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Basic Nanotechnology Processes

E SC 212

Unit 2
An Introduction to Uses of Plasma in Processing

Lecture 3
Plasmas and Deposition

Outline

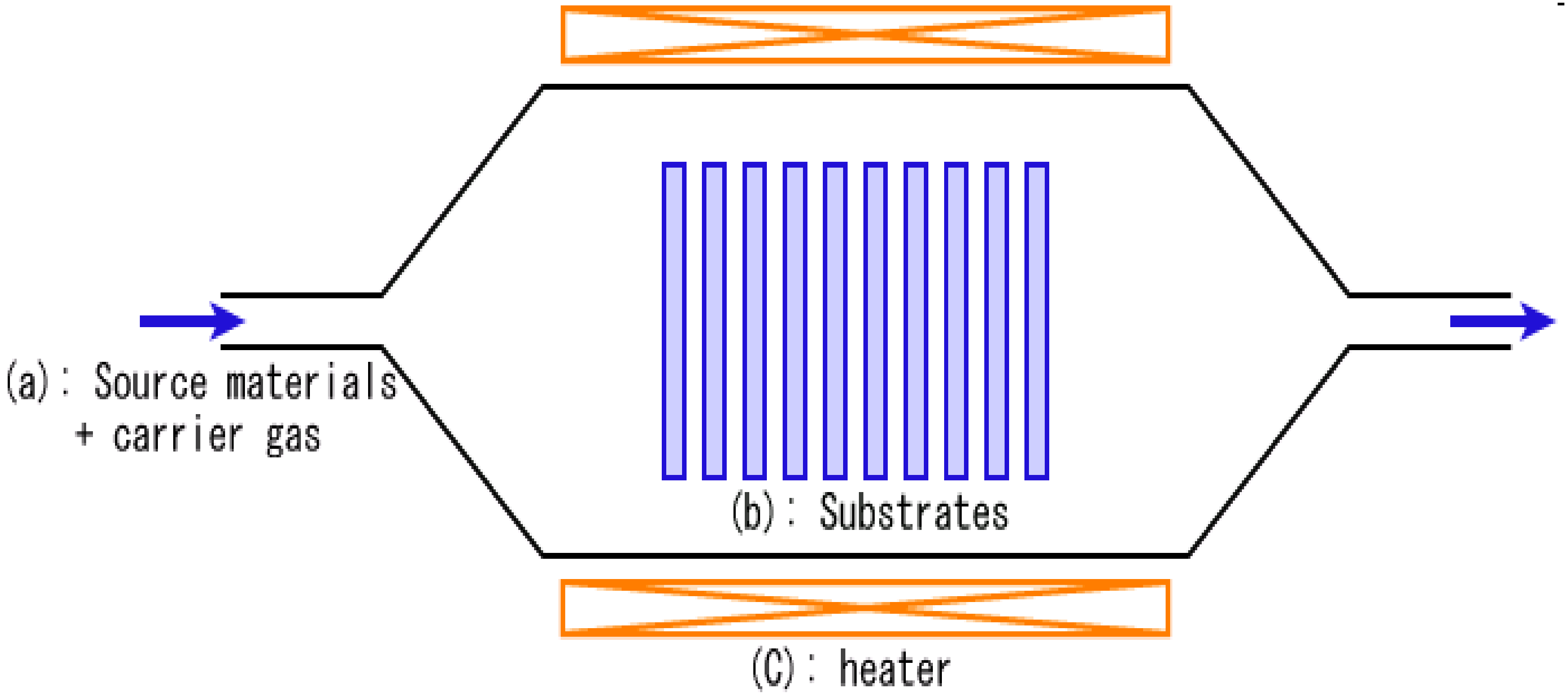
- Some more additive processes
- Plasma enhanced chemical vapor deposition (PECVD)
- Plasma Enhanced atomic layer deposition (PEALD)
- Applications of PECVD and PEALD.

Additive processes

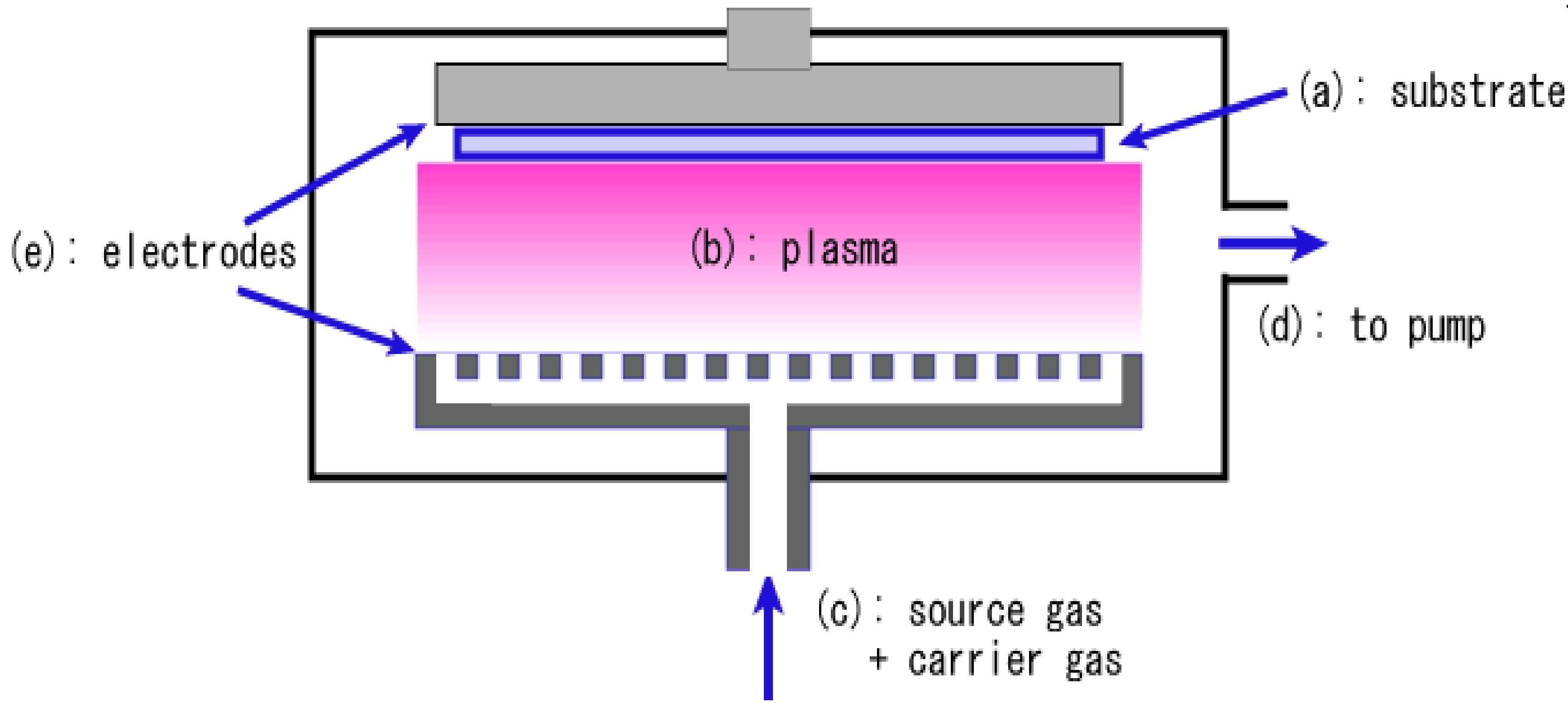
- These are deposition processes--- adding a material
- There are many types; e.g., evaporation, sputtering, chemical vapor deposition, plasma enhanced deposition, atomic layer deposition.

The Additive Processes we will discuss in this lecture (plasma enhanced chemical vapor deposition and plasma enhanced atomic layer deposition) both employ plasmas in the additive chemical process

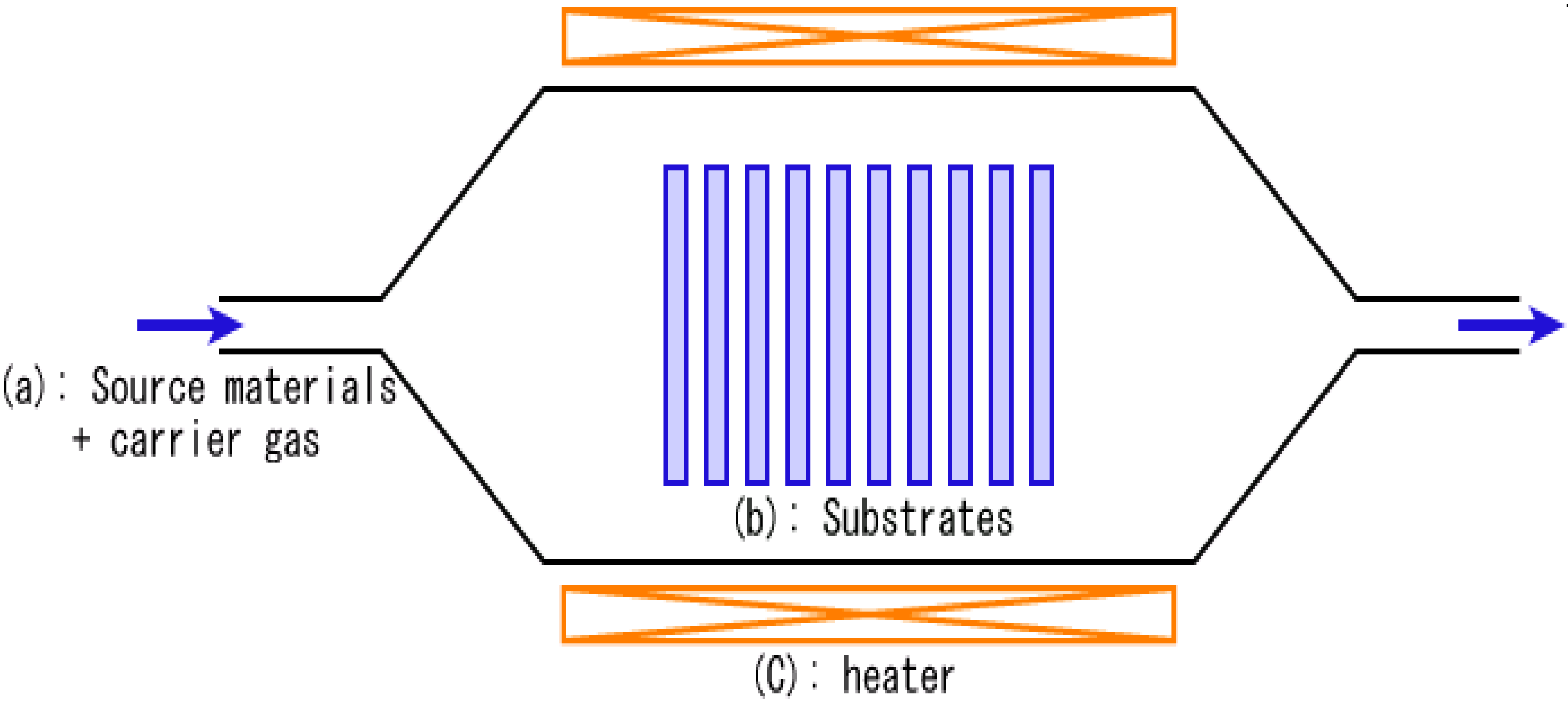
Chemical Vapor Deposition (CVD)



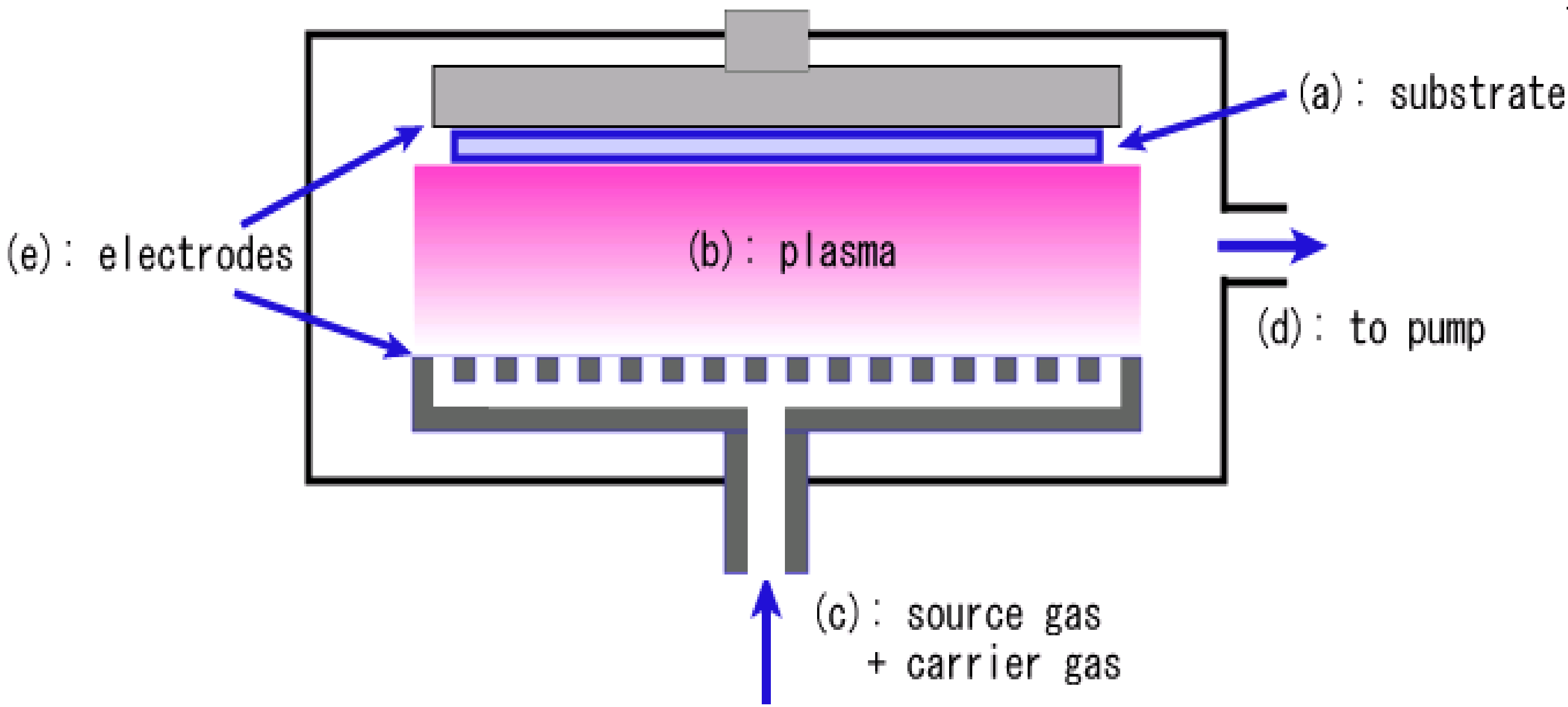
Plasma Enhanced Chemical Vapor Deposition (PECVD)



Example: In CVD approach a-Si:H is deposited from silane by heat-driven decomposition at 580 C.



Example: In PECVD approach a-Si:H is deposited from silane by plasma-driven decomposition at ~230C.

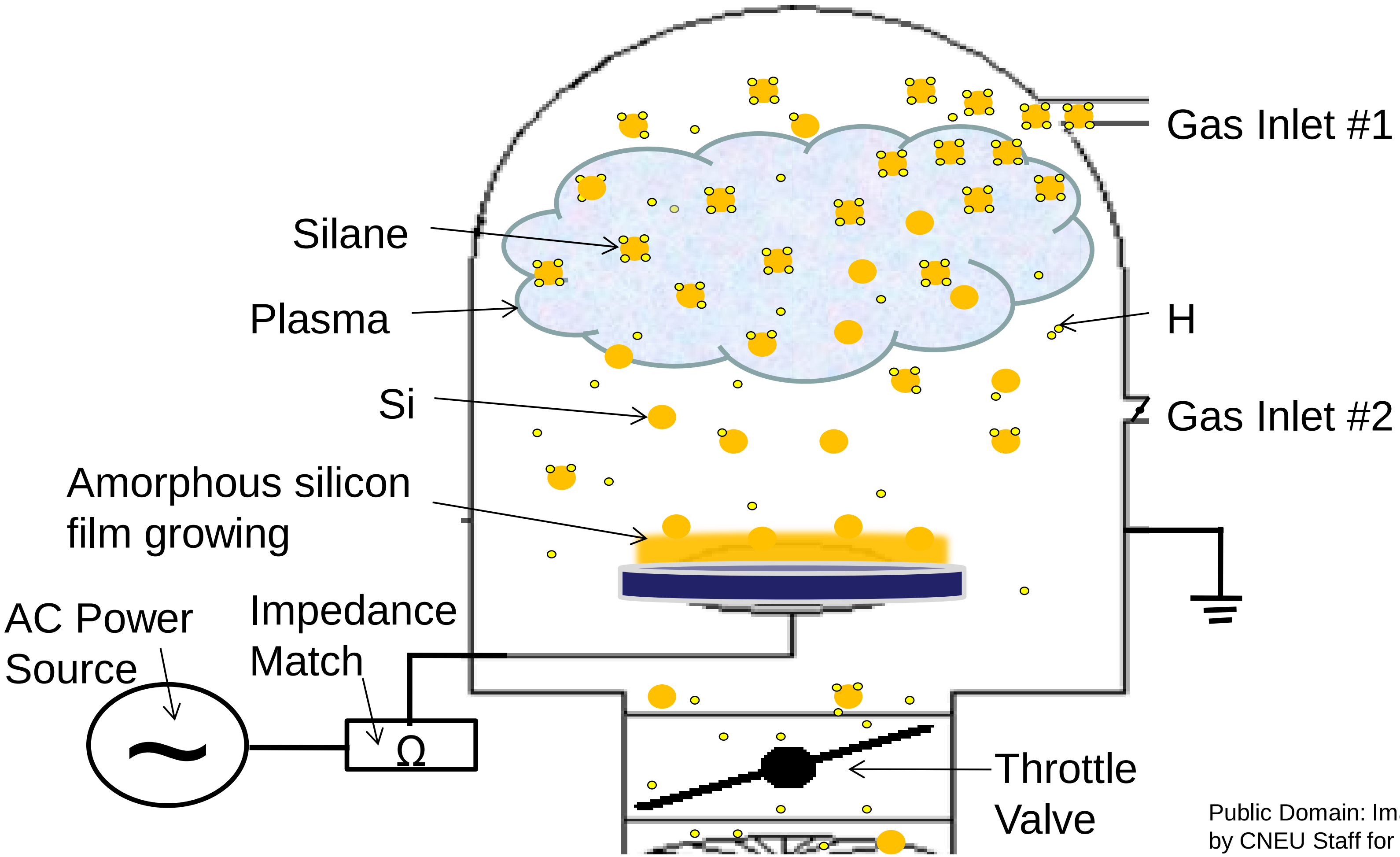


Comparison

- Big difference in processing temperatures
- Difference in a-Si:H films produced
- Difference in hydrogen content
- Difference in structure

PECVD

In PECVD, gas molecules (e.g., the precursor Silane) are broken apart by a plasma. The radicals, ions, and electrons produced result in a chemical reaction on the substrate producing the creation of a film as shown . The substrate is not involved in the chemical reaction in PECVD.



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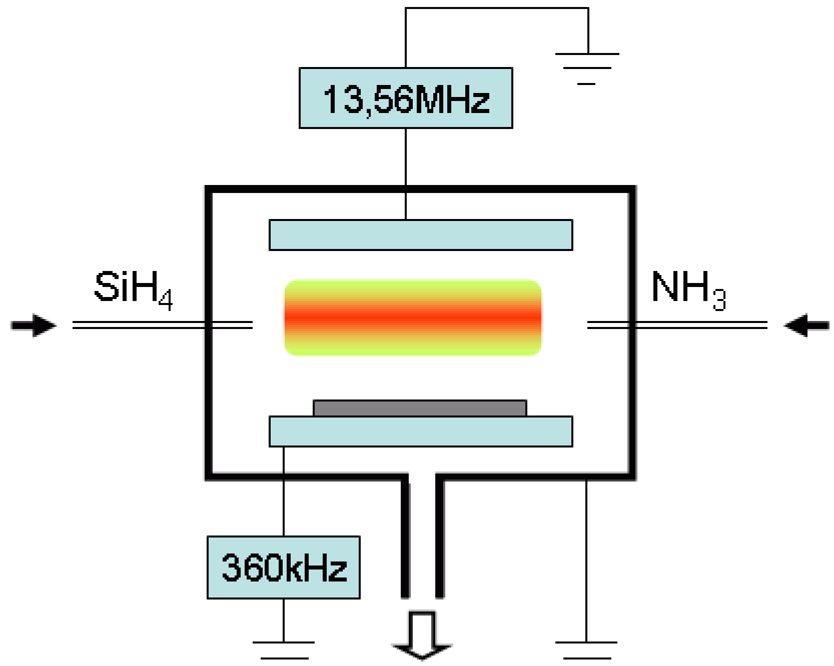
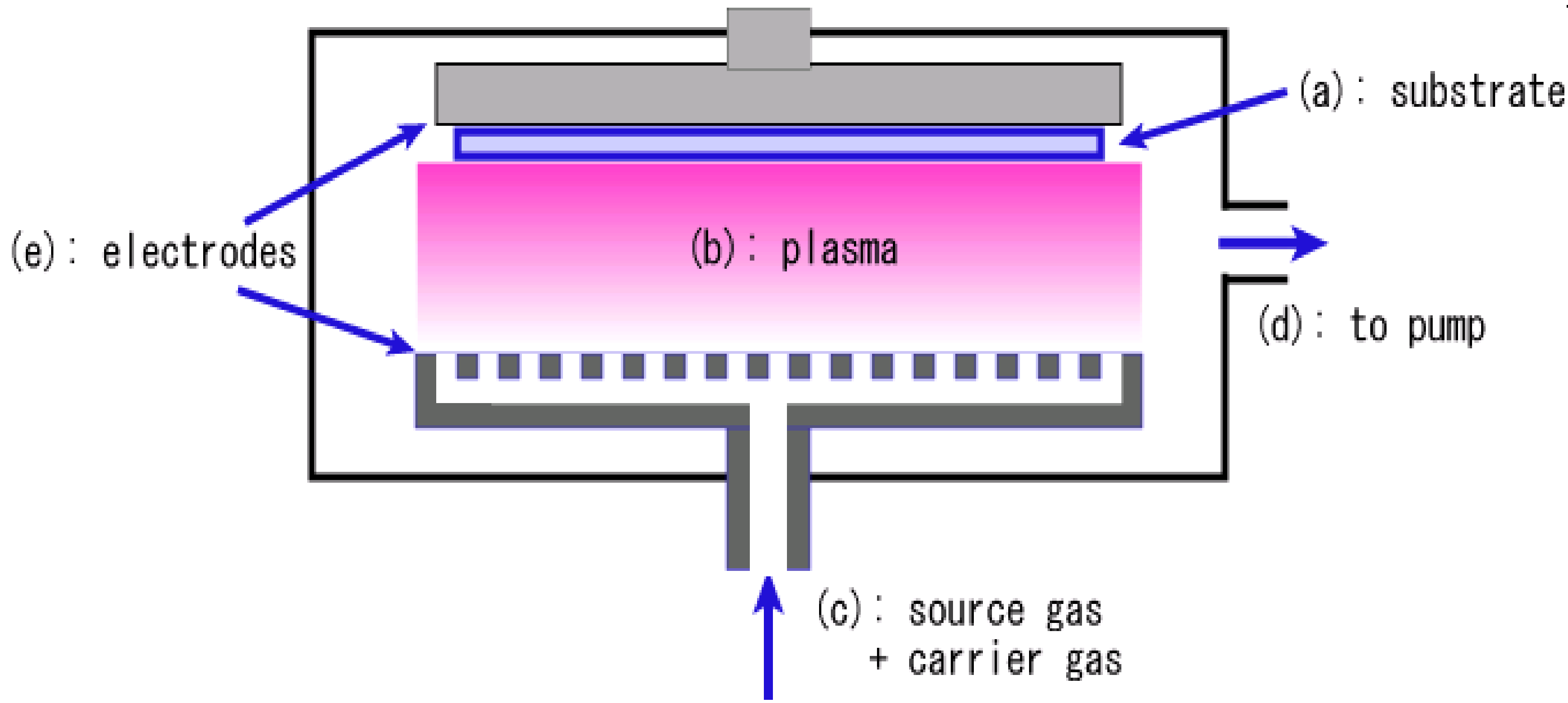
Other PECVD Electrode Configurations are Possible; e.g., the Triode PECVD reactor



Plasma Enhanced Chemical Vapor Deposition



PECVD Summary

Lower temperature processes compared to conventional CVD

Film stress can be controlled by high/low frequency mixing techniques

Dry plasma cleaning process with end-point control can reduce need for physical/chemical chamber cleaning (use of load-locks)

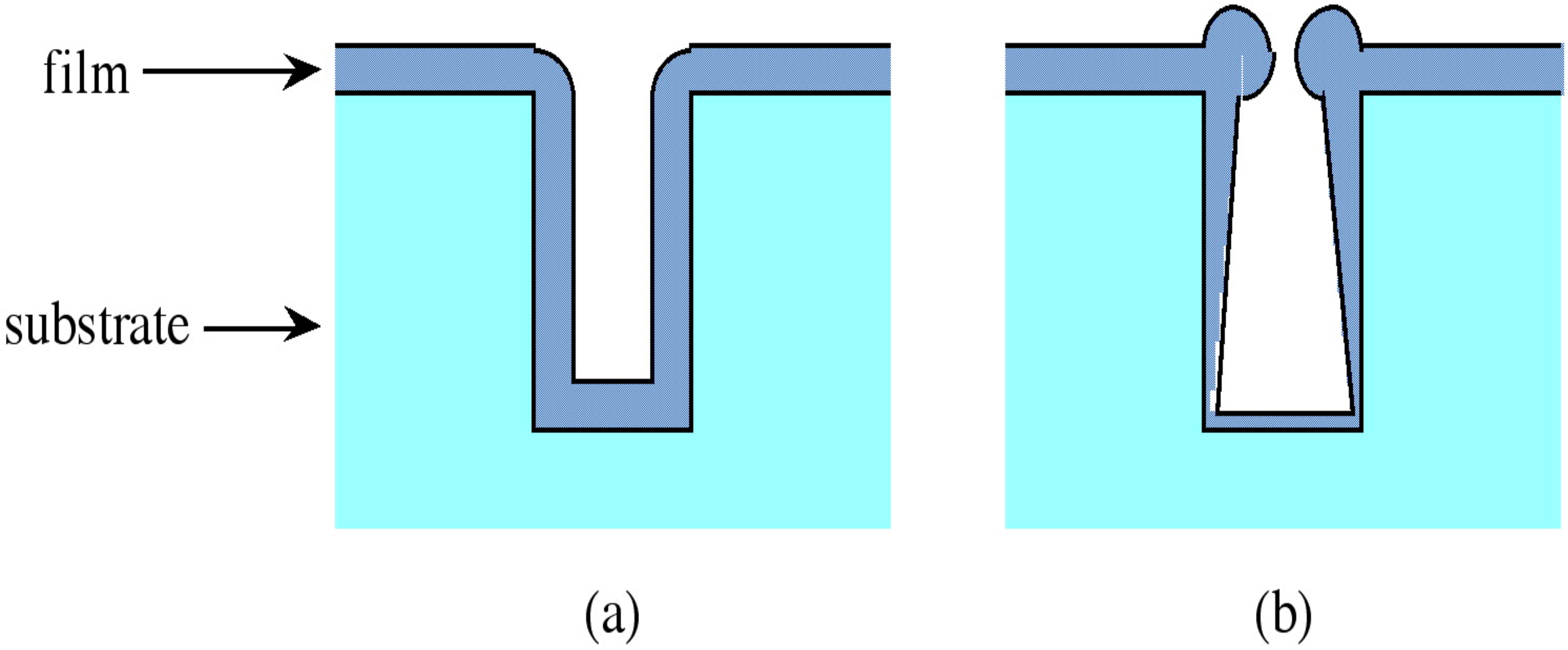
Control over stoichiometry via process conditions

Offers a wide range of materials

Conformal step coverage or void-free good step coverage

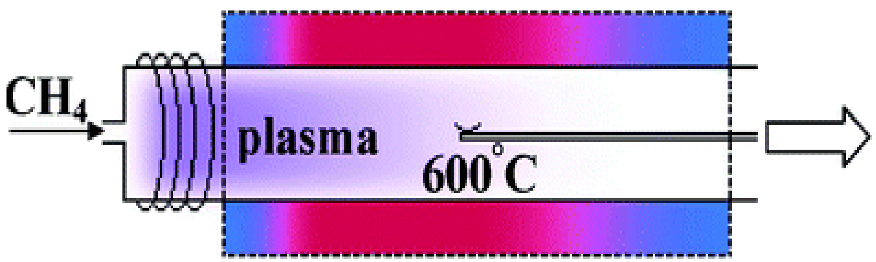
~ 60nm/min for a-Si:H deposition rate

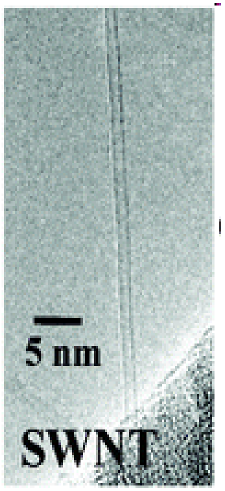
Step Coverage



PECVD tool used to fabricate a-Si:H TFTs for LCD Displays

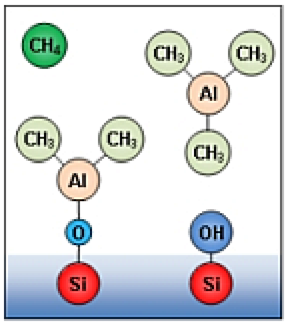
Some other Variations: Plasmas with Varying Degrees of Remoteness can be used in PECVD



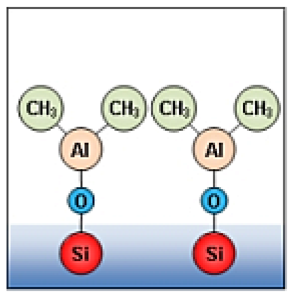


Atomic Layer Deposition (ALD) and Plasma Enhanced Atomic Layer Deposition (PEALD)

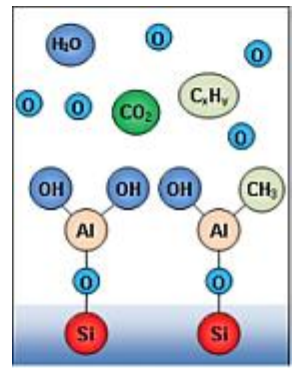
The ALD Cycle: Thermal or PE



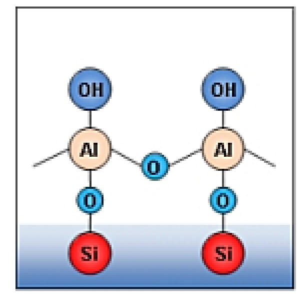
1. TMA Dose



2. TMA Purge



3. O2 Plasma



4. Short post plasma purge

ALD cycle for Al2O3 deposited using TMA and O2 plasma6. Only step 3 varies between H2O for the thermal process or O2 plasma.

Deposition rates vary from ~0.08-0.5nm/min (slow)

Plasma Enhanced ALD

Some Benefits of Remote Plasma Atomic Layer Deposition

In addition to the benefits of thermal ALD, remote plasma allows for a wider choice of precursor chemistry with enhanced film quality:

Plasma enables low-temperature ALD processes and the remote source maintains low plasma damage

Effective metal chemistry through use of hydrogen plasma rather than complex thermal precursors

Eliminates the need for water as a precursor, reducing purge times between ALD cycles - especially for low temperatures.

Higher quality films through improved removal of impurities, leading to lower resistivity, higher density, etc.

Ability to control stoichiometry

Plasma surface treatment

Plasma cleaning of chamber is possible for some materials

Applications of PECVD and PEALD.

- PECVD—thin film deposition (semiconductors, insulators)
- PECVD—nanoparticles (e.g., CNTs)
- PEALD—thin film deposition (insulators, some metals)

Summary

- Plasma enhance deposition techniques are widely used and very powerful
- Use of plasmas to enhance CVD lowers processing temperatures, gives different variations of a material (more knobs to tune for structure, stoichiometry)
- Use of plasmas to enhance ALD expands variety of materials that can be deposited and can enhance through-put.