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

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# What was already said

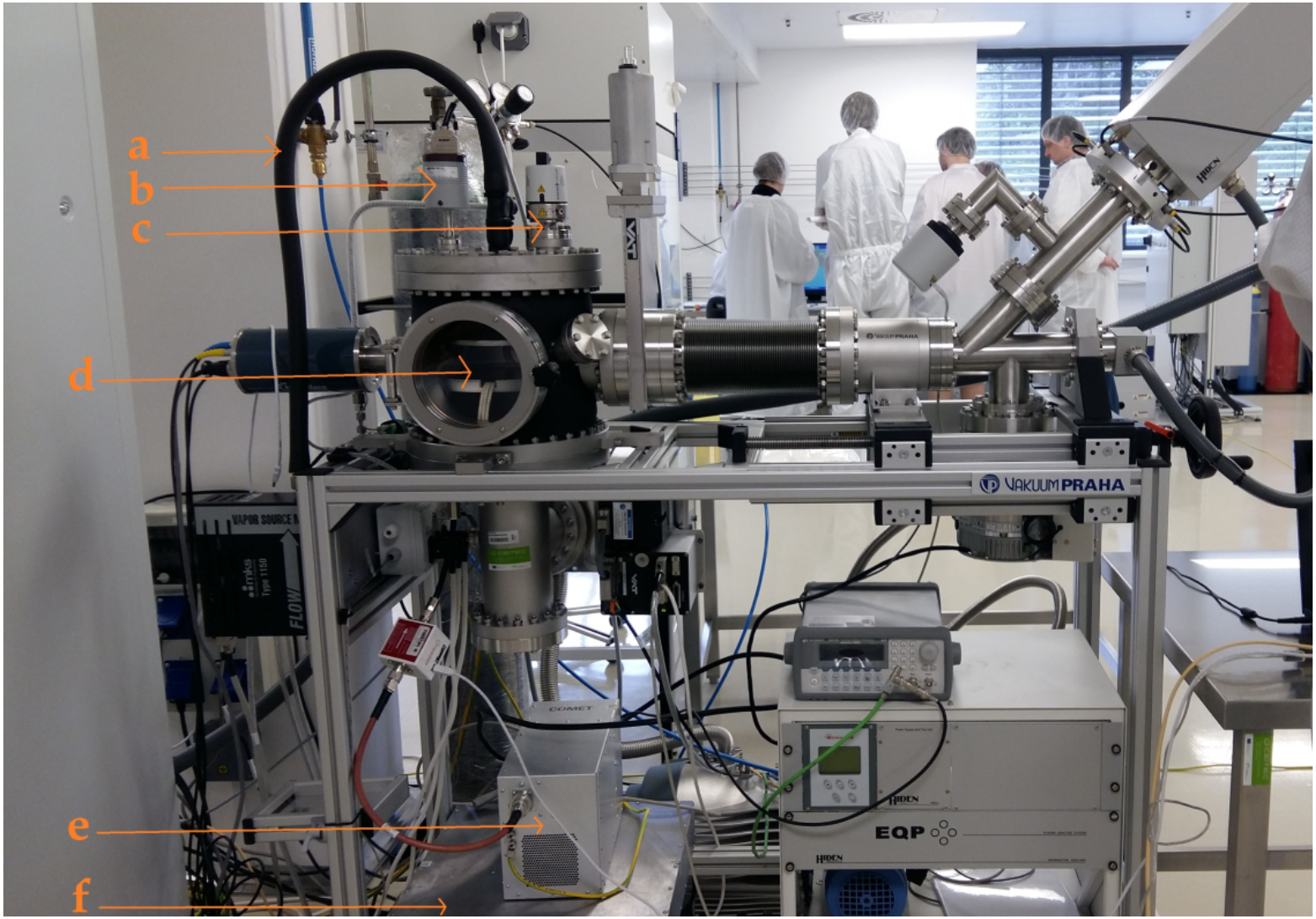
- **What is plasma and how to generate it**, sheath and what kind reactions are there
- **Kinetics and collisions** reactions, cross sections distribution functions
- **Types of plasma sources** with typical basic plasma parameters - LP/AP
- **Plasma treatment and PECVD**
- **Plasma polymers** - low 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!

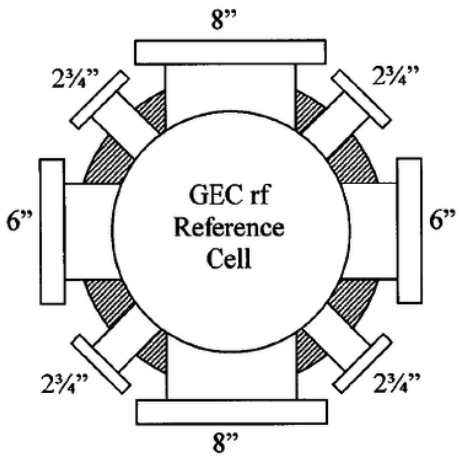
# So prepare...

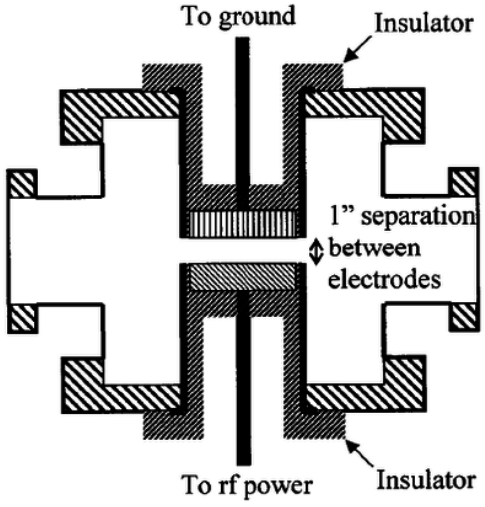
## Well, what do we need?

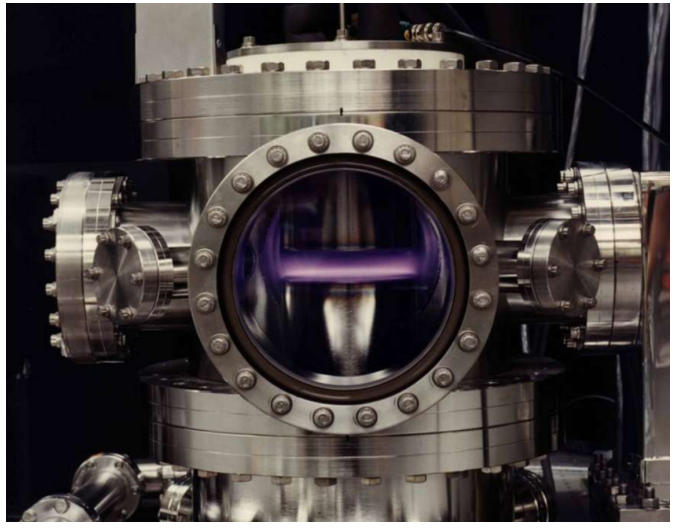


# Chamber

- 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
- $\Rightarrow$Chamber itself influences process - standard - **GEC** reference cell

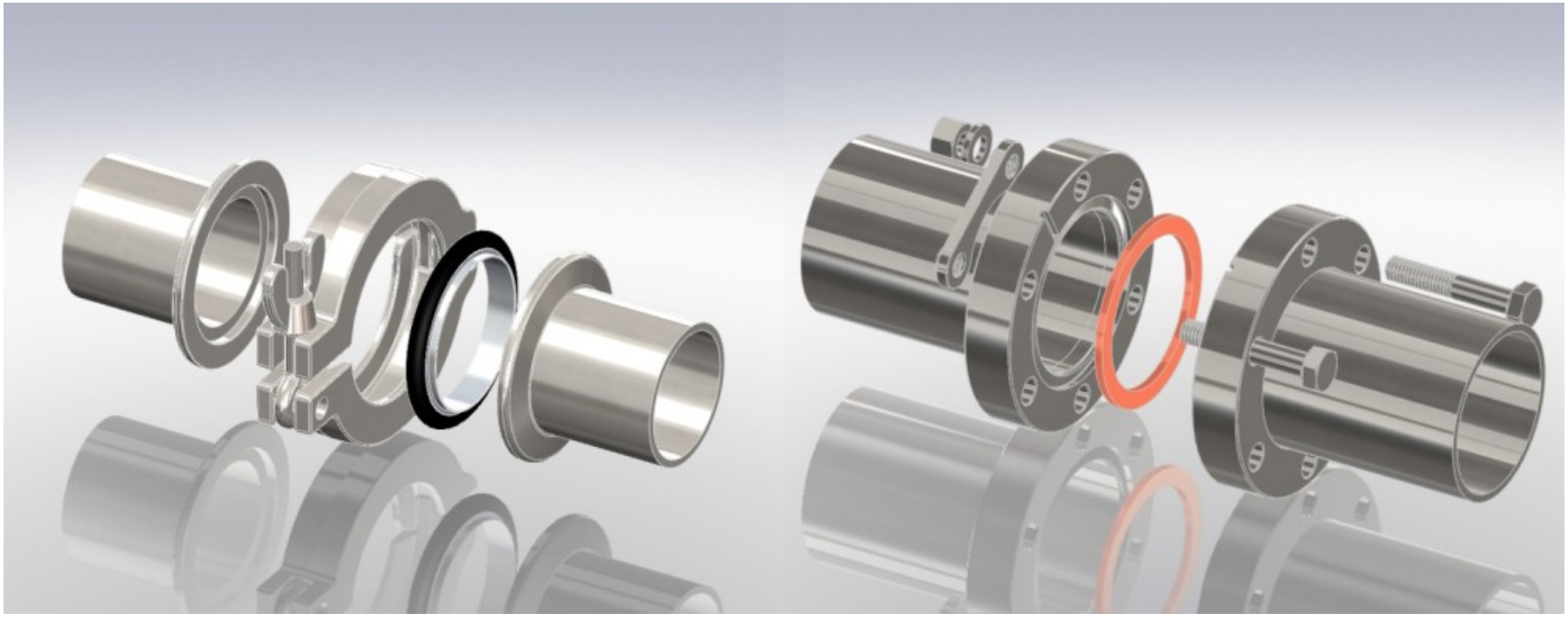


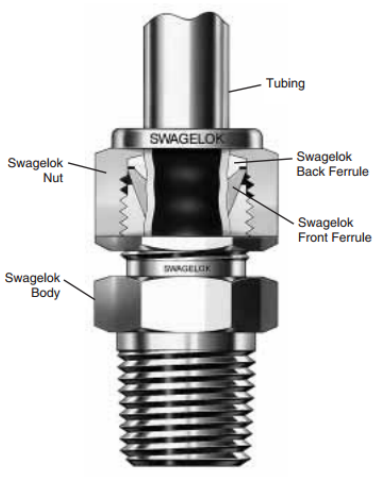
# Vacuum sealing

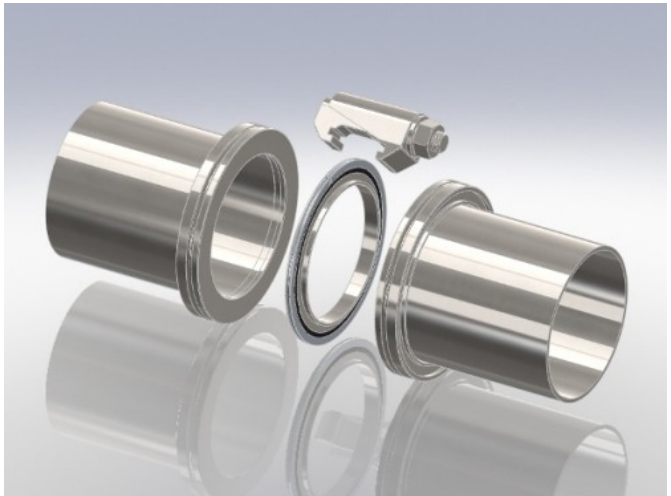
- KF/QF/DN - Klein Flange (KF), Quick Flange (QF) - elastomer O-rign + clamp, lower vacuum
- CF - Conflat - single-use copper gasket - bakeable - UHV vacuum



# Vacuum sealing II

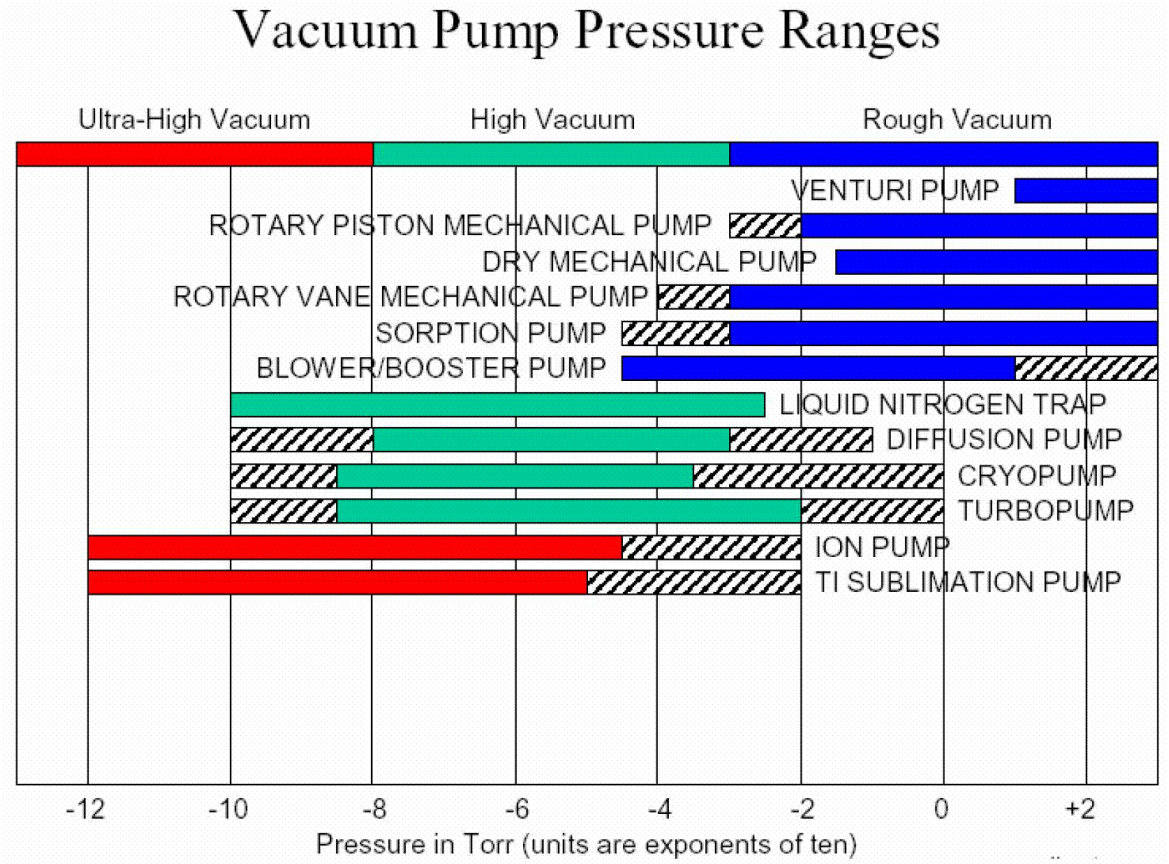
- swagelok systems - mainly for gas delivery - bevare of American sizes
- others - ISO flange, Wheeler flange



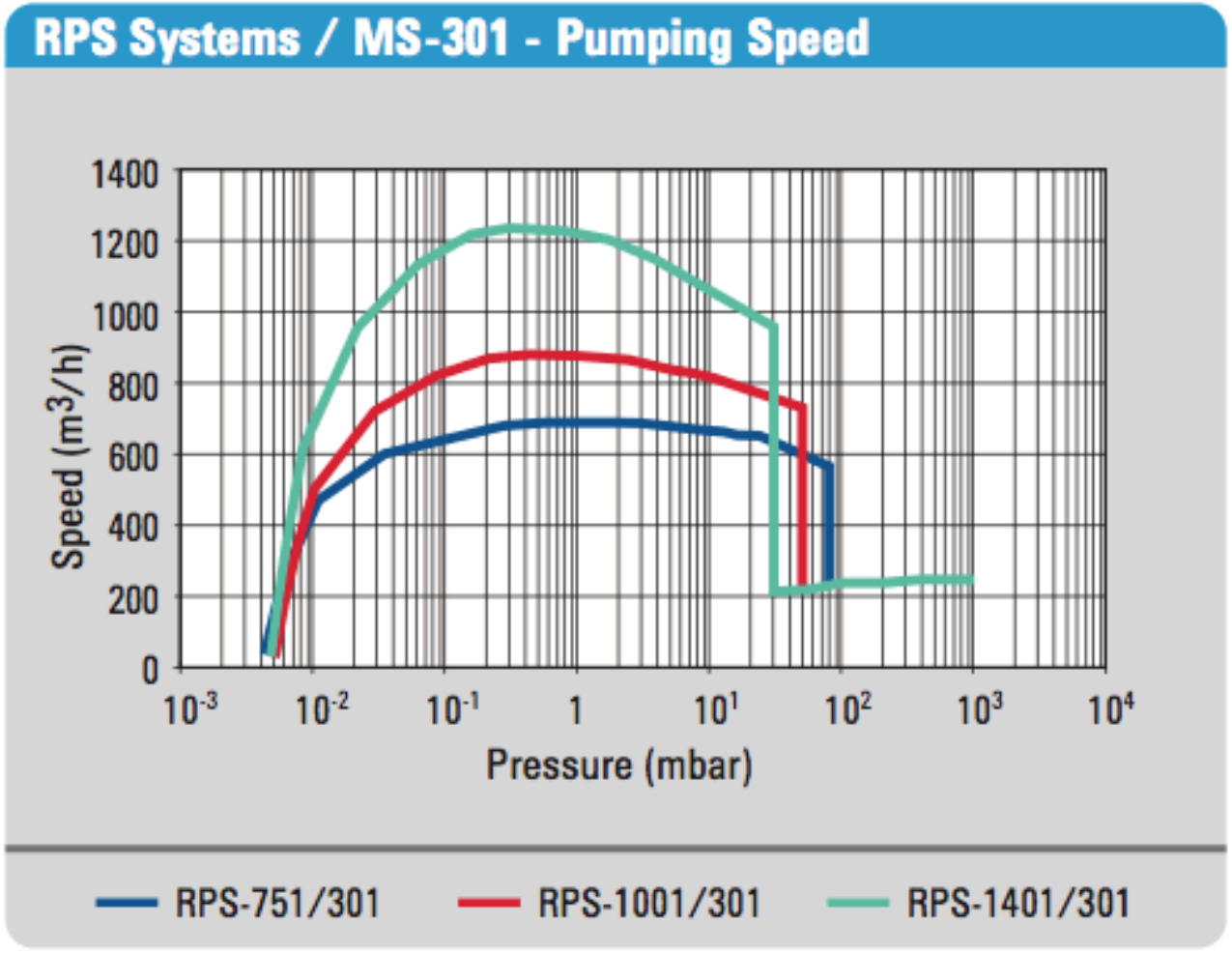
# Pumping

- 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.



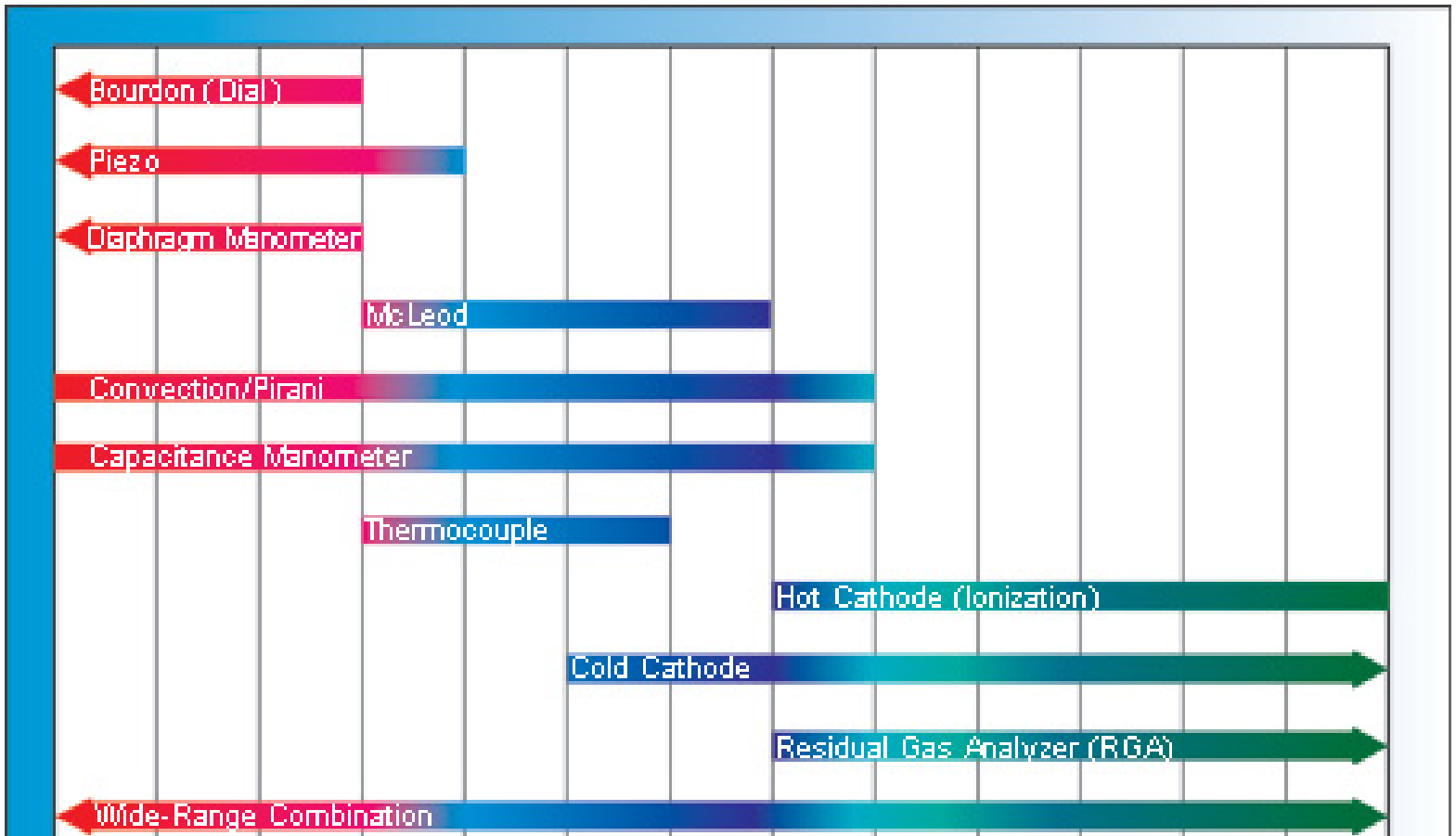
# Pumping II example

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



# Pressure measurement

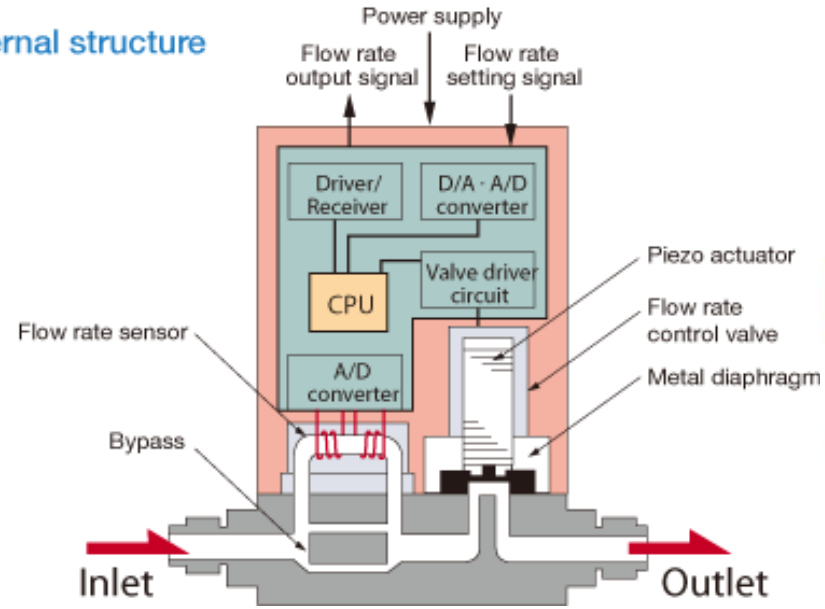
- U tube? Absolute vs relative gauges
- a single wide range gauge is often used (usually consists of Pirani + Ionization)
- additionally, absolute measurement by a capacitron (Baratron) - zero error

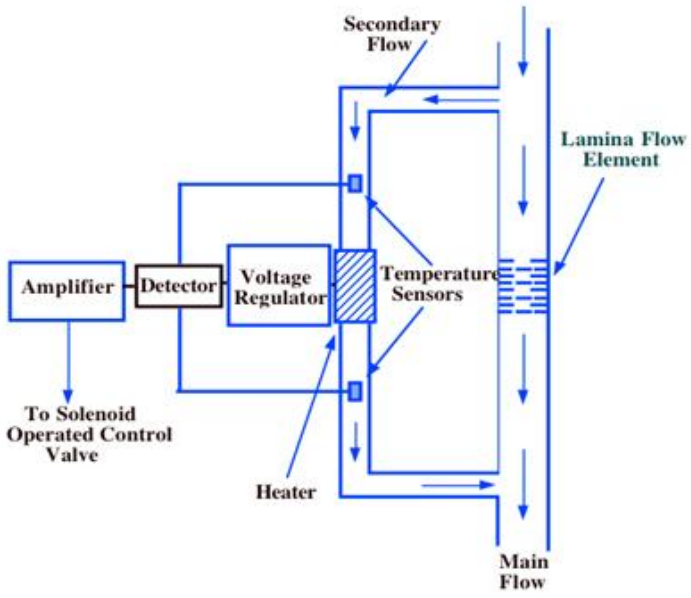


# Gases

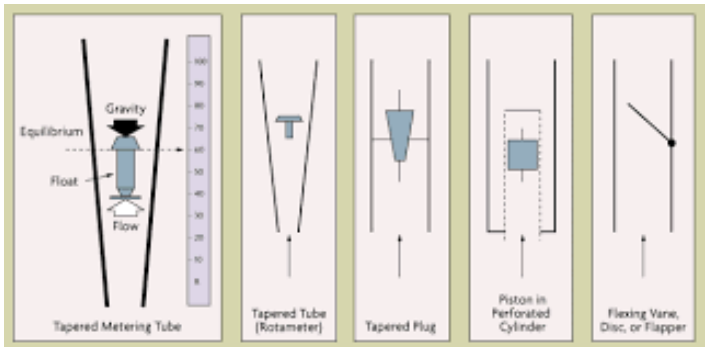
- how to deliver gases? gas bottle $\approx$ **200 bar**
- mass flow meters - **K-factors**

▶ Internal structure




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

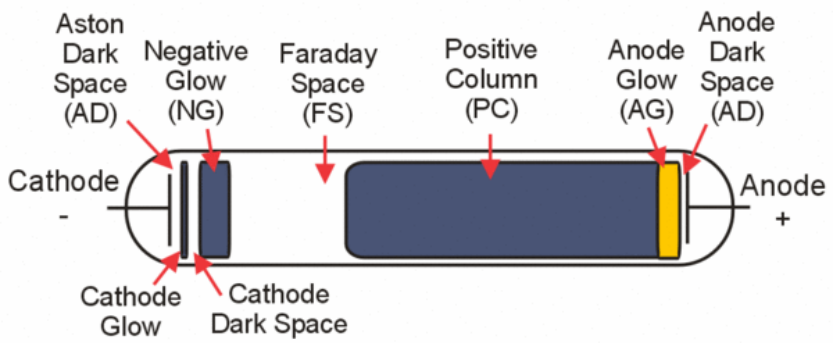
$$p = p_0 \exp\left(-\frac{S}{V}t\right) \tag{1}$$

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

$$Q = \frac{\Delta p}{\Delta t}\frac{V}{p_{\mathrm{atm}}} \tag{2}$$

# Electric Power

- Choosing a frequency - DC and AC

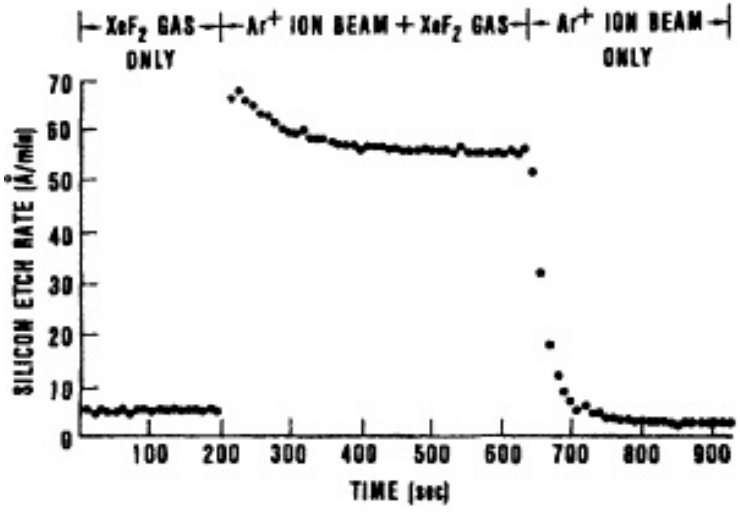


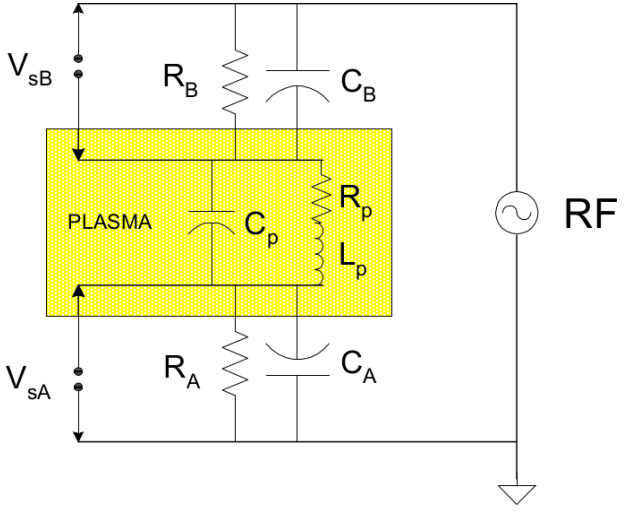

- At low frequency, discharge basically is still DC only with changing polarity of electrodes.
- how to choose frequency $\omega$ to get something new?
- important frequencies are $\omega_{\mathrm{pl,i}}$ and $\omega_{\mathrm{pl,e}}$
- capacitive and inductive coupling, microwave discharges

$$\omega_{\mathrm{pl}}^2 = \frac{n_{\mathrm{e}} e^2}{m\varepsilon} \tag{3}$$

# CCP discharges

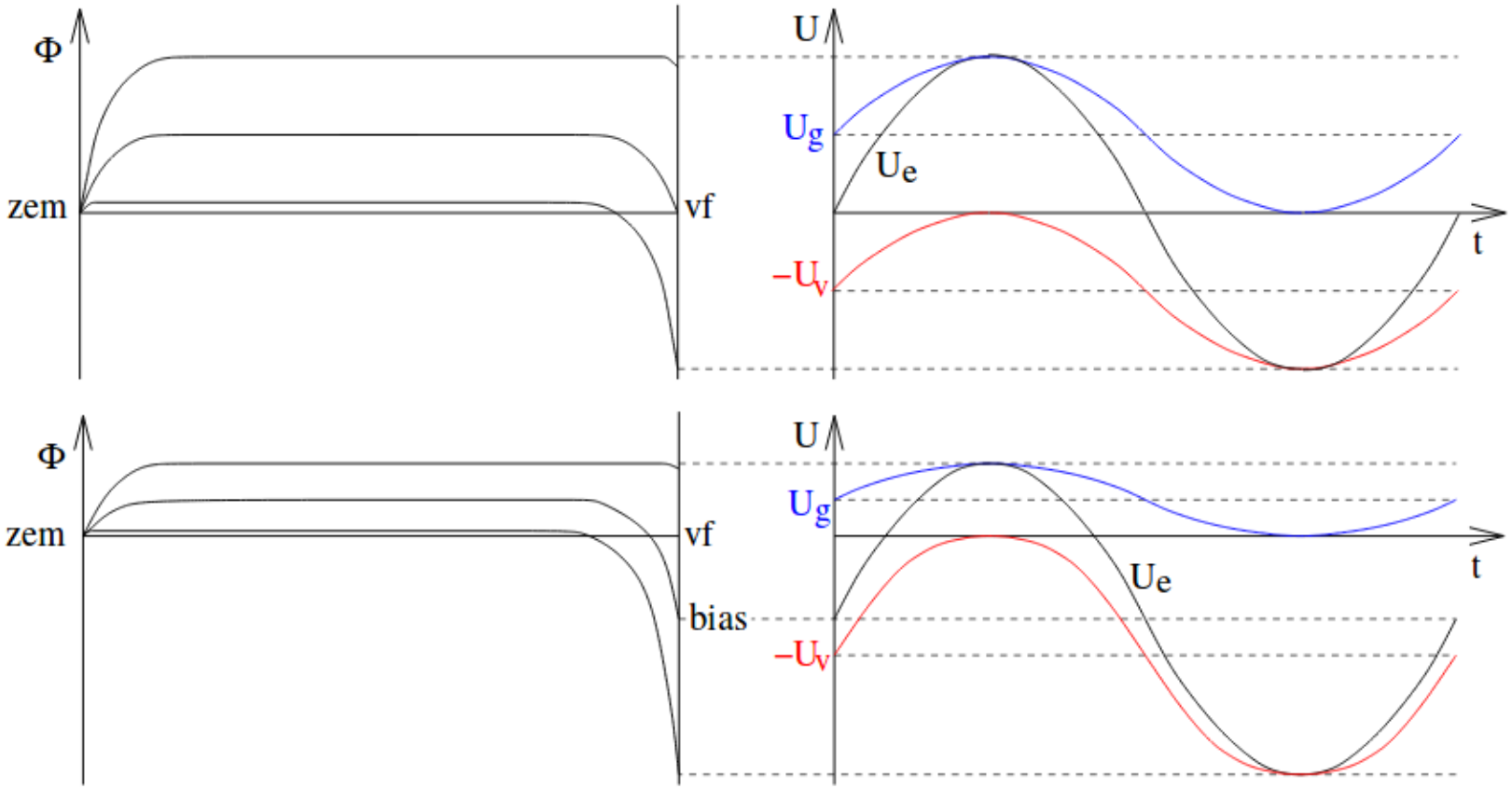
- capacitive coupling via sheaths, most used frequency 13.56 MHz
- versatile, large area processing, **ion bombardment** esp. reactive ion etching (RIE)
- rather complicated for understanding - heating mechanisms, eedf
- potentials in CCP discharges - iedf, higher harmonics
- CCP discharge asymmetry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



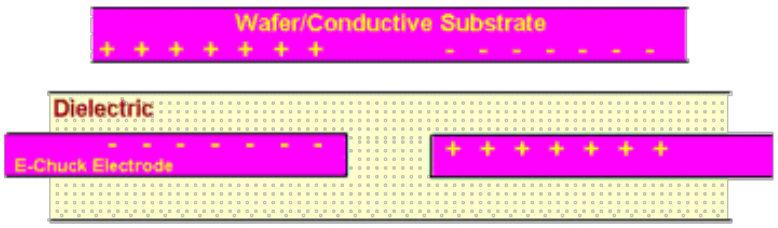
# Potentials in CCP discharges

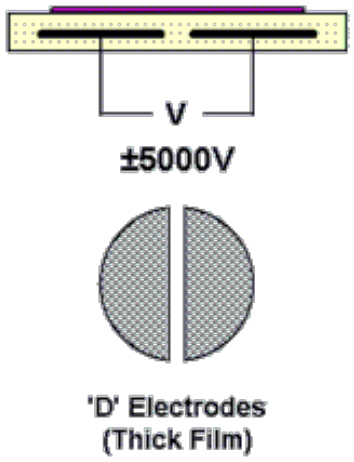
- Plasma must have higher potential than the most positive electrode
- usually there are only two, grounded tends to be naturally larger - with no net current $\Rightarrow$ **self-bias**

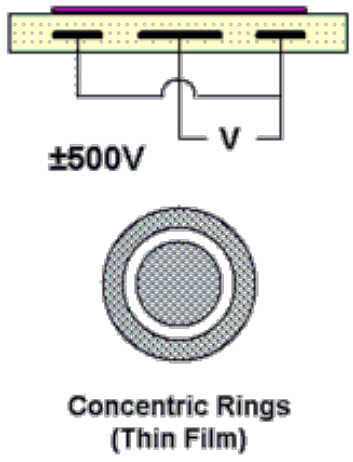


# Optional accessories

- **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)