Physical Vapor Deposition PVD

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Deposition

- The physical vapour deposition (PVD) process has been known for over 100 years. The term “physical vapour deposition” appeared only in the 60s.
- Applying a thin film on a surface ranges from nano meters to micrometers. Thin film is deposited on Substrates.
- Thin films are thin material layer ranging from fractions of a nanometer (monolayer)To several micrometers in thickness.
- At that time, the evolution of vacuum coating processes was needed, which was carried out through the development of well-known technologies, such as sputtering, vacuum, plasma technology, magnetic fields, gas chemistry, thermal evaporation, bows, and power sources control.

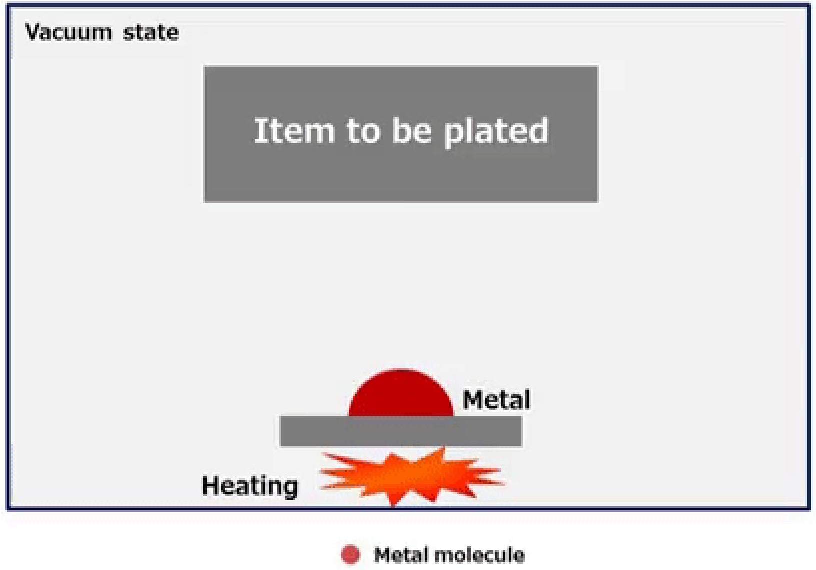
Physical vapor deposition

- PVD technique is a thin film deposition process in which the coating grows on the substrate atom by atom. PVD entails the atomization or vaporization of material from a solid source, usually called target. Thin films usually have layers with thicknesses as thin as some atomic layers to films with several microns.
- This process causes a change in the properties of the surface and the transition zone between the substrate and the deposited material.
- On the other hand, the properties of the films can also be affected by the properties of the substrate. The atomic deposition process can be made in a vacuum, gaseous, plasma, or electrolytic environment. Moreover, the vacuum environment in the deposition chamber will reduce the gaseous contamination in the deposition process to a very low level.
- Research has been focused on **improving the characteristics of coatings**, although the **enhancement of the deposition rate effectiveness** regarding this process has been the main concern of the industry linked to this kind of techniques.

Evaporation and Sputtering

- The most common surface coating methods in a gaseous state regarding the PVD process are **evaporation and sputtering**. These techniques allow for particles to be **extracted** from the target at very low pressure to be **conducted** and **deposited** onto the substrate.
- The reactor that was used in the evaporation process requires **high-vacuum pressure values**.
- Generally, these characteristics and parameters **have lower atomic energy and less adsorption of gases** into the coating's deposition.
- As a result, a transfer of particles with larger grains leads to a recognized **lesser adhesion** of the particles to the substrate, compared with the sputtering technique.

When metal is heated in a vacuum, [the metal] becomes a gas (sublimation) and forms a metal film on the item to be plated.



During deposition, some contaminant particles are released from the melted coating material and moved onto the substrate. Thus, the evaporation process is usually used for thicker films and coatings with lower surface morphological requirements, although this technique presents higher deposition rates when compared with the sputtering process.
Therefore, the sputtering process appears as an alternative for applications that require greater morphological quality of surfaces where roughness, grain size, stoichiometry, and other requirements are more significant than the deposition rate.

Benefits of PVD coatings

- PVD is an excellent vacuum coating process for the improvement of wear and corrosion resistance. It is highly required for functional applications, such as tools, decorative pieces, optical enhancement, moulds, dies, and blades. These are just a few examples of a wide range of already well-established applications. The equipment used in this technique requires low maintenance and the process is environmentally friendly. Benefits of PVD coatings are many.
- PVD can provide real and unique advantages that add durability and value to products. Deposition techniques have an important role in machining processes. Machining tools are probably one of the most exigent applications, which require characteristics, such as hardness at elevated temperatures, high abrasion resistance, chemical stability, toughness, and stiffness.
- In addition, PVD is also able to produce coatings with excellent adhesion, homogeneous layers, designed structures, graduated properties, controlled morphology, high diversity of materials and properties, among others .
- PVD processes allow the deposition in mono-layered, multi-layered and multi-graduated coating systems, as well as special alloy composition and structures. Among other of this process, the variation of coating characteristics continuously throughout the film is undoubtedly one of the most important.

CVD Types

SPUTTERING

- MAGNETRON
- Ion Beam
- Diode
- Triode
- Reactive Sputter Deposition

MAGNETRON:

- RF–RADIO FREQUENCY
- DC–DIRECT CURRENT
- MEP–MAGNETICALLY ENHANCED PLASMA
- UBMS–UNBALANCED MAGNETRON SPUTTERING
- DMS–DUAL MAGNETRON SPUTTERING
- HiPIMS/HPPMS–HIGH-POWER IMPULSE/PULSE MAGNETRON SPUTTERING

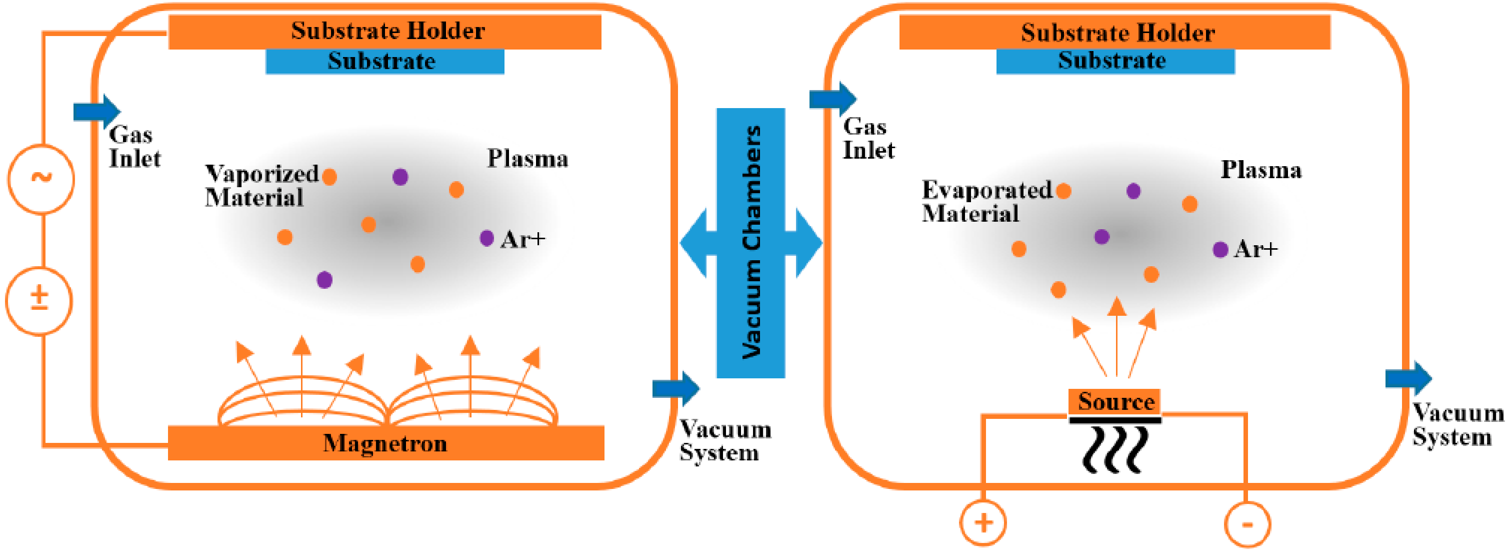
EVAPORATION

- ARC
- E-Beam
- Inductive
- Resistive

ARC:

- Stirred
- Random
- Cathodic Arc Deposition

PVD technique



(a) (b)

Figure 2. Schematic drawing of two conventional PVD processes: (**a**) sputtering and (**b**) evaporating using ionized Argon (Ar+) gas.

In PVD techniques, a thermal physical process of releasing or collision transforms the material to be deposited the target into atomic particles, which are directed to the substrates in conditions of gaseous plasma in a vacuum environment, generating a physical coating by condensation or the accumulation of projected atoms. A higher flexibility in the types of materials to be deposited and a better composition control of the deposited films are the results of this technique. Two electrodes connected to a high voltage power supply and a vacuum chamber constitute the PVD reactors, as seen in Figure

Table 1. Typical features of the PVD [17–21].

Parameters	Sputtering	Evaporation
Vacuum	Low	High
Deposition rate	Low (except for pure metals and dual magnetron)	High (up to 750,000 A min^{-1})
Adhesion	High	Low
Absorption	High	Less absorbed gas into the film
Deposited species energy	High (1–100 eV)	Low (∼0.1–0.5 eV)
Homogeneous film	More	Less
Grain size	Smaller	Bigger
Atomized particles	More Dispersed	Highly directional

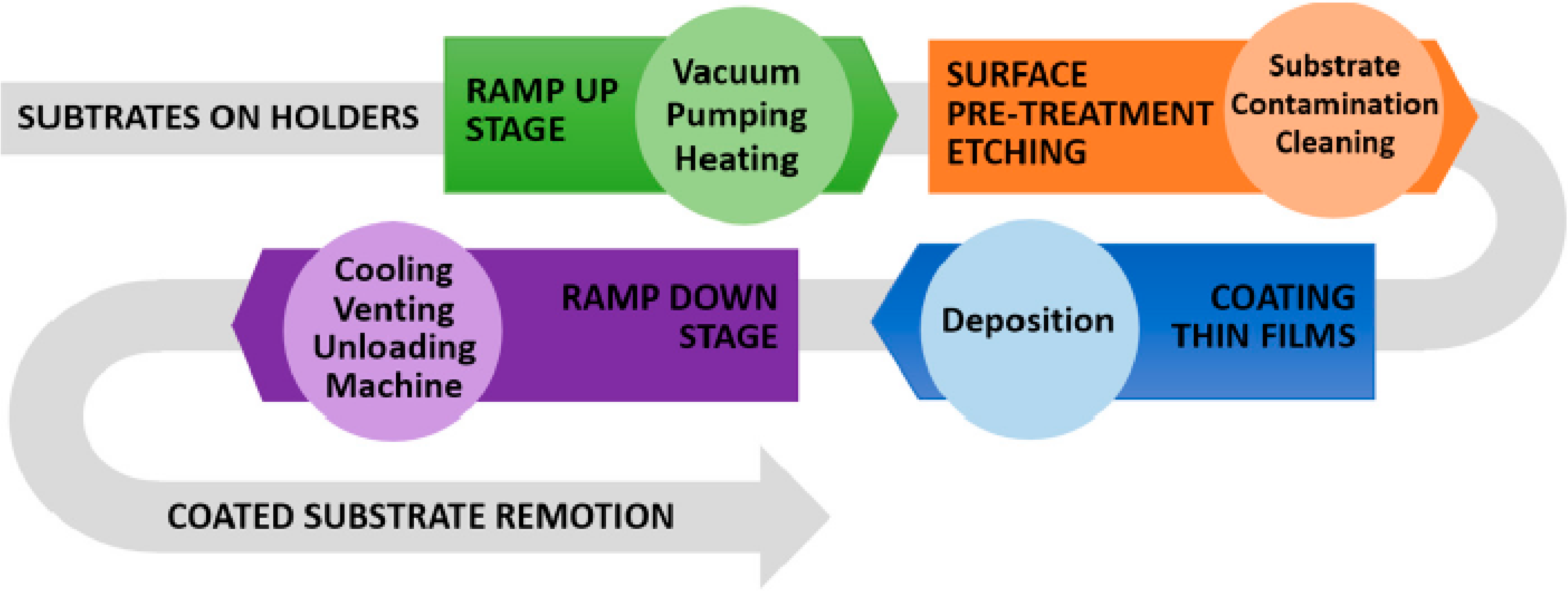


Figure 3. The processing flow for a classic PVD sputtering process.

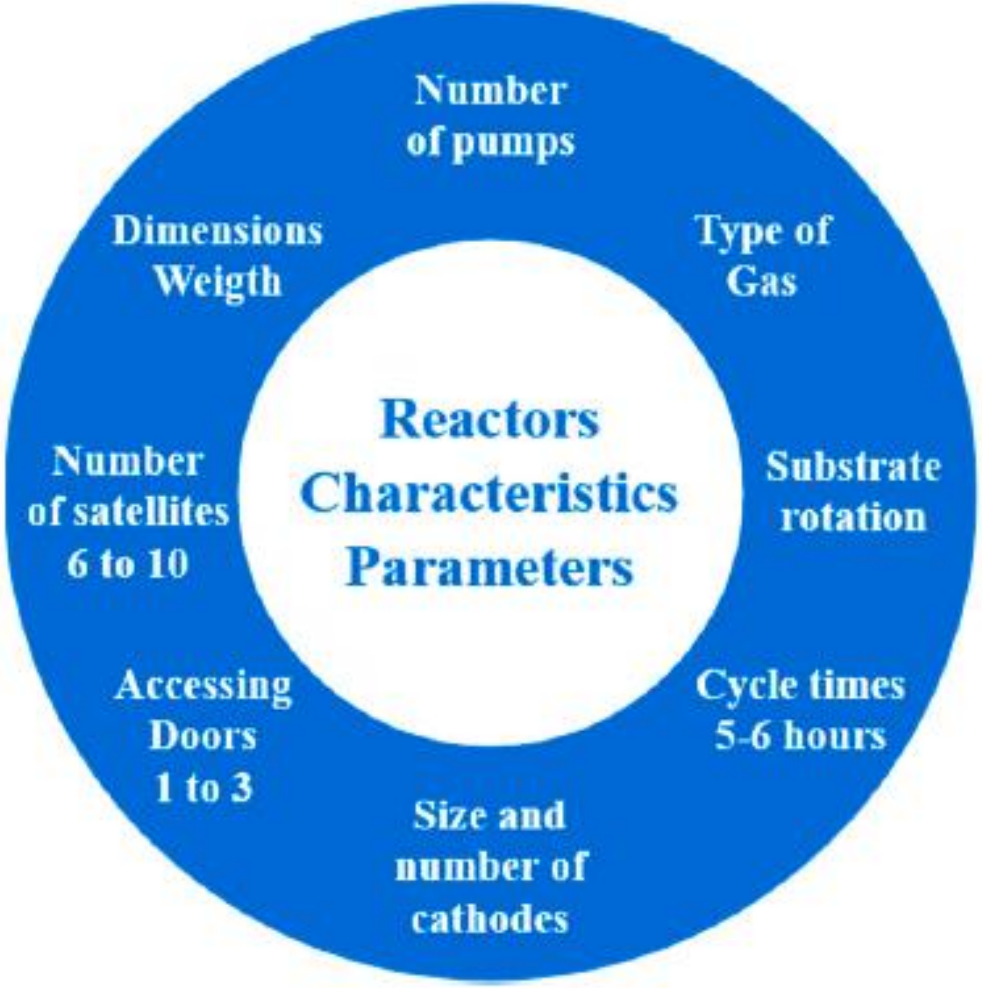


Figure 5. Characteristics and parameters chambers.

PVD Techniques

- **Evaporative deposition**
  - Electron beam vapor deposition
  - Pulsed laser deposition
- **Pulsed laser deposition**
- **Sputter deposition**
- **Ion induced deposition**
- **Cathode Arc Deposition**

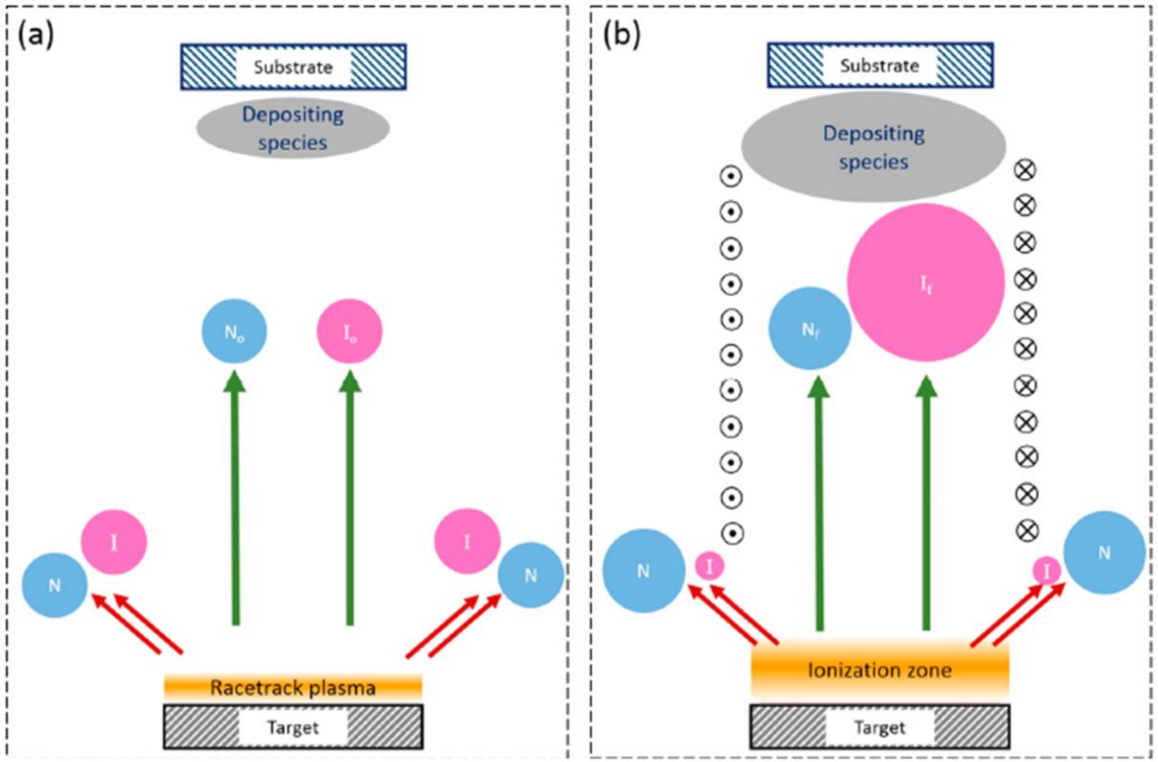


Figure 10. Schematic illustration of a film deposition, (**a**) without the external device and (**b**) with the application of an external magnetic field. Reproduced from [100] with permission. Copyright 2019 Elsevier.

Types of sputtering deposition

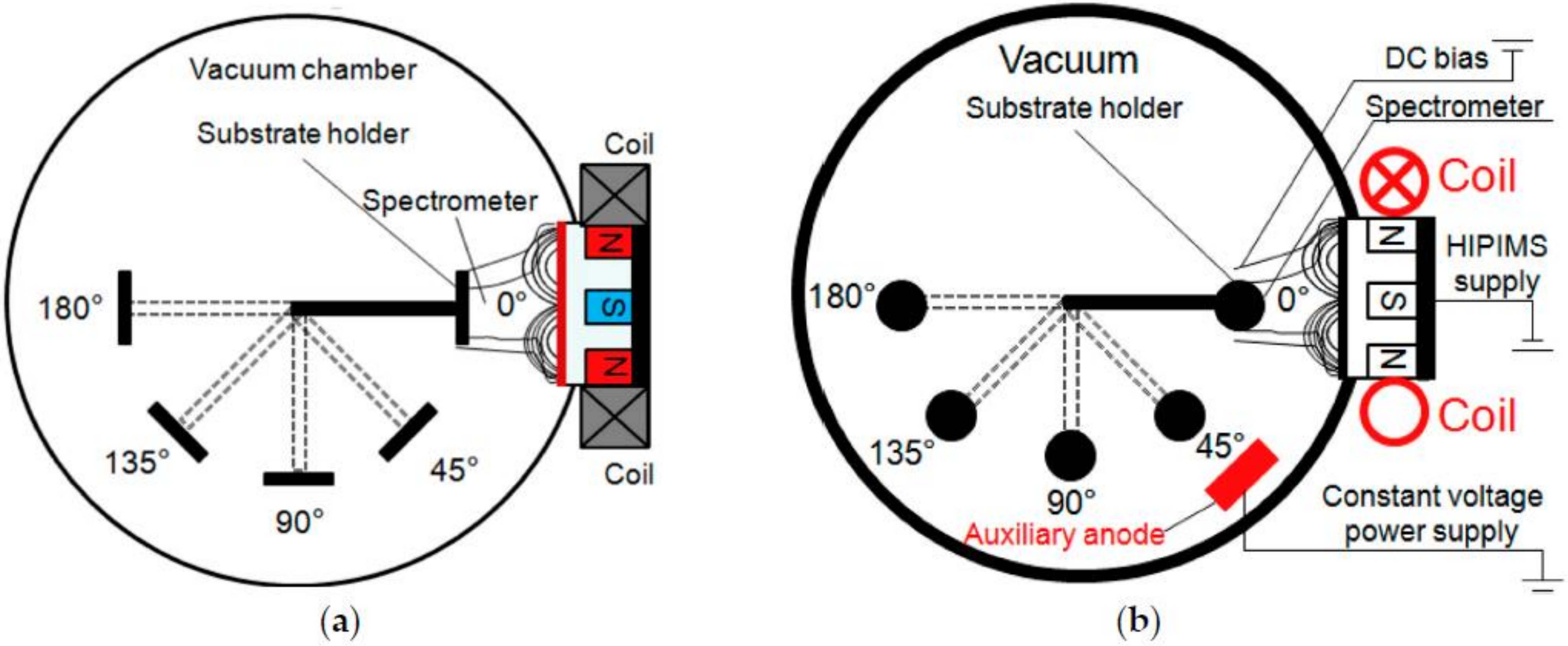


Figure 7. Vacuum system setup using (**a**) external unbalanced magnetic field, (**b**) external electric and magnetic fields, with the auxiliary anode. (**a**) Reproduced from [97] with permission. Copyright 2016 Elsevier. (**b**) Reproduced from [98] with permission. Copyright 2017 Elsevier.

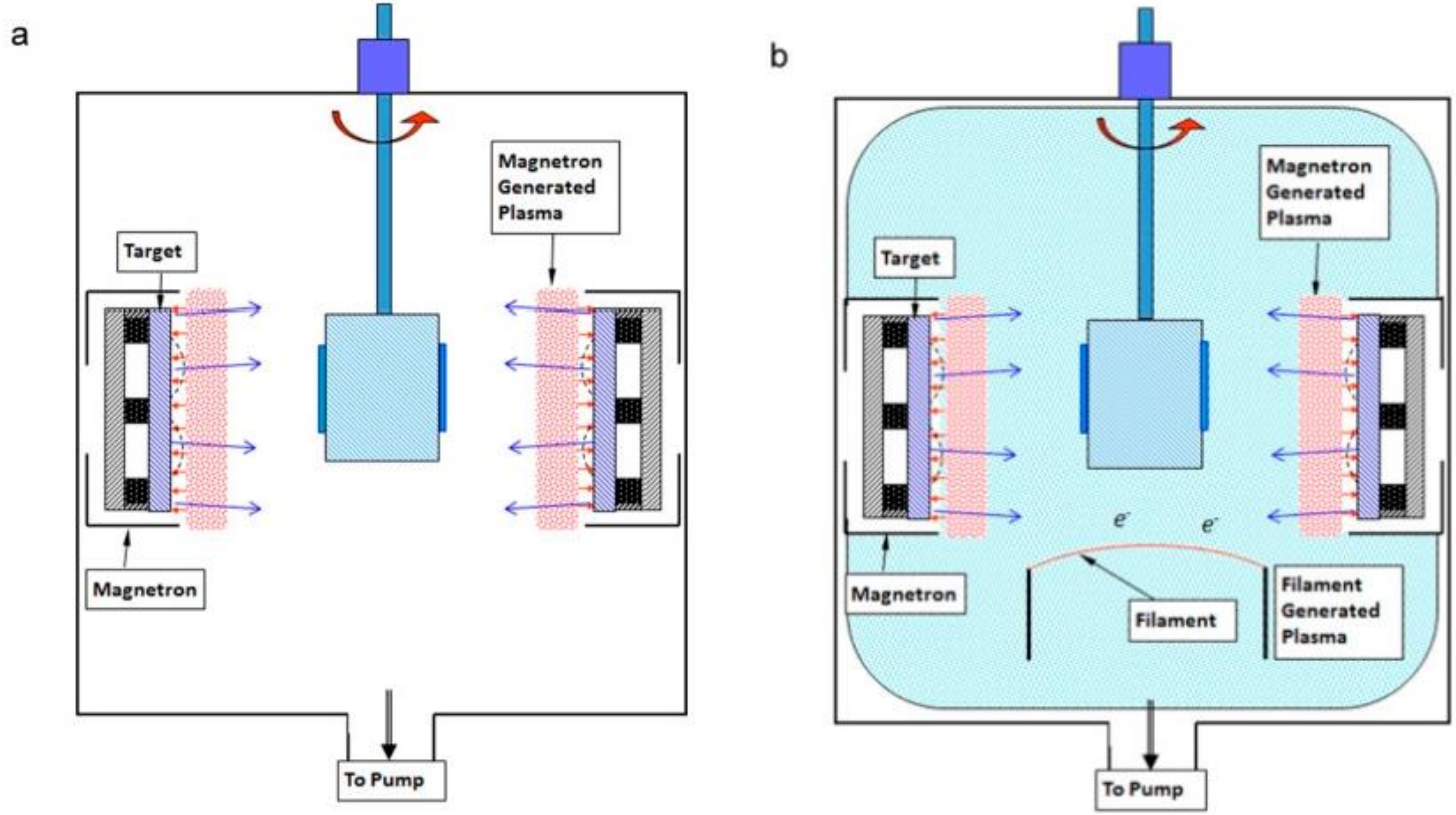


Figure 6. Schematic comparison between (**a**) conventional magnetron sputtering (MS), and the (**b**) plasma enhanced magnetron sputtering (PEMS) assisted process. Reproduced from [95] with permission. Copyright 2018 Elsevier.

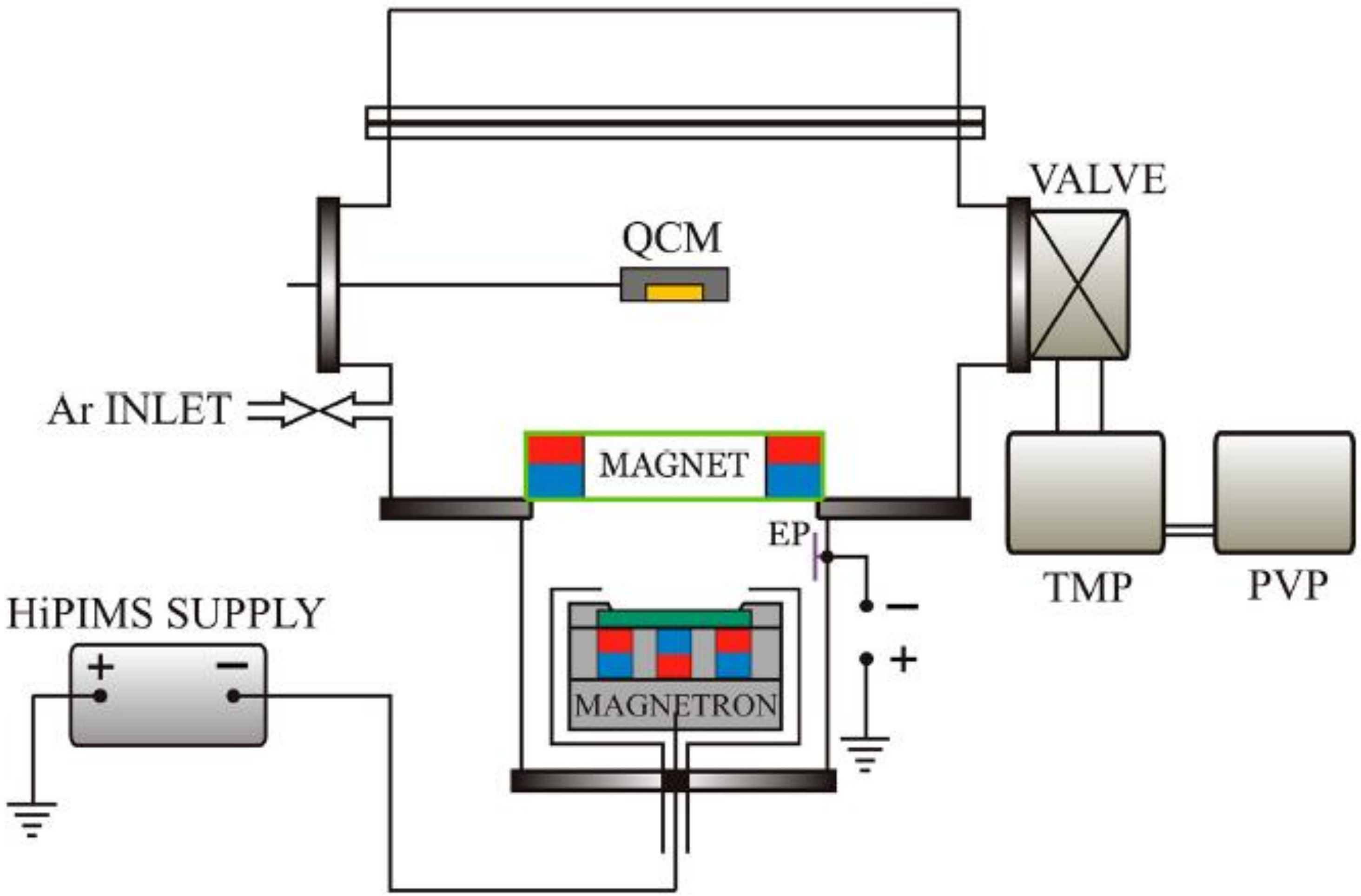


Figure 8. Schematic drawing of the experimental setup used in the work. Reproduced from [99] with permission. Copyright 2018 Elsevier.

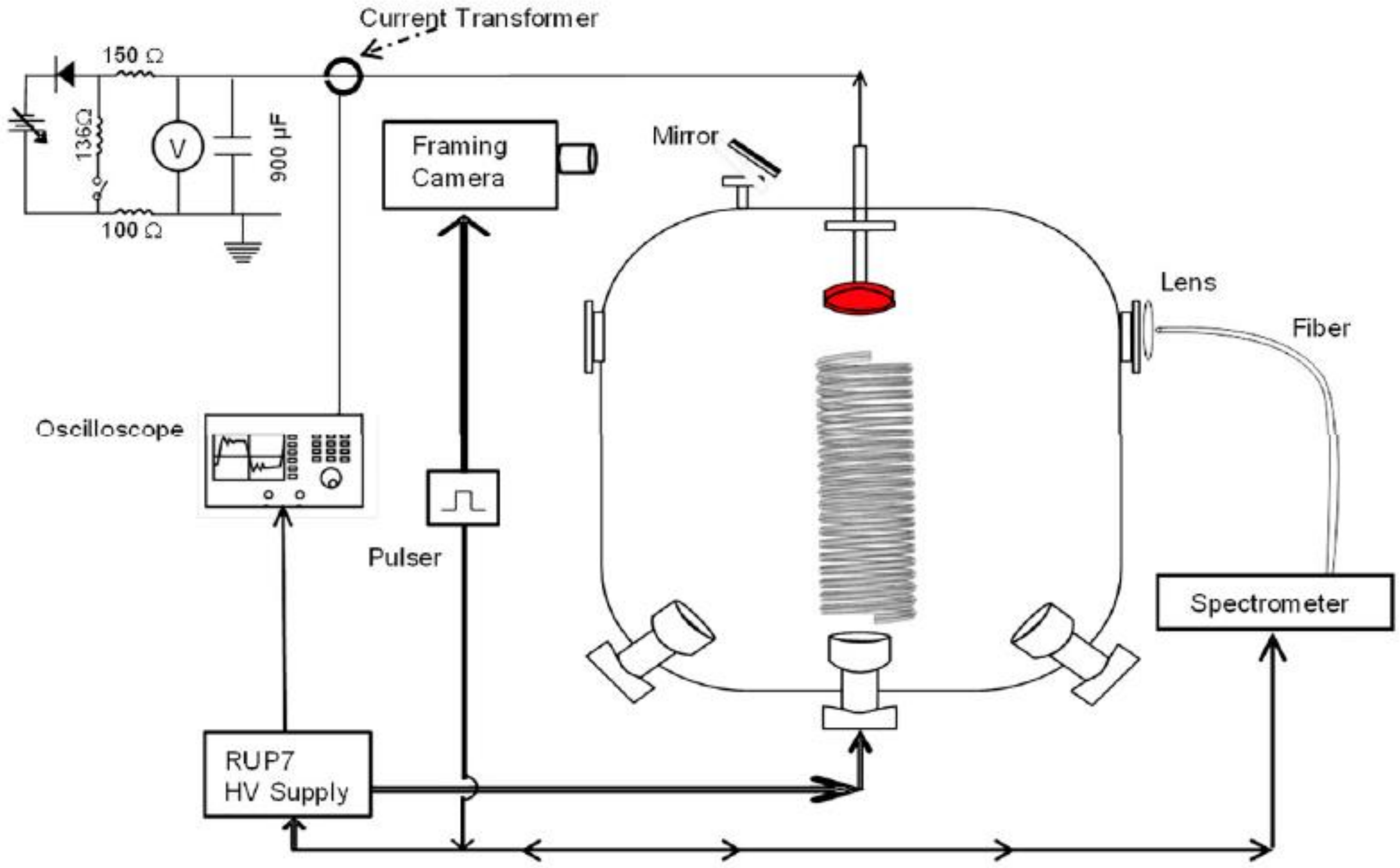


Figure 9. Experimental unit high power impulse magnetron sputtering (HiPIMS) deposition system showing the additional solenoidal coil. Reproduced from [100] with permission. Copyright 2019 Elsevier.

PVD advantages & Disadvantages

Advantages

- Environment friendly then paint & electroplating. more than one PVD technique can be used for coating.
- Usually, topcoats are not required
- Good strength and durability.

Disadvantages

- Cooling systems are required.
- Mostly high temperature and vacuum control needs skill & experience.
- PVD coated materials has no chemical interaction with the surface that deposited on.