so the chamber size must be large enough to reduce or avoid this. Second, the vacuum system's pumping speed must be high enough to prevent the background gas particle coverage of the target surface. The background pressure, current density of ion beam, and target body all play a role in surface coverage.

Ion beam sputtering deposition (IBSD) disadvantages include a slower growth and more difficult scaling. In addition, ion beam sources are extra complex than magnetrons, incorporating peripheral components [12].

4.2 Magnetron sputtering deposition

In the Magnetron sputtering technique, permanent magnets are used. As illustrated in the **Figure 11**, these magnets are placed behind the target to generate a

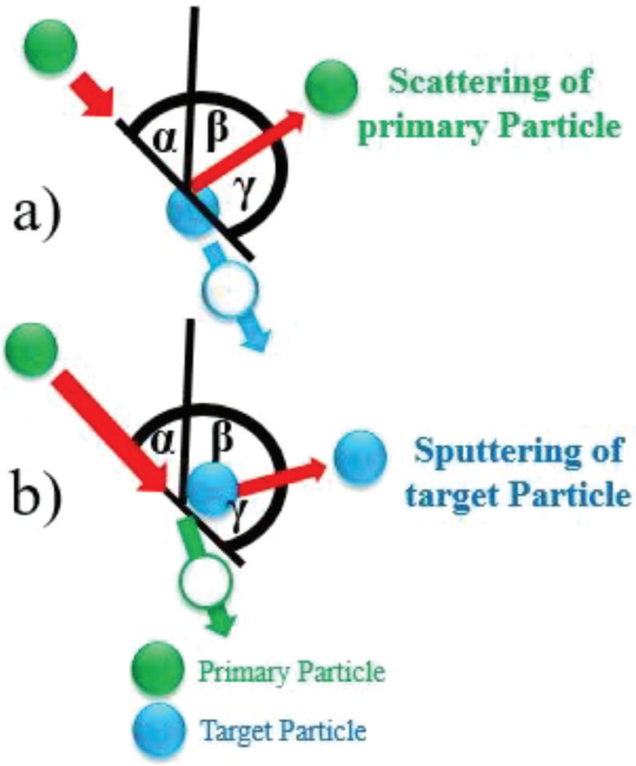

Figure 10.
Two particle collision (a) direct scattering and (b) direct sputtering processes.

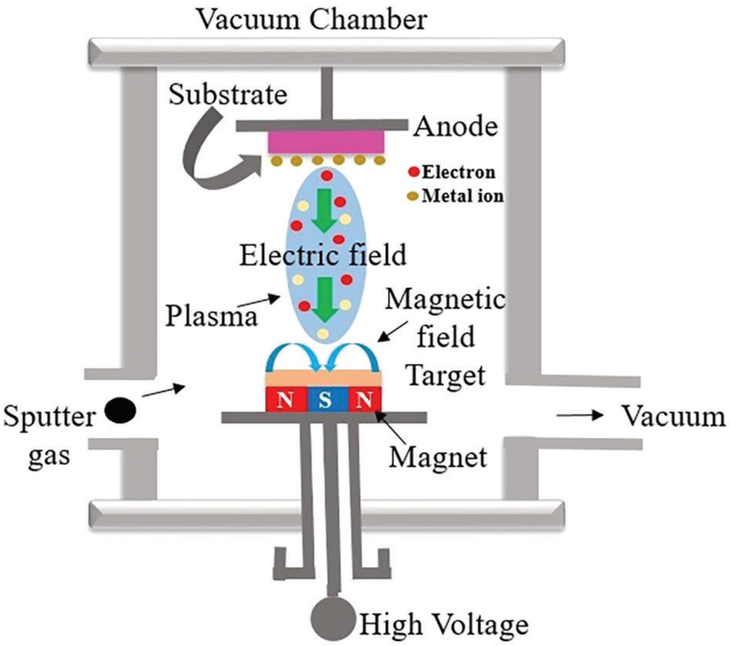

Figure 11.
Magnetron sputter deposition.

magnetic field. As ions are heavier than electrons so ions are scarcely influenced directly by the magnetic field. But the magnetic field causes the electrons to flow on a spiral course, extending their residence duration in the plasma. Now the likelihood of electrons colliding with background gas atoms will raise, causing a significant number of gas atoms to ionize.

In the presence of an electric field, gas ions speed up the bombardment of the target to produce sputtering atoms which eventually condense on the substrate to produce the required film. We conclude that the ionization rate and ion bombardment rate at the target surface raise under the effect of an electric field, and hence sputter rates increase [13].

4.2.1 Magnetron configuration

There are three main kinds of magnetron configuration as illustrated below.

1. Conventional magnetron/Balanced magnetron

2. Unbalanced magnetron

3. Closed-field unbalanced magnetron sputtering (CFUBMS)

4.2.2 Conventional magnetron/balanced magnetron

In 1986, papers to describe various magnetic field configurations of the substrates were published by Window and Savvides [14] which gave birth to the terms “balanced” and “unbalanced” magnetrons. Shortly thereafter, unbalanced magnetron technology was used to deposit thin films.

In a balanced magnetron (**Figure 12**), all lines of magnetic force originate from one pole and are closed by the other pole of the target. The magnetic flux strengths via the pole faces of the outer and inner magnets are equal or comparable. As the magnetic field controls the plasma transmission path, the balanced magnetron’s plasma is restricted or trapped at the cathode, which is advantageous for high rate cathode sputtering, but resulting production efficiency is relatively low and also prevents the large amount of bias current from reaching the substrate [15].

4.2.3 Unbalanced magnetron

The balanced magnetron can be unbalanced if the outer or inner set of magnets is strengthened or weakened. As the ion bombardment of growing films supports in

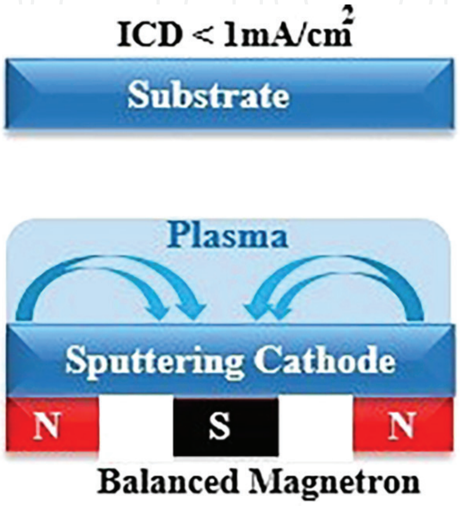

Figure 12.
Balanced magnetron.

the formation of thin films with better characteristics. The technology of unbalanced magnetron sputtering allows to get thin films with such improved properties. Fraser and Cook [16] initially highlighted the possibilities of this technology in 1977. It's been utilized to deposition and ion-bombard films at the same time.

By allowing some of the confined lines of magnetic field, which are parallel to the surface of cathode in balanced magnetron, to become perpendicular to the cathode surface in the unbalanced magnetron, the plasma purposely leaks and collide with the substrate. As a result, some of the electrons discharged from the cathode surface are allowed to exit the cathode region along those normal field lines, causing electrostatic forces to pull ions along with them. This produces a plasma beam that is focused towards the substrate surface, bombarding it as well as the forming film surfaces with ions from the sputtering gas.

As the mobility of electrons is significantly more than ions and their mean free path is also longer, so the surface of an insulating or isolated substrate submerged in this high density plasma will attain a negative charge and potential with respect to the plasma until the electron and ion fluxes become equal. The ions will collide with substrate under the effect of this floating potential [15].

4.2.4 Types of unbalanced magnetron

Savvides and Window [17] also introduced types of unbalanced magnetron, type I and type II as in **Figure 13**. Magnetic flux is important in both type I and type II.

The inner set magnetic flux in type I is greater than the outer set magnetic flux, whereas the inner set magnetic flux in type II is lower than the outer set magnetic flux. To put it another way, in type I, all field lines originate from the inner set of

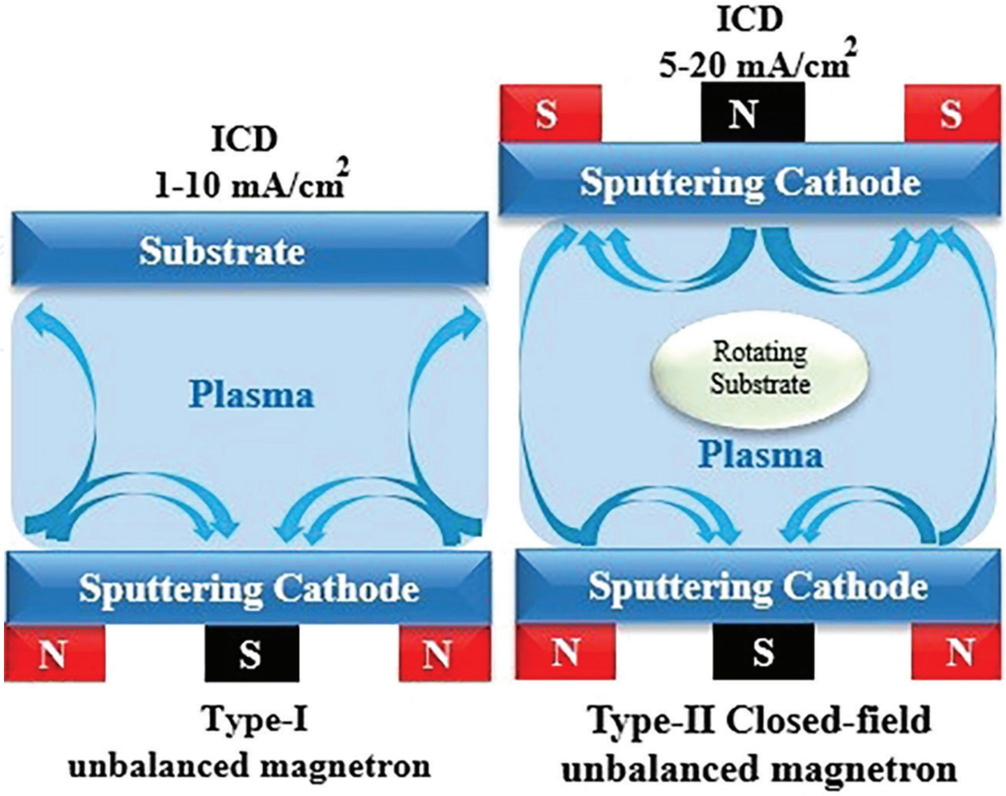

Figure 13.
Types of unbalanced magnetron.

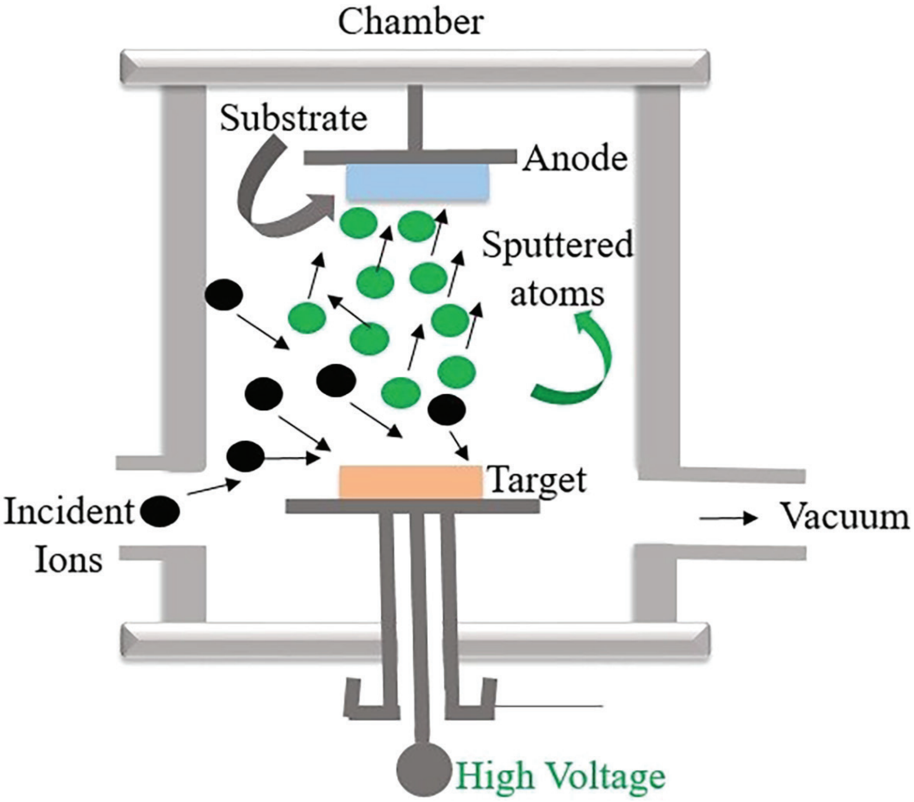

Figure 14.
DC sputter deposition.

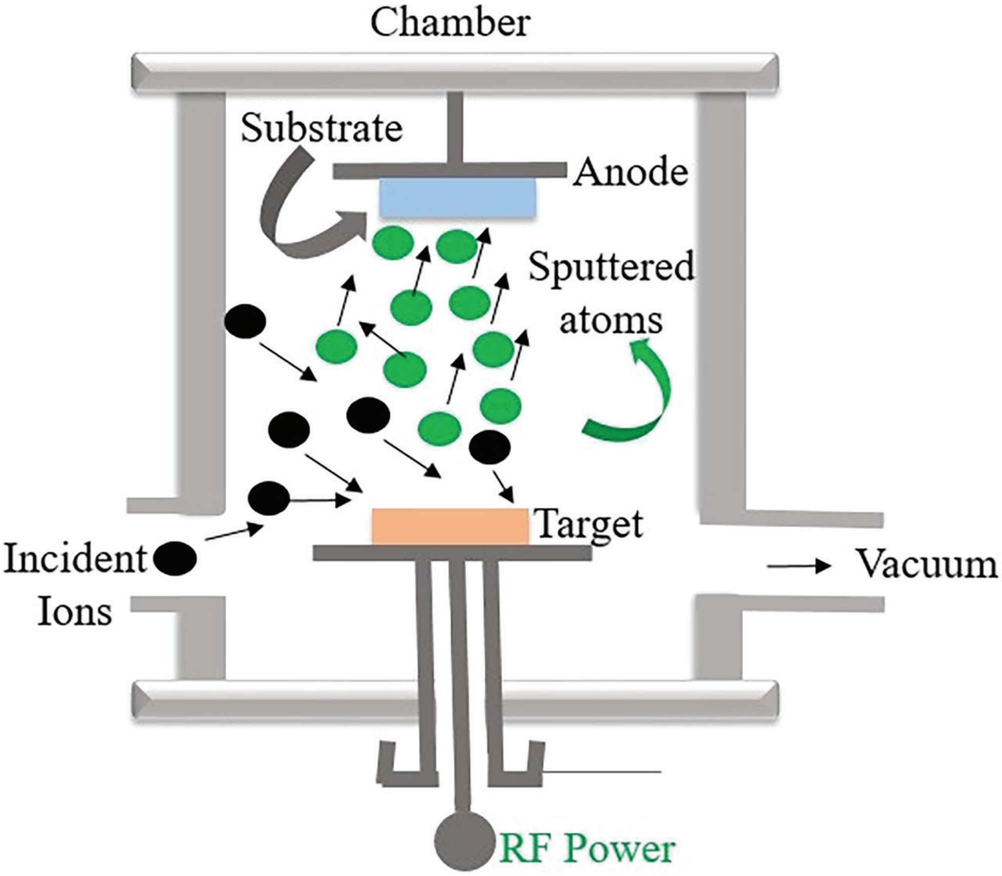

Figure 15.
RF sputter deposition.

magnets, with only a few reaching the outer set, whereas in type II, field lines comes out from the outer set of magnets, with only a few reaching the inner set.

4.3 DC and RF sputtering deposition

The power source in DC sputtering is direct current. Positively charged sputtering gas is propelled towards the target in this approach. As a result, atoms are ejected and deposited on the surface of substrate. Schematic diagram of DC is shown in **Figure 14**.

A cathode (the target) and an anode are connected in series with the blocking capacitor in RF sputtering as shown in **Figure 15**. The capacitor detects that power from the RF source is transferred to a plasma discharge. There are two stages of RF sputtering. The target material is negatively charged in the first cycle. Atoms get polarized as a result of this. The atoms of sputtering gas are drawn to the source that knock away source atoms. Here, the polarization of the target leaves source atoms and ionized gas ions on the surface of the target. The target is positively charged in the second cycle. This causes gas ions and source atoms to be emitted by depolarization. These are propelled towards the substrate, causing deposition [18].

5. Application of sputtering deposition processes

There are many advantages of sputtering deposition, some are listed below

- Deposition of any solid is possible.
- The vaporization source is provided by the sputtering target, which is steady and long-lasting.
- Vaporization can take place from all sides of a solid surface.
- Sputtering the target in specific ways results in a large area vaporization source.
- The sputtering target can give specialized vaporization geometries in some setups.
- Surface preparation on-site is simple to add into the process.
- Sputtering targets can be adapted to the surface of a substrate such as a cone or sphere.
- It is a flexible method for producing specialized nanostructures, stable colloidal particles, metallic, semiconductor and magnetic nanoparticles on the liquid surfaces.
- Films with ion assisted deposition can be used to make films for engineering applications, an appealing end to a product, and such ornamental films soak up a big part of the industry. For example, sanitary objects with a silver or gold finish contribute to the product's appeal [2, 19, 20].

6. Conclusion

Sputter deposition was long regarded a black art, but today's spectrum of material types that can be deposited has greatly expanded. Sputtering technologies with low cost, the capacity for large-area films, and unique kinetic regime of deposition material can be used to create epitaxial complex oxide, carefully regulated heterostructures, superlattices of the best quality, and film repeatability.

Sputtering yield is affected by a variety of factors, including sputtering angle, incidence ion mass, dosage, and energy of impact ions. If the sputtering pressure is too high, material dispersion back to the target reduces the deposition rate dramatically. Higher pressures alter the film growth process and film morphology significantly. High Vacuum conditions are required for accurate measurements of the absolute sputtering yield so that impurities do not deposit on the sample during analysis. When it comes to designing thin film characteristics, the reactive sputtering technique is crucial. IBSD is a flexible method for customizing the properties of film-forming particles. Due to its flexibility and scalability, magnetron sputtering remains an intriguing and widely utilized technology, and has thus established a strong position for large-area thin film deposition. This explains why sputter deposition has such a broad range of applications. Sputtering procedures that lower impurity content are now available. As a result, research into a fuller description of this technique is ongoing.

This is a strong technology for creating materials that cannot be made any other way, and it'll only get more essential as time goes on. Despite how simple the approach is to apply; it poses enough hurdles to be scientifically fascinating. This explains why it is so popular among academics. There are, nevertheless, some unexpected elements to be uncovered, explained, and used.

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Conflict of interest

The authors declare no conflict of interest.

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