

Thin Film Capabilities Penn State Nanofabrication Facility

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Introduction

Thin films are used through out the world today. Their applications range from optical coatings to cutting tools to microelectronic. Thin film deposition is the technique of applying a material on to a substrate with thicknesses on the order of nanometers to ten's of microns. The Penn State Nanofab has several techniques for growing thin films, these include: (ALD) Atomic Layer Deposition, Evaporation, Sputtering, (PECVD) Plasma Enhanced Chemical Vapor Deposition and (LPCVD) Low Pressure Chemical Vapor Deposition.

ALD is a thin film technique that is based on sequential introduction of gas phase precursors to deposit a film one atomic layer for each precursor cycle.



Cambridge System

- Savannah, 200
- Sample sizes up to 8" dia
- Temperature range 15-400C
- Operating pressure 600mbar
- Recipe driven processes
- ALD, MOC, ZNO, IZO, Ta2O5

Al₂O₃ Recipe

- Chamber temperature: 300 °C
- 15 min 30 min
- Substrate: 1.5 inch
- Pressure: 750, 100, 600
- Power: 100, 100, 100
- Pump: 2
- Power: 100, 100, 100
- Pump: 2

Evaporation as it pertains to thin films is a process where the deposited material is heated in high vacuum by thermal or a focused electron beam to the point at which sufficient kinetic energy is provided to overcome the liquid-phase intermolecular forces so that the liquid at the surface becomes a vapor. The vapor is then directly transported to the substrate surface where the vapor then condenses as a growing film.



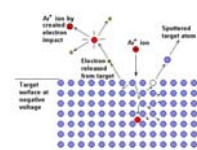
Semicon Evaporator

- Electron beam evaporation
- 4 variable pockets (7 arc)
- Au, Al, Cu, Ag, Ti, Cr, Pt, Pb
- Fe, Co, Ni, W, Mo, Ta
- Si, Ge, Sn, SiO₂
- RuO₄, Si₃N₄, C
- Thermal evaporation
- Au, Ag, Cu
- required for a beam resist Au coating

Murti Lecker Lab 18

- Electron beam evaporation
- 4 variable pockets (7 arc)
- Thermal evaporation
- 3 ports
- Evaporation source for substrate coating and ion assisted deposition
- Substrate cooling to 20 °C
- 18 in Ø in rotation or rotation
- Loadlock system
- Residual stress surface
- Automated water handling
- Material processed: Aluminum, Iron, Chromium, Copper, Nickel, Titanium, Zirconium, Silver, Gold, Tantalum, Chromium Fluoride, Iron, SiO₂, Silicon nitride, Si₃N₄

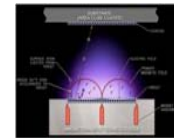
Sputtering is the removal of a material from a solid target by energetic ion bombardment in order to coat a substrate with the target material



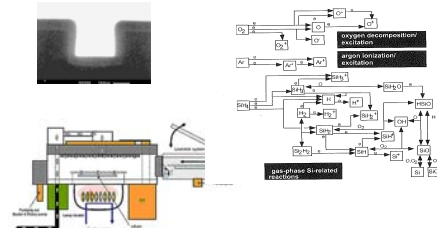
Ions penetrate the target and displace lattice atoms along the collision cascades
Momentum transfer is principally into the target; sputtered atoms can be ejected from the initial collision site
S is proportional to MI
MI(MI-MI) (MI-MI) where S is the sputter yield
S is proportional to 1/U where U is the surface binding energy

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- 3 Sources: 2 rf, IIG or pulse
- 6" substrates in rotation
- Heating to 800 C
- Load lock system
- Recipe driven processes
- Reactive sputter of Nitrides and Oxides
- RF trap on substrate
- Target Materials: Al, Au, Si, BN, BaTiO₃, Ca, Cr, Fe, Ge, I, ITO, Mg, Ni, Pt, PtSi, Si, Sn, Ta, Ti, TiAl, TiN, TiO₂, Y, Y₂O₃, W, Zn, Zn



PECVD Plasma Enhanced Chemical Vapor Deposition is a process used to deposit thin films from a gas state to a solid state. Chemical reactions involving a precursor gas occur as a result of dissociation and ionization of the gas within a plasma with film growth occurring at the substrate surface.

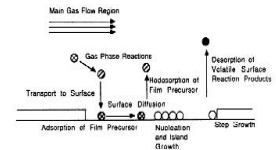


Applied Materials P5000 Cluster Tool

- Equipment Configuration
 - Three PECVD chambers
 - One thermal evap chamber
 - Gas shower
 - Recipe driven
 - Loadlock
 - RF source
 - 8 inch substrate
 - Substrate heating to 400C

- 3 PECVD chambers (A, B and D)
- 200mm substrates
- RF 13.65 MHz
- Substrate heating to 450 C
- Chamber A is configured for liquid source precursors for novel materials
- Chamber B is configured for Oxide and Nitride processes using SiH₄, N₂O and H₂ as the primary precursors
- Chamber C is a dual frequency chamber (13.65 MHz and 450 KHz) configured for a-Si and doped a-Si

(LPCVD) Low Pressure Chemical Vapor Deposition is a process used to deposit thin films from a gas state to a solid state. Chemical reactions involving a gas or mixture of gases occur as a result of dissociation and/or reaction of the gas under reduced pressure and elevated temperature with film growth occurring at the substrate surface. Gases react at hot wafer surface to create solid films.



Silicon Nitride
 $3 \text{ SiCl}_2\text{H}_2 + 4 \text{ NH}_3 \rightarrow \text{Si}_3\text{N}_4 + 6 \text{ HCl} + 6 \text{ H}_2$
Polysilicon
 $\text{SiH}_4 \rightarrow \text{Si} + 2 \text{ H}_2$
Amorphous Silicon
 $\text{SiH}_4 \rightarrow \text{Si} + 2 \text{ H}_2$
LTO (Low Temperature Oxide)
 $\text{SiH}_4 + \text{O}_2 \rightarrow \text{SiO}_2 + 2 \text{ H}_2$

• Equipment Configuration
- Computer controlled
- Recipe driven
- Manual Loading
- 6 inch substrate size
- Substrate heating to 900C



In Summary

Each tool and technique has its advantages and disadvantages. The details of the process and materials needed for the fabrication of the end product combine with the tool capabilities to ultimately determine which tool set would be optimal. In an effort to determine which tools best fit a particular fabrication process users are encouraged to interface with the staff.

There are several mechanisms currently in place to help facilitate these interactions:

- New User Project Overviews
- Tool trainings
- Follow-up meeting with the staff as needed.

For more information on what tools are available or how to get started please visit:

<http://www.mri.psu.edu/facilities/NNIN.asp>