PCVD / PECVD

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PCVD / PECVD

1 Basic Definition

PCVD / PECVD (Plasma-Enhanced Chemical Vapor Deposition) is a thin film deposition technique in which plasma is used to activate chemical reactions of precursor gases.

- Plasma provides energy to break precursor molecules.
- Reactive species form and deposit as a thin film on the substrate.

2 Core Components of the Process

2.1 Precursor Gas

- Contains atoms that form the thin film.
- Usually a chemically reactive compound.
- In the laboratory: **Orthocarboranes** are used.
- Other examples:
  - Silane (SiH_4) $\rightarrow$ Silicon / SiO_2
  - Metal-organic precursors $\rightarrow$ Carbides / Nitrides

2.2 Inert / Carrier Gases

Examples:

- Argon (Ar)
- Helium (He)
- Nitrogen (sometimes)

In the laboratory, **Ar and He** are used.

- Do not usually become part of the film.
- Assist plasma formation and transport precursor vapour.

2.3 Plasma Source

Plasma is generated using:

- RF (Radio Frequency) power
- Microwave power
- RF frequency is lower than microwave frequency.
- Higher frequency generally produces denser and more energetic plasma.
- In the laboratory: **RF power only** is used.

2.4 Substrate

- Surface on which the film grows.
- In the laboratory: **Silicon wafer** is used as substrate.

3 Process Flow (Stepwise)

1. Vacuum chamber is pumped down to low pressure (important for purity).
2. Carrier gas flows through the bubbler.
3. Carrier gas picks up precursor vapour.
4. Gas mixture enters the plasma region.
5. Plasma dissociates precursors into radicals and ions.
6. Radicals react on the substrate surface forming a thin film.
7. Reaction by-products are removed through exhaust.

Note: Even though orthocarborane is fully vaporising, carrier gases are still used for stability and control.

4 Bubbler System

4.1 Purpose

To convert liquid precursor into vapour.

4.2 Working Principle

Carrier gas bubbles through a heated liquid precursor, carrying vapour into the chamber.

4.3 Important Control Parameters

- Bubbler temperature
- Carrier gas flow rate

Both parameters control precursor concentration.

Important Point

Some precursors do not require a bubbler:

- High vapour pressure precursors
- Already gaseous precursors
- Examples: Silane gas, Ammonia gas

5 Role of Inert / Carrier Gas

- Transport precursor vapour
- Stabilize plasma
- Control deposition rate
- Improve film uniformity
- Prevent precursor condensation

Important Point

Inert gases generally do not chemically form the film, but they can influence film microstructure and stress.

6 Role of Plasma

Plasma consists of:

- High-energy electrons
- Ions
- Radicals

6.1 Functions of Plasma

- Break precursor molecules
- Enable low-temperature deposition
- Activate surface reactions
- Improve film adhesion

Key Advantage

Plasma allows deposition at **100–400°C**, compared to thermal CVD which requires **700–1100°C**.

7 Important Process Parameters

7.1 Base Pressure

Pressure before gas introduction.

- Removes contamination
- Ensures process purity

7.2 Operating Pressure

Controls:

- Plasma density
- Collision frequency
- Reaction rate

7.3 Gas Flow Rate (sccm)

Controls:

- Film composition
- Deposition rate

7.4 Plasma Power

- Higher power increases ion energy and deposition rate
- Excess power may cause surface damage

7.5 Substrate Temperature

Controls:

- Film crystallinity
- Film stress
- Reaction completion

7.6 DC Bias

- Applied voltage on substrate
- Controls ion bombardment energy
- Influences film density and adhesion

Important Point

Higher bias leads to stronger ion bombardment, resulting in denser films but increased stress.

8 Why Inert Gas Is Needed Even If Precursor Is Vapour

- Controlled delivery of precursor
- Plasma stability
- Uniform gas distribution
- Prevention of condensation

Important Point

Without carrier gas, vapour flow becomes unstable and deposition becomes non-uniform.

9 Deposition Mechanism

Two main reaction zones:

- **Gas-phase reactions:** Plasma generates radicals.
- **Surface reactions:** Radicals adsorb and form solid film.

Key Concept

Film growth mainly occurs on substrate surfaces, not in the bulk gas phase.

10 Advantages of PCVD / PECVD

- Low temperature processing
- High purity films
- Good thickness uniformity
- Good adhesion
- Wide material compatibility

11 Limitations

- Possible plasma-induced damage
- Film stress formation
- Complex equipment
- Limited conformality compared to ALD

12 Applications

- Semiconductor fabrication
- Dielectrics and passivation layers
- Optical fibers and refractive index control
- MEMS devices
- Sensors and microstructures
- Protective and wear-resistant coatings

13 Carrier Gas vs Precursor

Property	Carrier Gas	Precursor
Reactivity	Inert	Reactive
Forms film	No	Yes
Controls plasma	Yes	No
Transport medium	Yes	No