EE 527 MICROFABRICATION

Lecture 11

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CVD/CVD SAFETY ISSUES

- CVD often uses hazardous gases
  - poisonous
  - pyrophoric / flammable / explosive
  - corrosive
  - dangerous combinations: e.g. SiH_4 + halogens
- Gases often produce solid products when in contact with air (small leaks): particles (contamination, clogging of gas lines and meters)

CVD/COMMON GASES FOR CVD

Gas	Formula	Hazard	Flammable limit (vol% in air)	Exposure limit (ppm)
Ammonia	NH_3	toxic, corrosive	16-25	25
Argon	Ar			
Arsine	AsH_3	toxic		0.05
Diborane	B_2H_6	toxic, flammable	1-98	0.1
Dichlorosilane	SiH_2Cl_2	flammable, toxic	4-99	5
Hydrogen	H_2	flammable	4-74	
Hydrogen chloride	HCl	corrosive, toxic		5
Nitrogen	N_2			
Nitrogen oxide	N_2O	oxidizer		
Oxygen	O_2	oxidizer		
Phosphine	PH_3	toxic, flammable	pyrophoric	0.3
Silane	SiH_4	flammable, toxic	pyrophoric	0.5

from S.M. Sze, VLSI Technology

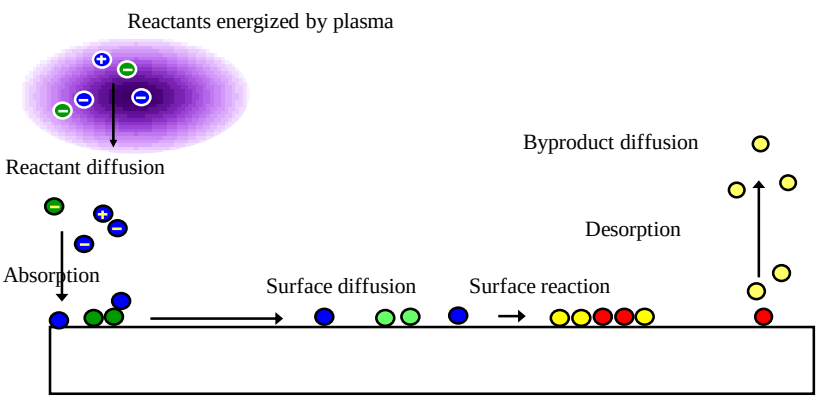
PLASMA ENHANCED CHEMICAL VAPOR DEPOSITION (PECVD)

- Reaction similar to that of CVD except driven at a much higher energy state.
- High energy state allows reactions unattainable through standard thermal excitation.
- High energy states are achieved by ionizing the gas born reactant at low pressures with RF or microwave electric fields.
- The chemical reaction from the highly excited reactants result in thin film deposition or etching.

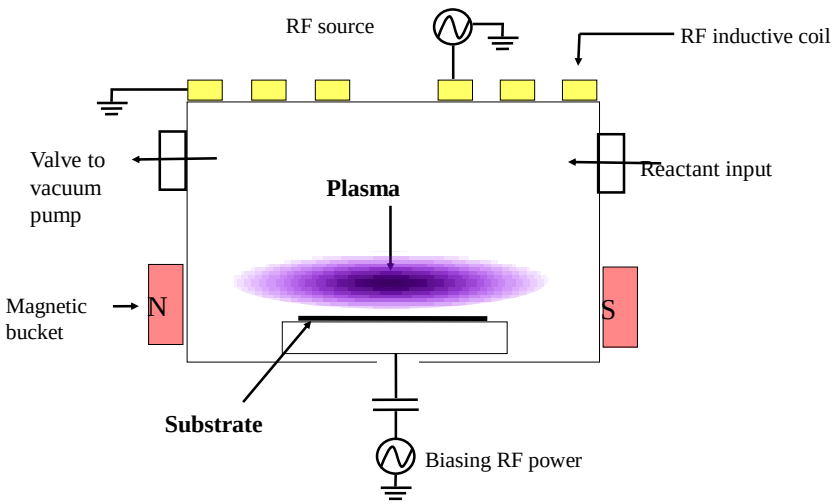
PECVD/BASIC STEPS OF PECVD

1. Electron impact ionization and dissociation
2. Diffusion and transport of species to the wafer surface
3. Adsorption/chemisorption of species on the wafer surface sites
4. Surface diffusion and dissociation
5. Reaction of adsorbed species with substrate
6. Desorption of reaction products

PECVD/PECVD PROCESS FLOW

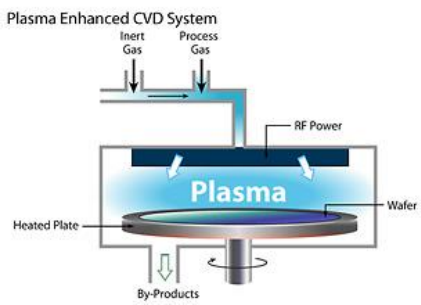


PECVD DEPOSITION CHAMBER



Reference: G. Mathad et Al. "Plasma Processing for Silicon-Based Integrated Circuits" **Interface**, Summer 1999, pg 39 fig7.

PECVD



http://www.dowcorning.com/content/etronics/etronicschem/etronics_newcvd_tutorial3.asp

Plasma Enhanced CVD

- parallel plate electrodes with glow discharge
- samples on grounded electrode
- heated ground plate
- gas introduced from center, outer edge, or shower head
- contamination by loosely adhering deposits
- less uniform

CVD/CVD SUMMARY

Process	Advantage	Disadvantage
APCVD	• Low cost equipment • Fast deposition (no pump down)	• Poor step coverage • Particle contamination • High temperature process
LPCVD	• High film purity & uniformality • Conformal step coverage	• Low deposition rate • High temperature process
PECVD	• Low temperature process • Fast deposition • Controllable film stress • High etch rates possible	• Particle contamination • Chemical contamination • Substrate damage • High cost equipment

ATOMIC LAYER DEPOSITION

- ALD deposits one atomic layer at a time, offering ultimate thickness control.

The process of ALD: ALD works in pulsed mode,

- A pulse of the first precursor, typically an organometallic compound.
  - Chemical bonds are formed between precursor gas molecules and the surface atoms.
- A purging nitrogen gas removes the non-reacted precursors and the gaseous reaction by-products.
- A pulse of the second precursor
  - Chemical bonds are formed between the second precursor gas molecules and the first precursor gas molecules.
- Purge or evacuation of the reaction chamber.

ALD/APPLICATIONS

- ALD is studied as a potential technique to deposit high-k (high dielectric) gate oxides in advanced CMOS.
  - In high-*k* gate oxides, where the control of ultra thin films is essential.

$$HfCl_4\ (ad) + 2\ H_2O\ (ad) \rightarrow HfO_2(s) + 4\ HCl\ (g)$$

- Practical deposition rates are around 0.1 nm/cycle, and overall rates are typically a few nanometers per minute.