CHAPTER 2

2.1 Introduction
A brief overview of deposition techniques that have been employed for the preparation of NEG coatings is being described. The design and development of the in-house sputter deposition system and the fundamental principle of its working are also described elaborately. The calculations of different parameters and simulation of the ion electron paths under the influence of magnetic and electric field are included. Role of different steps during the growth of a film is described. Specific details about the substrates are given, e.g., substrate materials, substrate dimensions, cleaning and preparation as well as the expected properties of the deposited film. Targets preparation and cleaning are also discussed. Direct current diode type magnetron sputtering technique which was utilized in preparation of coatings has been discussed. Brief overview of other coating techniques is also mentioned. The advantages of sputtering technique over other techniques have been added.

2.2 Sputter deposition method for preparation of NEG coatings

2.2.1 Physics of Sputtering
The sputter deposition technique has been utilized for the preparation of coatings of NEG materials. The fundamentals of this technique will be discussed in this section.

Bunsen and Glove first observed sputtering over almost 150 years ago in a discharge tube [76]. The process of removal of atoms/molecules from solid surfaces through the irradiation of energetic species is known as sputtering. In sputtering, the sputtered individual atoms acquire enough energy (1 – 10 eV) higher than any other deposition (thermal evaporation, chemical decomposition), after escaping from the surface [77]. This process is called sputtering and schematically shown in Fig. 2.1. Unlike thermal evaporation, it does not
require heating [78, 79]. Atoms which are ejected by sputtering from a target are deposited on surrounding surfaces progressively forming a thin film coating after going through all the steps of film deposition such as adsorption, nucleation, island formation etc. on a dedicated substrate. Any energetic atomic particle, in the present case ions of noble gases (Ar, Kr), impinging on a surface can cause sputtering. Since it is easier to accelerate ions than neutral particles, hence only sputtering under ion bombardment is used in practice. The effect of ion bombardment on a material differs from that of electron and photon bombardment because the ion mass is of the same order as the mass of the atoms in the target. This permits an efficient momentum transfer to individual atoms, which is the key feature of ion sputtering.

The minimum energy required to expel an atom from a target is called the sputtering threshold [80, 81]. It depends on the material but is quite insensitive to the mass ratio between the impinging ion and the target atoms [80, 81]. In 1962, Stuart and Wehner, measured threshold values by the spectroscopic method [82] in noble gas plasma and the values were in the order of 15-30 eV. The typical sputtering yields were of the order of $10^{-4}$ to $10^{-5}$ atoms/ion. The threshold energy also strongly depends on the particular sputtering sequence involved.

2.2.2 Sputtering Yield of different elements (Ti-V-Zr) used in NEG coatings

The role of the sputtering yield of the co-sputtered metal for the deposition of alloy films is important as it provides some kind of qualitative information about the chemical composition.
It is defined as the ratio of number of sputtered atoms to the number of incident particles. It is a measure of efficiency of sputtering. The sputtering yield $S$ is defined as,

$$S_{\text{sputtering yield}} (S) = \frac{\text{No. of Sputtered Atoms}}{\text{No. of Incident particles}}$$

Experimental values of $S$ range from $10^{-5}$ to as high as $10^3$ [83]. However, in a most practical sputtering process, the range of $S$ is narrower from $10^{-1}$ to 10.

There are a number of factors which affects the sputtering yield. Most important of the factors are given below:

a) Energy of the incident particles  
b) Target materials  
c) Incident angles of particles  
d) Crystal Structure of the target surface

The sputtering yield, $S$, can be measured by the following methods:

1) Weight Loss of the target  
2) Decrease of target thickness  
3) Collection of the sputtered materials  
4) Detection of sputtered materials in flight
Fig. 2.2: Variations of sputter yield with energy of incident ion.

Fig. 2.2 shows typical variation of the sputtering yield with incident ion energy. From the figure, it can be inferred that:

a) there is a low energy threshold for sputtering. The sputtering yield \( S \) is proportional to \( E^2 \),

b) at the energy region in the order of 100 eV, the sputtering yield is proportional to \( E \) [84, 85] as the incident ions collide with the surface atoms of the target, and the number of displaced atoms will be proportional to incident energy.

c) the sputtering yield is maximum as shown in Fig. 2 as plateau (\( E \approx 10 \text{ – } 100 \text{ keV} \)) in the high energy region as the incident ions travel beneath the surface and the sputtering yield is not governed by the surface scattering.

d) the sputtering yield varies with the angle of incidence of the ions. Metals [Au, Ag, Cu and Pt] which have very sputtering yield, show only slight variation with incident angle. The low sputtering yield metals [Fe, Ta and Mo] show very pronounced angle effect [83, 86]. The yield increases with angle and shows a maximum at angles between 60º and 70º.
The sputtering yield of group IVB (Ti, Zr, Hf) and VB (V, Nb, Ta) elements which are used in the preparation of NEG coatings with Ar\(^+\) ions as sputtering species are given in Table 2.1 and more details are given in reference [87]. Typical sputter yields in a low-energy region measured by Stuart and Wehner are shown [87]. Sputter yield vary with the angle of incident ions and for details see the reference [87].

Table 2.1: Sputtering yield of IVB and VB elements for Ar\(^+\).

<table>
<thead>
<tr>
<th>Target</th>
<th>Ar(^+)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100eV</td>
</tr>
<tr>
<td>IV B</td>
<td></td>
</tr>
<tr>
<td>Ti</td>
<td>0.081</td>
</tr>
<tr>
<td>Zr</td>
<td>0.12</td>
</tr>
<tr>
<td>Hf</td>
<td>0.16</td>
</tr>
<tr>
<td>VB</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>0.11</td>
</tr>
<tr>
<td>Nb</td>
<td>0.068</td>
</tr>
<tr>
<td>Ta</td>
<td>0.10</td>
</tr>
</tbody>
</table>

2.2.3 Advantages of Sputter deposition over other techniques

Sputter deposition technique has been used to prepare the NEG films of getter materials due to certain benefits over other techniques.

- Sputtering allows the deposition of the film having compositions of target source that also depend upon the sputtering yield of the materials. As in case of ternary alloy deposition on SS304 substrate, the target which was prepared by inter-twisting the wires of Ti, V, Z in (1:1:1). The deposited film had a composition of Ti\(_{20}\)V\(_{44}\)Zr\(_{36}\) following the sputter yields of the individual elements (vanadium has the highest sputter yield, followed by Zr and Ti, See Table 2.1).
- It is reasonably simple and can be used for wide range of materials.
- Suitable for uniform and distributed coating on long, narrow vacuum chambers/pipes. The cylindrical type sputtering system which has been developed is very useful for coating in long and narrow pipes where the substrate in pipe form can be used and target is axially placed in the centre of the system.
• The kinetic energy of the sputtered atoms is large (1 – 10 eV) as compared to other physical vapour deposition techniques so deposited films are mechanically stronger. The deposited film of NEG materials was tested with scratch test.

• Since the magnetron sputtering deposition is a low pressure discharge technique, deposited films are cleaner compared to other techniques.

• Allows co-sputtering using composite targets. In the present work three targets Ti, V and zirconium in elemental form were co-sputtered for the deposition of the alloy thin films of NEG.

• Deposition takes place away from the equilibrium. The highly energetic sputtered species are quenched on the substrate surface and non equilibrium state can lead to formation of exotic materials. Studies revealed that atoms emission reflects the lattice symmetry. In FCC metals, it has been demonstrated that atoms are preferentially ejected along the [110] direction, but ejection in [100] and [111] directions also occurs to lesser extent [88].

• As in the case of evaporation, sputtering also shows the cosine distribution of sputtered atoms with slight deviation and it is energy dependent. At high energy it is extended normal to target and at lower energy it is compressed. Much more material is ejected from the sides than in the direction normal to the target in case of “under cosine”. The distribution approaches a cosine distribution at higher energy which provides the uniform ejection of the material from the target.
2.2.4 Parameters of Sputtering deposition

Deposition parameters are important because they control the morphology of the deposited film. Glow discharge is important in order to get the better idea of sputtering deposition which is a plasma based deposition technique. In a diode gas-discharge tube, the minimum voltage which initiates the discharge is given by [89],

\[ V_s(Volt) = a \frac{pl}{\log pl + b} \]  

where \( p \) is the gas pressure in mbar, \( l \) is the electrode separation in cm, \( a \) and \( b \) are constants.

The relation between spark voltage \( V_s \) and the gas pressure \( p \), is called famous Paschen’s Law. The typical experimental results shown in Fig. 2.3 exhibit the minimum spark voltage at gas pressure \( p_m \) [89].

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**Fig. 2.3:** A plot of spark voltage as a function of gas pressure measured for Cu electrodes in air (electrode spacing, 5 mm) [89].
To initiate a discharge, the gas pressure $p_s$ under a given electrode separation, $l$, is expressed by,

$$p_s \geq \frac{\lambda_0}{l} \quad (2)$$

Where $\lambda_0$ is the mean free-path of electrons in the discharge given as $\lambda_0 = 1/p_c$, where $p_c$ is the elastic cross section between electrons and gas atoms. $P_c$ values for different noble gases which are used as discharge gases are given in Fig. 2.4 [90, 91]. So for $l=10$ cm separation, the pressure should be higher than $5 \times 10^{-3}$ Torr to initiate the breakdown and forming discharge. In a diode type discharge, when the discharge is initiated in a low pressure gas, the mode of discharge varies with discharge current.
2.2.5 Cylindrical Type, DC-Magnetron Sputtering system for deposition of NEG coatings

In DC-Magnetron Sputtering system one of the electrodes is a cold cathode and the other is the anode. The cathode is having the target materials to be deposited. The substrates are placed on the anode. The sputtering chamber is filled with sputtering gas, typically argon gas at 4x10⁻³ – 12 x 10⁻³ mbar. A magnetic field is superposed on the cathode and glow discharge which is parallel to the cathode surface is created. The electrons in the glow discharge show cycloidal motion, and centre of the orbit drifts in the direction of \( \mathbf{E} \times \mathbf{B} \) with the drift velocity of \( \frac{\mathbf{E}}{\mathbf{B}} \), where \( \mathbf{E} \) is the electric in the discharge and \( \mathbf{B} \) is the superposed on transverse magnetic field, respectively. The magnetic field is oriented such that these drift paths for electrons form a closed loop. This electron-trapping effect increases the collision rate between the electrons and the sputtering gas molecules. This enables one to lower the sputtering gas pressure to as low as 10⁻⁵ mbar, but more typically 10⁻² mbar. In the magnetron sputtering system, the magnetic field increases the plasma density which leads to increases in the current density at the cathode target, effectively increasing the sputtering rate at the target. Due to the gas’s low working pressure, the sputtered particles traverse the discharge space without collision, which results in a high deposition rate.

In this thesis, a cylindrical magnetron sputtering system has been used to deposit NEG films. The schematic of the cylindrical magnetron is shown in Fig. 2.5. It consists of electrodes arranged in a cylindrical geometry. The target, fabricated as a cylinder, is surrounded in a \( 2\pi \) geometry by anode substrates so that a radial electric field is established between these electrodes. Simultaneously, a uniform magnetic field is applied parallel to the z-direction by means of permanent magnet or electromagnet or via a co-axial solenoid. Electrons emitted radially from the cathode immediately find themselves trapped between perpendicular electric and magnetic fields where they hop around the target circumference in
closed orbits defined by the Lorentz-force geometry. As in the case of the planar magnetron, an intense cylindrical plasma column is created near the cathode by the enhanced gas-ionization efficiency. Cylindrical magnetron sputtering has been commercially employed for many years in coating razor-blade cutting edges with platinum/chromium. The sputter deposition of diamond like carbon on stainless-steel blades coated with a niobium glue layer is the latest advance in blade technology. This type of magnetron deposition technique is of paramount importance in the coating of NEG materials on large substrate areas. The NEG coating inside the cylindrical pipe is beneficial because the pipe itself is treated as substrate (anode) which is kept at ground potential.

Fig.2.5: Schematic diagram of a cylindrical sputtering set-up.

2.3 Historical View of Sputter deposition

Sputtering or cathode sputtering is used for the deposition of thin films. Several sputtering systems have been proposed for thin-film deposition including DC diode, RF diode, Magnetron and Ion Beam Sputtering. The magnetron sputtering was first proposed by Penning in 1936 [93]. A prototype of the planar was invented by Wasa in 1967 [94].
2.4 Simulation of Cylindrical type DC magnetron sputtering and experimental setup

The simulation of the ion trajectories was done by using SIMION 8.0 software and has been shown in Fig. 2.6 (Magnetic field = 300 Gauss, cathode voltage = 800V(-tive), anode at ground). The electrons move cycloidal with different radii in opposite direction under the influence of both electric field $E$ and Magnetic field $B$ perpendicular to each other. Ions, being heavy, feel very little affect of magnetic field so their path is almost linear. Confinement in crossed electric and magnetic fields increases the electron path length and thereby enhancing the ionizing efficiency near the cathode that results in a dense plasma and a higher discharge current. In the simulation, three concentric cylindrical lenses were considered; the biggest cylinder is treated as solenoid where magnetic field is applied. The middle cylinder which kept at ground is considered as substrate. The inner most cylinder is treated as target which is kept at a negative potential.

The electronic and ionic radii in the electric and magnetic fields are given by:

$$R_{\text{electron}} = 3.37 \times 10^{-7} E^{1/2}(\text{eV})/ B \text{ (Gauss)}$$

$$R_{\text{ion}} = 911 \times E^{1/2}(\text{eV})/ B \text{ (Gauss)}$$

![Fig.2.6: Simulated trajectories of ions/electrons in sputtering system (top view)]()
**Fig. 2.7:** Schematic diagram of the cylindrical type DC-magnetron sputtering deposition system.

**Fig. 2.8:** Photograph of the DC-magnetron sputtering system showing pumps and electronic instruments.
Experimental setup is an indigenously developed cylindrical type DC-magnetron sputter deposition system schematically shown in Fig. 2.7 and photographs of the system are shown.
in Fig. 2.8 and Fig. 2.9. In developing the system, the available literature was surveyed and then simulated to fix up parameters (Magnetic field = 300 Gauss, cathode voltage = 800V(-tive), anode at ground) of the coating system. The system includes a cylindrical type DC-magnetron sputtering system with target holder in the centre of the cylindrical pipe and substrate holder is attached to the same flange as shown in Fig.2.10, parallel to the target with special attachment where 6 substrates can be placed simultaneously. The big size substrate in the form of SS304L sheet can also be held by the welded support inside the cylindrical pipe and also the pipe itself can be used as a substrate, so that different types of substrates can be coated with NEG films using this arrangement. The substrate-to-target distance is about 45 mm. One 1kW arc protected DC power supply was integrated to supply of voltage to the target. The substrate holder was held at ground potential. A dedicated vacuum system consisting of a 500 l/s turbo molecular pump and a high performance rotary backing pump are employed to pump down the chamber from atmosphere. Gas flow control is done via mass flow control valves and a manual high precision leak valves. A solenoid of internal diameter 250 mm ϕ and length 390 mm, having 500 turns is used to produce the required magnetic field to start the arc discharge at low voltage and low pressure. For a solenoid of fixed number of turns the magnetic field can be controlled by the manipulation of current only as (B ∝ I). The calculated magnetic field is plotted as a function of distance and current respectively in Fig. 2.11 and in Fig. 2.12.
Fig. 2.11: Measured profile of magnetic field as a function of distance.

Fig. 2.12: Measured profile of magnetic field as a function of current.
The plot showing the variation of axial magnetic field with distance was measured with the help of Hall probe. The simulation of the ions trajectories was done with the help of SIMION 8.0 software package.

Maximum axial field at the centre

\[ B = \mu_0 n I \frac{L}{(4R^2 + L^2)^{1/2}} \]

where \( n = \frac{N}{L} \) is no. of turns, in our case 520, \( L \) = length of the solenoid, in the present case 390mm, \( R \) = Radius of the solenoid and \( I \) is the current in A.

2.5 Deposition Conditions and steps in growth of NEG film

The nature of the film is governed by the deposition parameters such as deposition rate, substrate temperature, substrate material and deposition atmosphere [92]. The chemical composition of deposited films is governed by the substrate temperature and/or the deposition atmosphere. Under low substrate temperatures, the chemical composition of deposited films coincides with that of the source materials. Under high substrate temperature, the vapour pressure increases which results in the change of the chemical composition of the deposited film from the source materials due to re-evaporation of the high vapour pressure materials from the film. Gas molecules that are frequently included in the film, also affect the film composition during deposition. The active gas molecules are reacted chemically with the deposited materials and form its compounds.

There are three main steps involved in the growth of thin films;

1) *Production of the proper atomic, molecular, or ionic species,*

2) *Transport them to the substrate through some medium* and

3) *Condensation on the substrate, either directly or via chemical or electrochemical reaction, to form a solid deposit.*
Thin films always start to form via nucleation and growth process. Pictorial representation of the type of growth process is given below:

![Diagram showing different growth processes of thin films](image)

**Fig. 2.13:** Pictorial representation of the growth process of a thin film.

The general picture of step-by-step growth process is as follows:

a) The units which are coming out from the materials (target), on impacting, lose their velocity component normal to the surface and are physically adsorbed to the surface depending on the sojourn time.

b) At first the absorbed species are not ahead of thermal equilibrium with the substrate and move over the substrate surface which gets them in forming bigger cluster.

c) These clusters are known as nuclei and are thermodynamically unstable. These may tend to desorb in time, depending on the deposition parameter. If the deposition parameter is such that a cluster collides with other adsorbed species before getting absorbed, it starts growing in time and becomes thermodynamically unstable after reaching a critical size (overcoming nucleation barrier). The step involving the formation of stable, chemisorbed, critical sized nuclei is called the nucleation stage.
d) The critical nuclei grow in number as well as in size until a saturation nucleation density is reached. The nucleation density and the average nucleus size depend on a number of parameters such as the energy of the impinging species, the rate of impingement, the activation energies of adsorption, desorption, thermal diffusion, and the temperature, topography, and the chemical nature of the substrate. A nucleus can grow both in lateral and perpendicular growth through surface diffusion or by direct impingement of the incident species. The rate of lateral growth is much higher than the perpendicular growth and grown nuclei are called *islands*.

e) Coalescence stage is the next stage in which small island start coalescing with each other in an attempt to reduce the substrate surface area. This is called *agglomeration* and can be enhanced by surface mobility (increasing substrate temperature) of the adsorbed species.

f) Larger islands grow together, leaving channels and holes of uncovered substrate. The structure of the films at this stage changes from discontinuous type to porous network type. Filling of the channels and holes takes place to form a complete, continuous film.

g) After a continuous film is formed, the anisotropic growth takes place normal to substrate in the form of cylindrical columns. The initial nucleation density determines the lateral grain size or crystallite size. If re-crystallization occurs during the coalescence stage, the lateral grain size is larger than the average separation of the initial nuclei and the average grains per unit area of the film is less than the initial nucleation density. The grain size normal to the substrate is equal to the film thickness. Thicker films are the results of re-nucleation on previously grown grains.

The mechanism of thin film growth has been described in the literature as follows. It is started by the adatoms on the surface of the substrate. The adatoms will be trapped at a
nucleation centre after a Brownian movement. The mean residence time of adatoms, \( \tau_s \), is given as,

\[
\tau_s = \tau_v e^{\left(\frac{E_{ad}}{kT}\right)}
\]

where \( \tau_v \) is the period of vibration perpendicular to the surface assumed to be almost \( 1/\nu \) (=10\(^{-13}\) s ), where \( \nu \approx 10^{13} \) Hz is a frequency of lattice thermal vibration, and \( E_{d} \) is adsorption energy of adatoms on the substrate in the range 0.1 to 1 eV.

The thermal equilibrium time of the adatoms, \( \tau_e \), is given as,

\[
\tau_e = \tau_s e^{-\left(\frac{E_{ad}}{kT}\right)}
\]

If \( E_{ad} >> kT \), the adsorbed atom will stay at the surface of the substrate where \( \tau_s >> \tau_e \). If \( E_{ad} \approx kT \), the adatom will re-evaporate from the substrates. The adatoms will diffuse on the surface showing Brownian movement, the travelling time for diffusion on the surface is given as,

\[
\tau_d = \tau_p e^{\left(\frac{E_{d}}{kT}\right)}
\]

Where \( \tau_p \) is a period of vibration parallel to the surface assumed to be almost \( 1/\nu \) (=10\(^{-13}\) s ), where \( \nu \approx 10^{13} \) Hz) and \( E_{d} \) is the surface diffusion energy for the adatoms against the potential barrier on the substrate surface.

The mean travelling distance of the adatoms, \( X \), is given as,

\[
X = (D_s \tau_s)^{1/2}
\]

\[
D_s = \frac{a_0^2}{\tau_s}
\]

where \( a_0 \) denotes a lattice spacing of surface atoms of the substrates. Since \( \tau_p \approx \tau_v \), so,

\[
X = a_0 e^{\frac{E_{ad} - E_{d}}{2kT}}
\]

Both \( E_{ad} \) and \( E_{d} \) are crucial for the growth of thin films. The growth of the thin film is also governed by the surface energy of the film, \( \gamma_f \), surface energy of the substrates \( \gamma_s \), and the
interfacial energy between thin film and substrates, $\gamma_{fs}$. The island growth will be prevalent at $(\gamma_s - \gamma_{fs}) < \gamma_f$ and the layer growth at $(\gamma_s - \gamma_{fs}) > \gamma_f$.

There are three types of growth stages that are described and shown in Fig. 2.13,

(a) Island type or Volmer-Weber,

(b) Layer type or Frank-van der Merwe type,

(c) Mixed type or Stranski-Krastonov Type.

The crystallographic and topographical details of different islands are randomly distributed, so that when they touch each other during growth, grain boundaries and various line and point defects are incorporated into the film due to mismatch of geometrical configurations and crystallographic orientations. If the grains are randomly oriented, the film shows a ring-type diffraction pattern and are said to be polycrystalline in nature.

There are number of parameters that affect the quality of the thin films. Some of these are described below.

**2.5.1 Effect of substrate temperature**

The substrate at increased temperature enhances the mobility of the adsorbed species at the surface which results in increasing the surface diffusion. The grain size of film is increased by increasing the substrate temperature. Another effect of increasing the temperature of the film is that the post deposition annealing also results in increased grain size. The grains are smaller in post annealing as compared to keep the substrate at higher temperature during deposition. It happens due to involvement of higher activation-energy in the process of thermal diffusion in post annealing. Effects of heat treatments are more pronounced in thick films.
The relationship between the substrate temperature, kinetic energy of the ions and deposition rate can be understood by the zone model of Thronton (Fig. 2.14).

2.5.2 Adhesion of the film

The substrate cleaning, chemical nature and micro-topography of the film profoundly affect the adhesion of a film on a substrate and the film starts peeling off with time. The adhesion is better for higher values of kinetic energy of the incident species, adsorption energy of the deposit and initial nucleation density. Loose and porous deposits formed under conditions of high super-saturation and poor vacuum adversely are affected in adhesion. Contaminants present on the substrate surface may increase or decrease the adhesion of the film depending upon the increase or decrease of the adsorption energy.

2.5.3 Different types of targets used for NEG coatings

As the NEG films in the present work are ternary alloy they needed to be co-sputtered from three different metallic targets for the preparation of the film. In a cylindrical type
sputtering system, the target is prepared by inter-twisting of three metallic wires of 1mm diameter and 400 mm length. The wires were 99.7 % pure and procured from Sigma Aldrich Company. Some of the targets are shown in Fig. 2.15.

There are number of targets used to prepare the coatings of NEG materials in different compositions. These targets are Ti(1)Zr(1), Ti(1)Nb(1)Zr(1), Ti(2)V(1)Zr(2), Ti(1)V(1)Zr(1), Ti(1)V(2)Zr(1), Ti(1)V(1)Zr(2) etc.

![Fig. 2.15: Different types of inter-twisted ternary targets of (Ti-V-Zr) used in sputtering system.](image)

**2.5.4 Types of substrate:**

In Fig. 2.16 different types of substrates (UHV pipes of SS304L size CF40 and 350mm, size CF100 length 300 mm and sheet of SS304L of dimension 0.2 X 250 x 300mm³) have been shown which are coated inside with NEG materials using the cylindrical type magnetron sputter system. NEG coated and uncoated surfaces can be clearly seen in Fig. 2.16. All of these coatings are used and tested to achieve XHV after thermal activation at activation temperature. For the characterization of the film, small portions for the prepared films were cut and used to mount on a specially designed substrate holder as shown in Fig.2.10.
2.6 Other techniques used for NEG coatings

2.6.1 Vacuum Arc deposition

The first sample of ternary coating of NEG material was prepared by a vacuum arc deposition technique as shown in Fig. 2.17 [95]. It is also a physical vapour deposition in which an electric arc is used to vaporize the material from a cathode target. The vaporized material then condenses on a substrate, forming a thin film. The arc evaporation process begins with the striking of a high current, low voltage arc on the surface of a cathode or target that gives rise to a small (usually a few µm wide), highly energetic emitting area known as a cathode spot.

The localized temperature at the cathode spot is extremely high (around 15000 K), which results in a high velocity (10 km/s) jet of vapourised cathode materials. A small ingot of composite material of Ti$_{0.2}$V$_{0.4}$Zr$_{0.4}$ about 20 mm in diameter was used as a target in these experiments. Electrodes of size 18 X 8 mm$^2$ were prepared. A DC dielectric arc was struck between the two electrodes. The pressure was kept 6 X 10$^{-5}$ mbar during the deposition. The SS304L substrates were used to deposit the film.
2.6.2 Planar type RF-sputtering system

This technique is similar to the DC- magnetron sputtering deposition as described in previous section, the only difference is that an RF-power is used in place of DC-power to create the arc discharge. This technique is versatile and can be used to deposit all type of materials such as metallic, insulator and alloy. RF-sputtering has benefitted in depositing the insulated materials where DC-sputtering does not work due to build of positive charge inside the target and deposition stops due to the unavailability of conduction path for the build up of positive charge. The sign of anode cathode bias is varied at a high rate with the RF-frequency. The
very first ternary target of Ti$_{0.3}$V$_{0.3}$Zr$_{0.3}$ was prepared by bonding the Ti, and Zr strips on a V 75 mm diameter disk in equal proportion. The RF power of 200 watts at 13.56 MHz was used for this purpose. The SS304L substrates of size 10 × 10 mm$^2$ were used on which the NEG film was deposited [96]. The base pressure was 5 × 10$^{-6}$ mbar and discharge was started in the Ar atmosphere of 5 × 10$^{-3}$ mbar with a deposition time of 4 h. A schematic diagram of the planar RF-sputtering system is shown in Fig. 2.18.