Application of Plasma in for semiconductor device fabrication

Application of plasma processing:

Two major applications are:

1. Plasma Deposition – Here thin film of semiconductor material is grown. The products are continuously accumulated on the substrate surface. Used in different device fabrication like solar cell, IC etc.
2. Plasma Etching – Here the products are instantaneously removed from the surface. This is one important step during IC fabrication.

Both technologies include similar mechanisms: plasma phase chemical reactions, particle transport, and surface reactions. For etching applications, the film surface atoms are constantly reacted with chemicals supplied from the plasma phase reactions. Reaction products are instantaneously removed. For deposition applications, chemicals supplied from the plasma phase react on the film surface. Reaction products remain and accumulate on the surface.

Plasma Enhanced Chemical Vapour Deposition (PECVD) process:

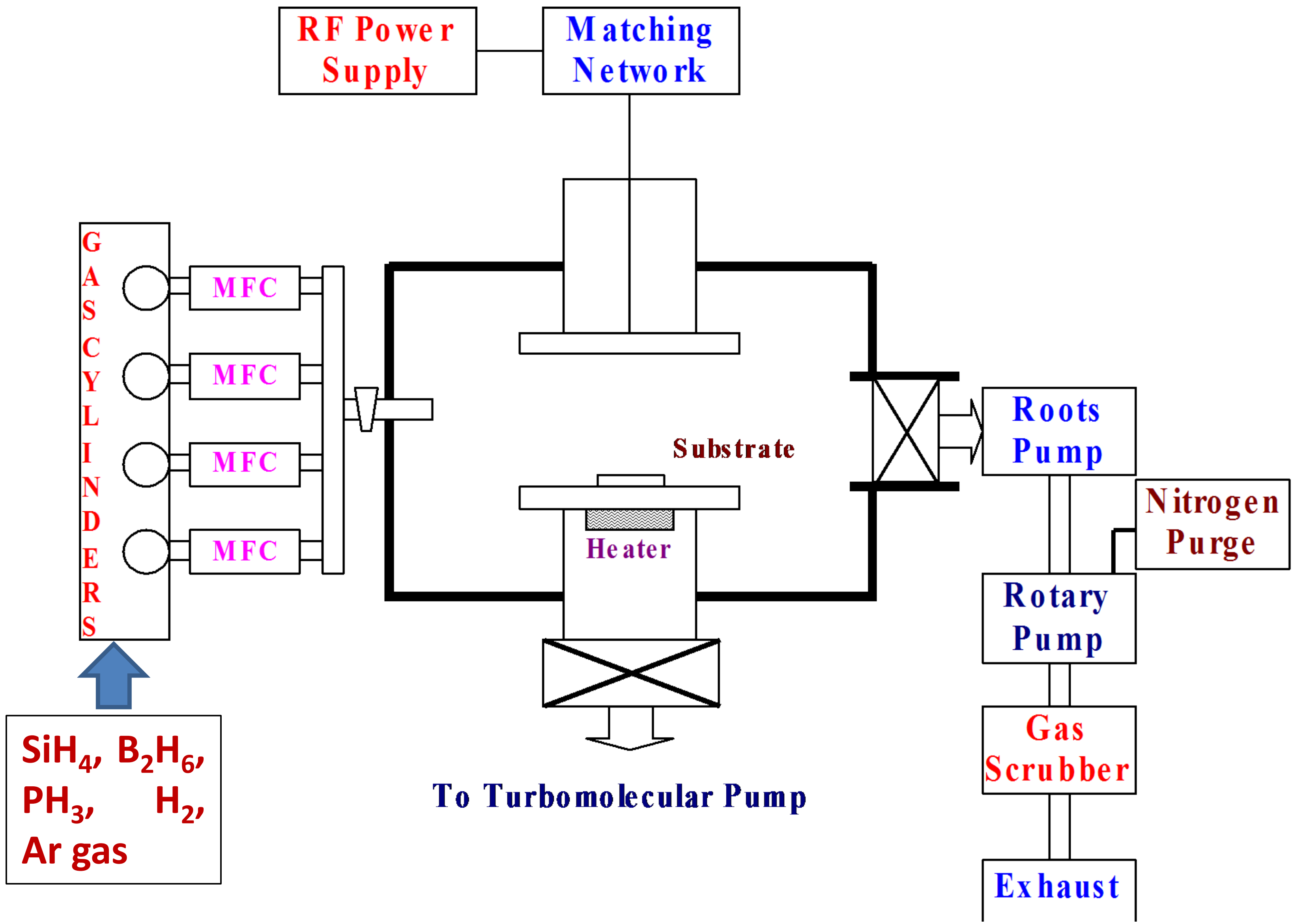
PECVD is a chemical vapor deposition technology that utilizes a plasma to provide some of the energy for the deposition reaction to take place. This provides an advantage of lower temperature processing compared with purely thermal processing methods. PECVD allows for tunable control over the chemical composition of a thin film.

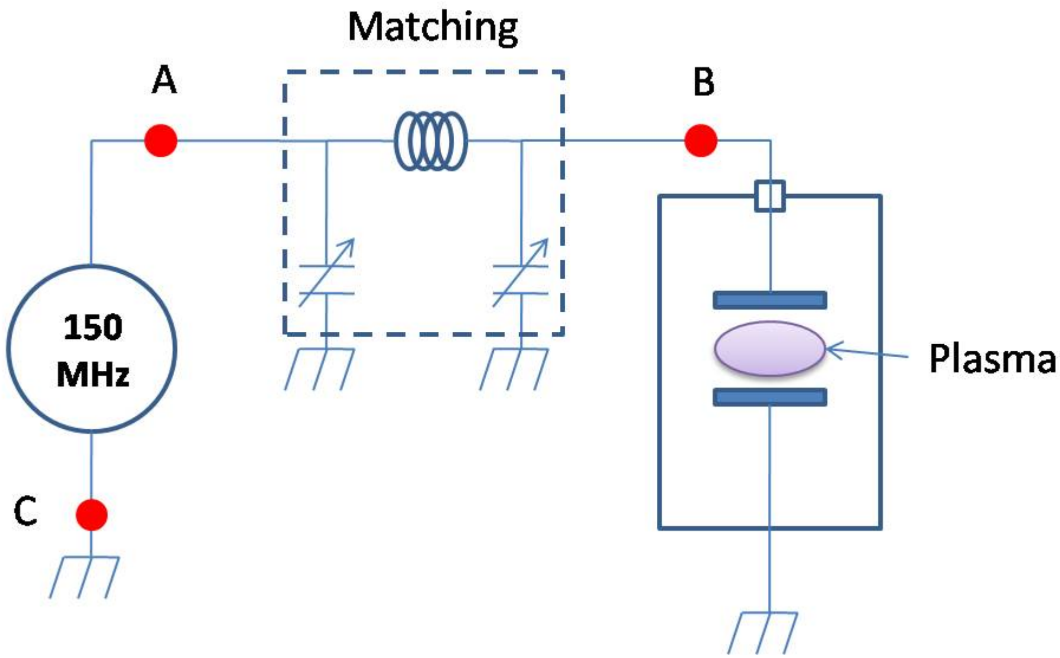
Initially gasses are introduced in the vacuum chamber. Then plasma is formed by giving some power. Within plasma gas phase reaction takes place. Finally materials are grown on the substrate.

Silane (SiH_4) is the source gas to deposit Silicon thin film

SiH_4 -> SiH_3 -> SiH_2 -> Si:H

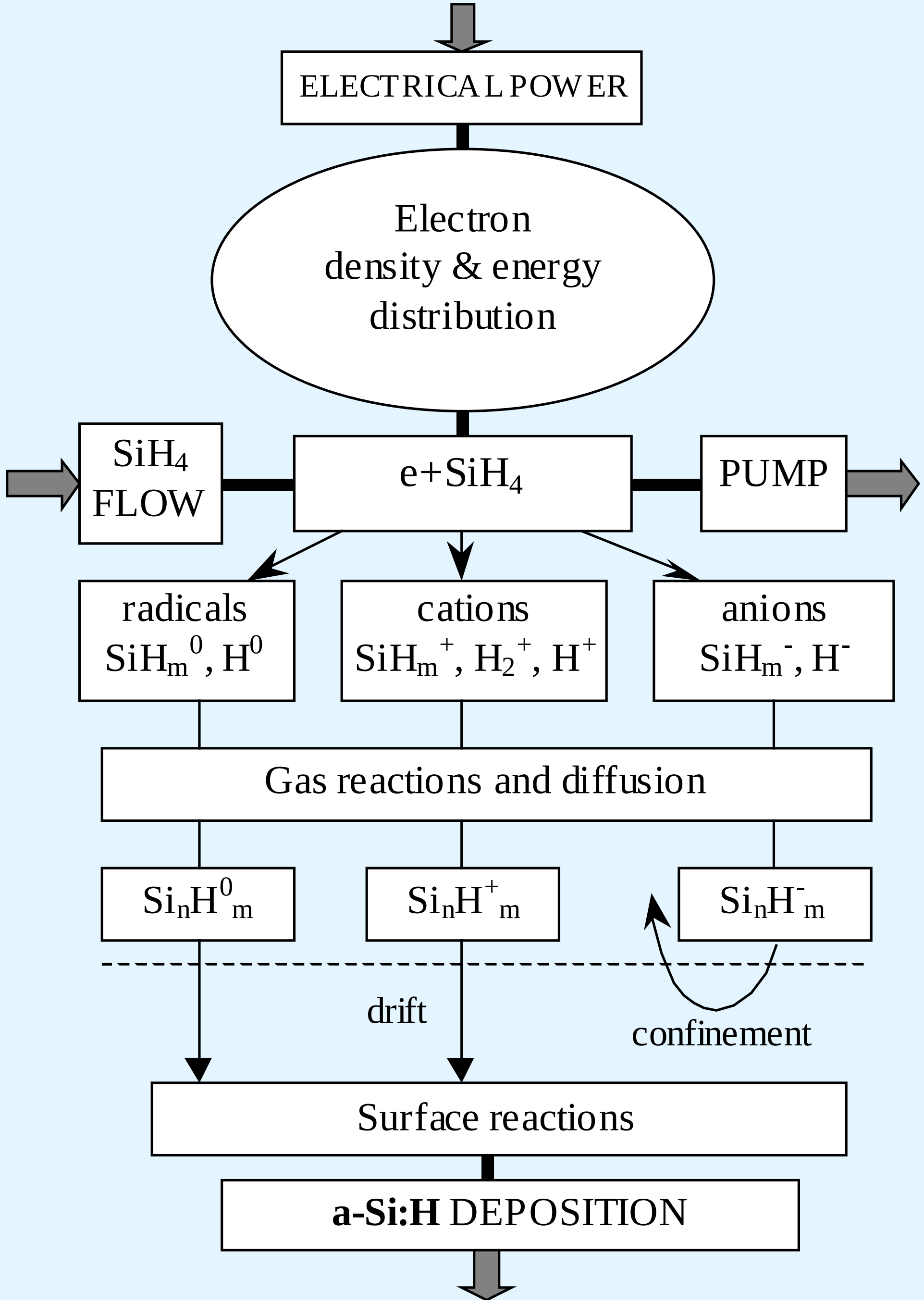
Plasma Enhanced CVD (PECVD) System





Why Matching Network:

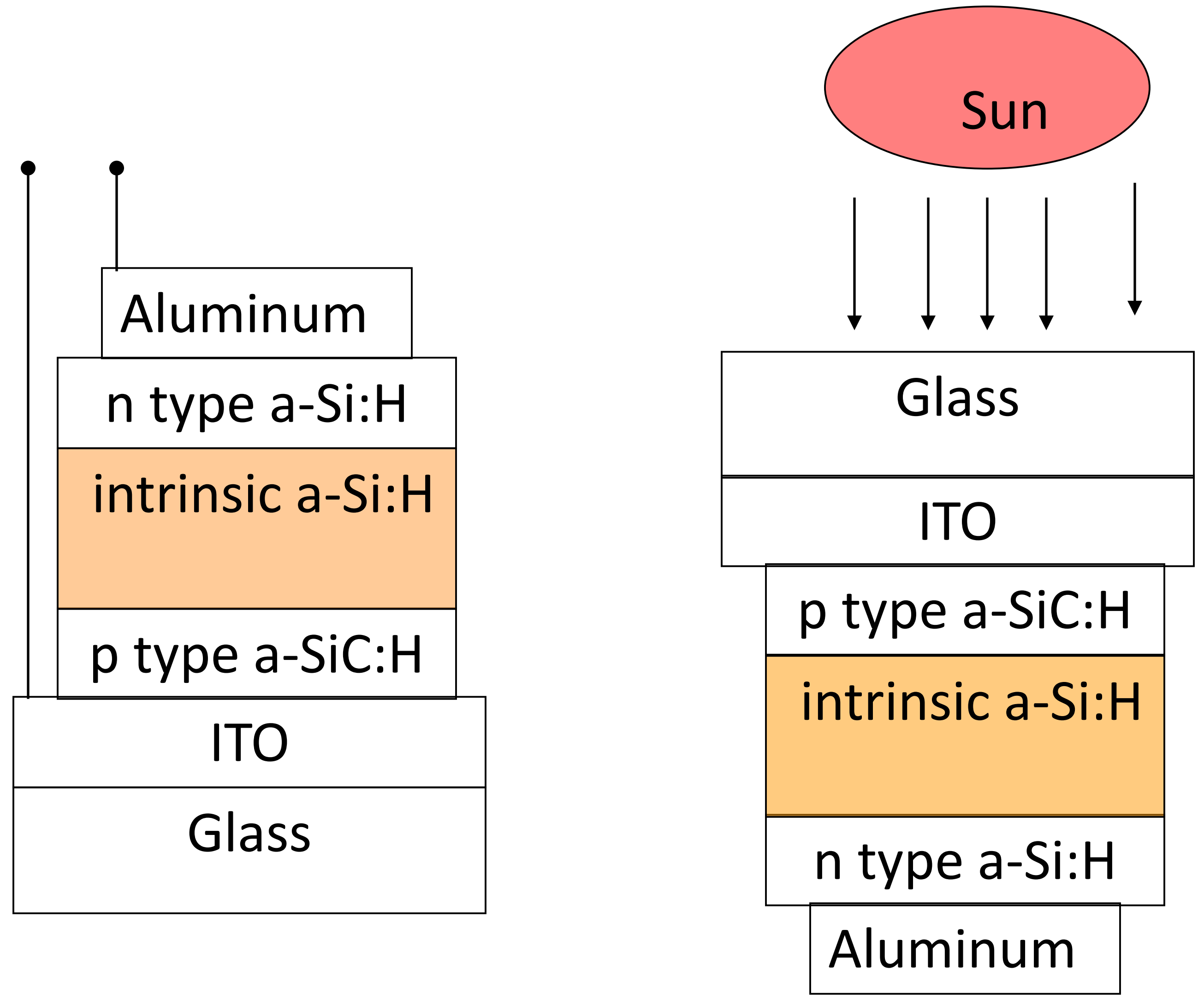
A matching network is needed for operating a plasma generator with an RF power supply. This is to eliminate the reflected power at the power supply/antenna interface so that the maximum power output from the supply is delivered into the plasma generator. Maximum power is transferred from source to load when the load resistance equals the source resistance and the load reactance.



ELECTRICAL POWER
Electron
density & energy
distribution
SiH_4
FLOW
e+SiH_4
PUMP
radicals
SiH_m^0, H^0
cations
SiH_m^+, H_2^+, H^+
anions
SiH_m^-, H^-
Gas reactions and diffusion
$Si_nH^0_m$
$Si_nH^+_m$
$Si_nH^-_m$
drift
confinement
Surface reactions
a-Si:H DEPOSITION

PECVD is a multifaceted procedure which is currently used for several applications such as the fabrication of coatings, powders, fibers, and uniform components. Metals, composites of nonmetallic materials such as carbon, silicon, carbides, nitrides, oxides, and intermetallics can be deposited through CVD. Considering one of the main applications of CVD, which is the synthesis of thin films and coatings, this procedure has in general overcome some of the problems Facing the chemical synthesis of thin films, and simplified the process by having a single-step uniform fabrication. In the CVD technique, a precursor gas flows into a chamber, over the heated substrates to be coated, and deposition of thin films on the surface occurs due to the chemical reaction in vapor phase.

a-Si thin film solar cell fabricated by PECVD



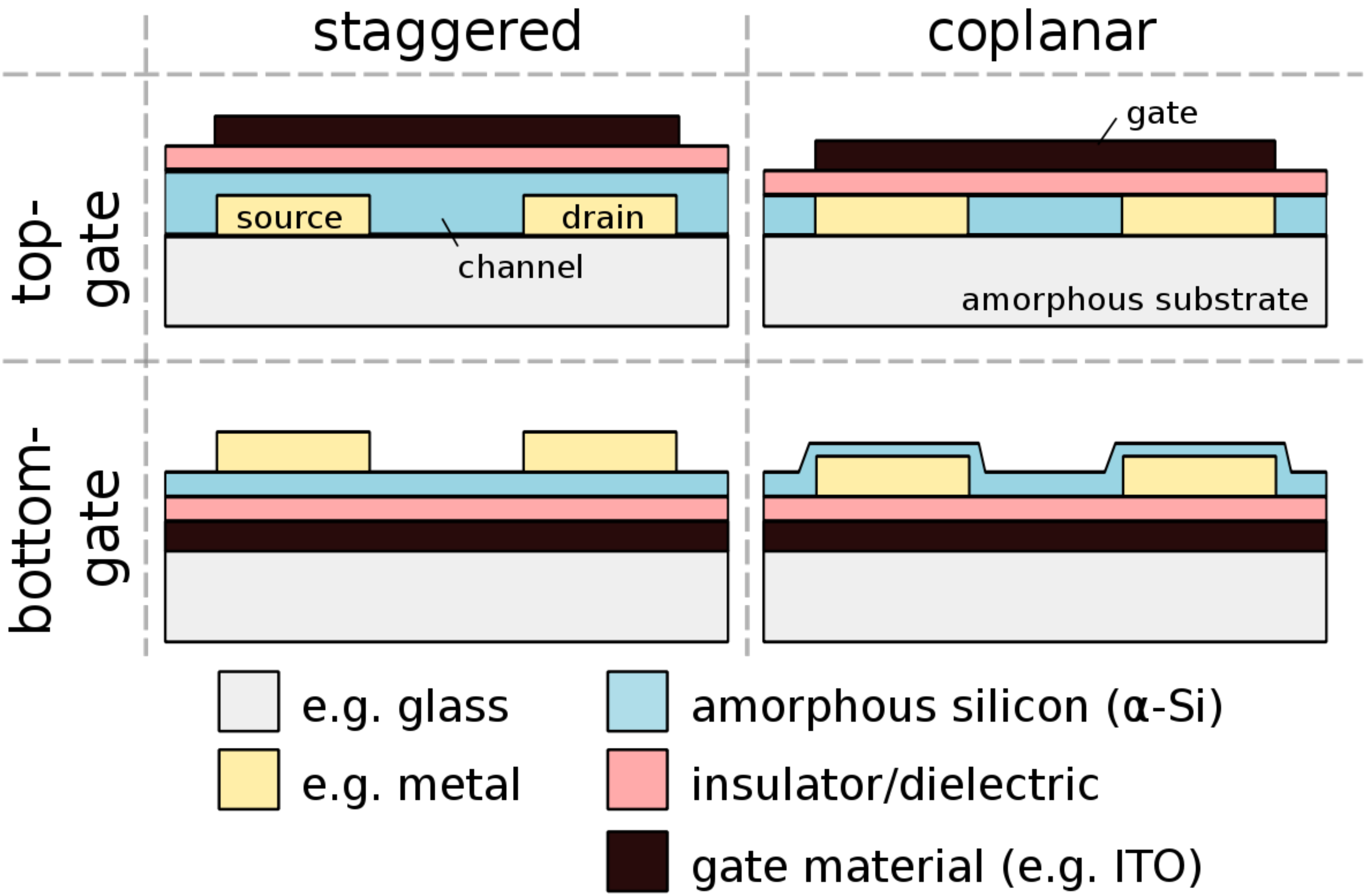
Gas used: ⇨ Silane, Argon, Methane, Diborane and Phosphine

- Intrinsic a-Si:H layer – from SiH_4+Ar

$SiH_4 \rightarrow SiH_3 \rightarrow Si:H$

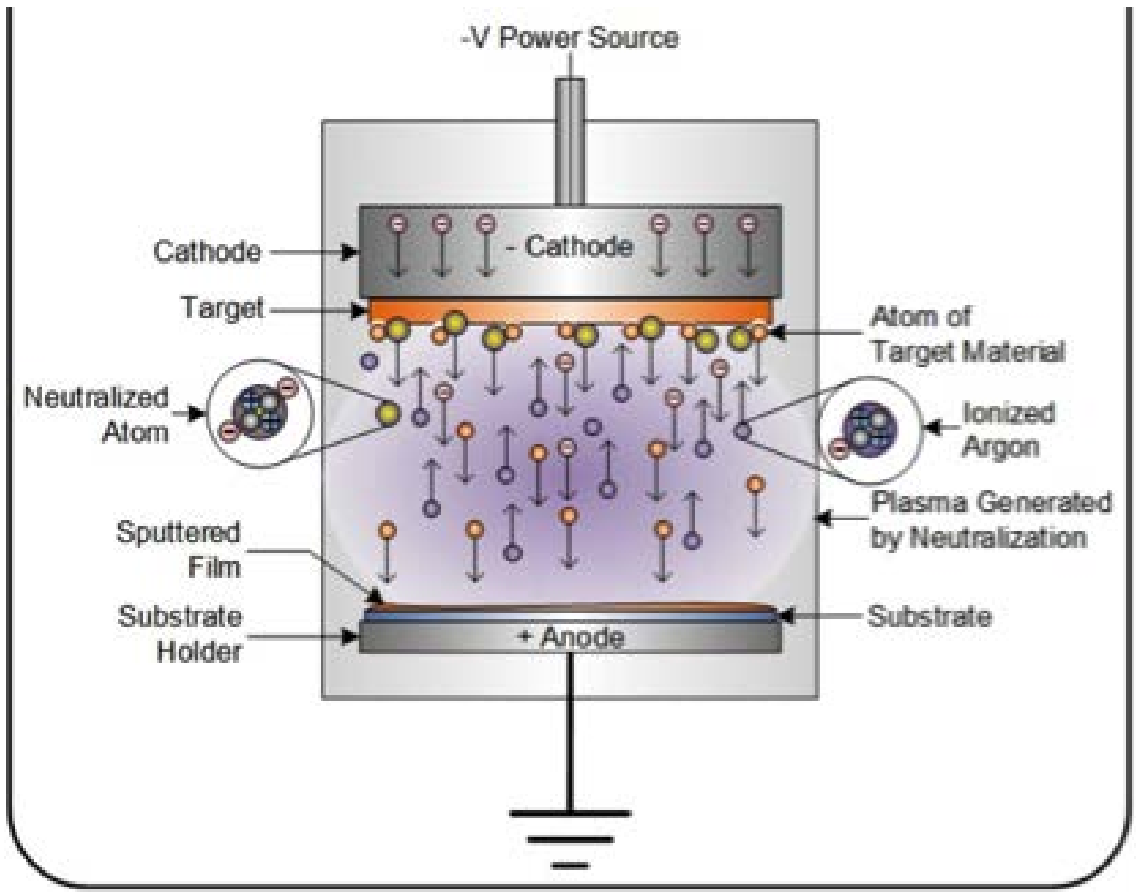
- p type SiC layer – from SiH_4+ B_2H_6 + CH_4 +Ar
- n type a-Si:H layer – from SiH_4+PH_3 + Ar

Amorphous silicon thin film transistor



Sputtering – Physical Vapour Deposition

Sputtering is the process whereby atoms are ejected from a target or source material that is to be deposited on a substrate.



RF Sputtering

Sputter deposition of insulating materials cannot be done with DC power. Materials such as oxides, nitrides, and ceramics have very large DC impedance and require prohibitively high voltages to ignite and maintain a plasma. Luckily, the impedance of these materials changes with the frequency of the applied power. Using power delivered at radio frequencies (RF) – typically at 13.56 MHz – and an automatic impedance matching network, the total impedance of the circuit can be regulated to 50 Ω which is suitable for plasma ignition in typical sputtering environments.

Indium Tin Oxide (ITO) development by RF Sputtering

Indium tin oxide (ITO) is one of the most widely used transparent conducting oxides (TCO) because of its two main **properties**: its electrical conductivity and optical transparency. It is also a relatively inexpensive material and is easy to be deposited as a thin film on glass, polymer, and other substrates. Thin films of indium tin oxide are most commonly deposited on surfaces by physical vapor deposition, such as the various sputtering techniques.

As with all transparent conducting films, a compromise must be made between conductivity and transparency, since increasing the thickness and increasing the concentration of charge carriers increases the material's conductivity, but decreases its transparency.

Effect of deposition conditions on deposition rate of ITO