Thin Films Deposition F4280: An appendix for a plasma deposition cookbook

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What was already said

- **What is plasma and how to generate it**, sheath and what kind reactions are there
- **Kinetics and collisions** reactions, cross sections distribution functions
- **Types of plasma sources** with typical basic plasma parameters - LP/AP
- **Plasma treatment and PECVD**
- **Plasma polymers** - low energy organic PECVD
Why an appendix for a plasma deposition cookbook?

- “Baking - a simple process where a command like place in a 350 °F oven for 15 minutes’ leads to a lot of chemistry and a bit of physics as the many chemical compounds that make up cake batter react. A recipe doesn’t specify all of the reactions that occur, because they will happen on their own when you introduce heat.”

- But first you sort of need to know where to find things and how to use them!
So prepare...

Well, what do we need?
What will be the **pressure**? - LP - glass, PMMA, stainless steel... all with appropriate sealings - KF and CF standards, swagelok

- design is more of an engineering problem - size of samples, windows + much more

- geometry affects electric fields, gas flow patterns, possibly temperature distribution

⇒ Chamber itself influences process - standard - **GEC** reference cell
Vacuum sealing

- **KF/QF/DN** - Klein Flange (KF), Quick Flange (QF) - elastomer O-ring + clamp, lower vacuum
- **CF** - Conflat - single-use copper gasket - bakeable - UHV vacuum
Vacuum sealing II

- swagelok systems - mainly for gas delivery - beware of American sizes
- others - ISO flange, Wheeler flange
Pumping

- what types of pumps do we have? Which of them are relevant?
- oil vs dry pumps - tricks?
- it is rather useful to know principle and limitations of different types of pumps... there is not enough space for that.
Pumping II example

- what type of pump is this?
- can it pump atmospheric pressure?
Pressure measurement

- U tube? Absolute vs relative gauges
- A single wide range gauge is often used (usually consists of Pirani + Ionization)
- Additionally, absolute measurement by a capacitron (Baratron) - zero error
Gases

- how to deliver gases? gas bottle ≈ 200 bar
- mass flow meters - **K-factors**

For a high flow - a floating ball flow meter
Gases II

- homogeneity of the gas mixture - gas mixers
- inlet of gases into the chamber - shower head
- depending on the gas, pressure and geometry we can distinguish degree of mixing
  - plug flow
  - back-mixing flow
  - well mixed flow
- Throttling valves to adjust pumping speed and working pressure

\[ p = p_0 \exp \left( -\frac{S}{V} t \right) \]  

For independent measurement of the gas flow (leak rate, liquid vapors):

\[ Q = \frac{\Delta p}{\Delta t} \frac{V}{p_{atm}} \]
Choosing a frequency - DC and AC

- At low frequency, discharge basically is still DC only with changing polarity of electrodes.
- how to choose frequency $\omega$ to get something new?
- important frequencies are $\omega_{pl,i}$ and $\omega_{pl,e}$
- capacitive and inductive coupling, microwave discharges

$$\omega_{pl}^2 = \frac{n_e e^2}{m \epsilon}$$ (3)
CCP discharges

- capacitive coupling via sheaths, most used frequency 13.56 MHz
- versatile, large area processing, ion bombardment esp. reactive ion etching (RIE)
- rather complicated for understanding - heating mechanisms, eedf potentials in CCP discharges - iedf, higher harmonics
- CCP discharge asymmetry - geometric/electric
- independent energy and ion flux - dual frequency and other tricks
- generator requires a matching unit (to achieve load of 50 Ω)
Potentials in CCP discharges

- Plasma must have higher potential than the most positive electrode
- Usually there are only two, grounded tends to be naturally larger - with no net current ⇒ self-bias
Optional accessories

- **Temperature control** - both cooling and heating + feedback
- **Leak detection**
- Various **characterization and process control** techniques
  - Light - spectroscopy using emission or absorption
  - Charged particles + electric fields -
  - Neutral species - mass spectrometry, laser induced fluorescence
  - Power signal
- Sample movement and manipulation - mechanical clamping and electrostatic chuck
Additional reading and info:

Books covering similar topics:

- **General thin film deposition (easy)** - Thin-Film Deposition: Principles and Practise, D. Smith
- **General plasma (easy)** - Principles of Plasma Processing, F. Chen and J. Chang
- **General plasma (hard)** - Principles Of Plasma Discharges And Materials Processing, Lieberman M. and Lichtenberg A.
- **CCP (hard)** - Physics of Radio-Frequency Plasmas, Pascal Chabert

Courses - Vakuová fyzika 1, 2 (Czech only), Fyzika plazmatu 3 (CCP mainly)