Vacuum technology
High/ultrahigh vacuum pumps and gauges

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1

Vacuum pumps
Principle of operation

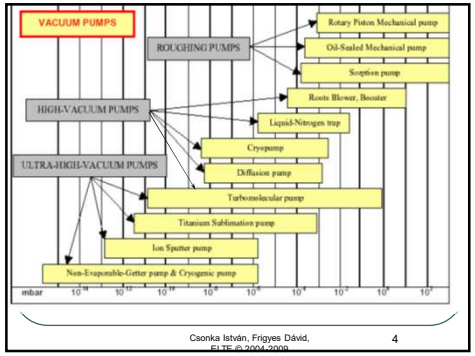
- compression
  - Rough vacuum pumps: the extracted volume is to be compressed above atmosphere
  - High vacuum pumps: rough vacuum pressure is enough (~two-stage rotary vane pump)
  - UHV…
- Trapping
  - Lower background pressure is tolerated

2

High vacuum pumps

- Rough vacuum is a must
- Pressure range
- Pumping speed (gas-dependent!)
  - Static/dynamic system
  - Volume
  - Gas load (XPS, direct EI-MS, GC-MS, HPLC-MS)
- Gas load caused by the pump itself (oil)

3



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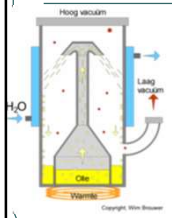
Diffusion pump

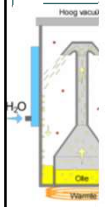


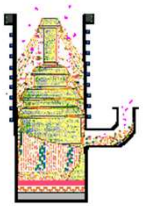
Molecular flow!
Switch on:
- •cooling (!)
- •Pump down (as short as posssible)
- •Heat-up (3/4-1 h)
- •HV-valve open (not too fast)

Switch off:
- •HV valve close
- •Heat off (+1/2-1h)
- •Rough off
- •Cooling off

5

Diffusion pump

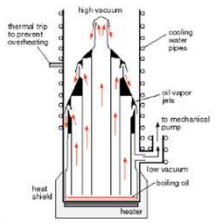


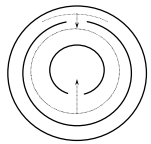


•Cooling off

6

Multistage diffusion pump





Fractionation

7

Backflow (oil flowing to recipient)

- Always present, some solutions for decreasing:
  - Mexican cap, cold cap
  - Water-cooled baffle
  - lN_2 trap
  - Peltier-trap
  - Diffstak/Diffset™ special shape pumps
- If too high (e.g. oil on a glass window) → troubleshhoting (or design problem)

8

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- If too high (e.g. oil on
  troubleshhoting (or des

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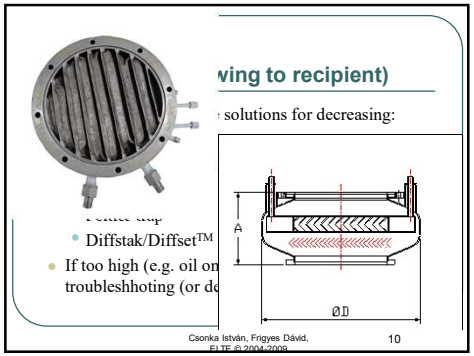

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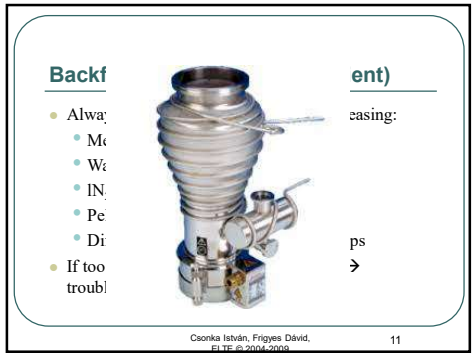

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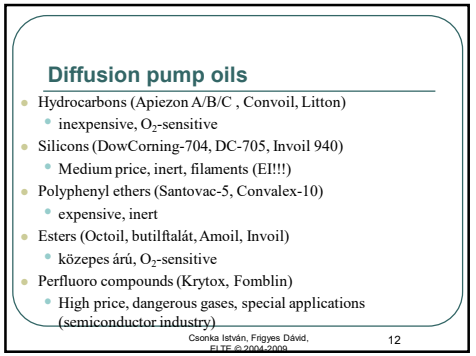

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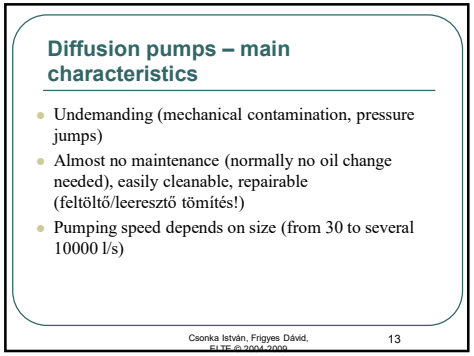

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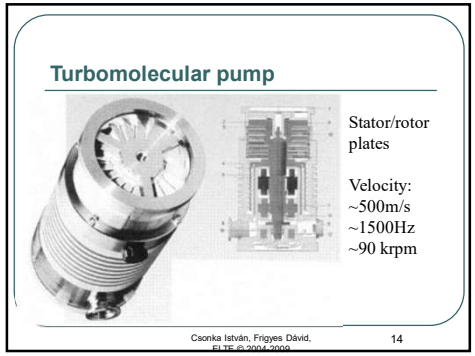

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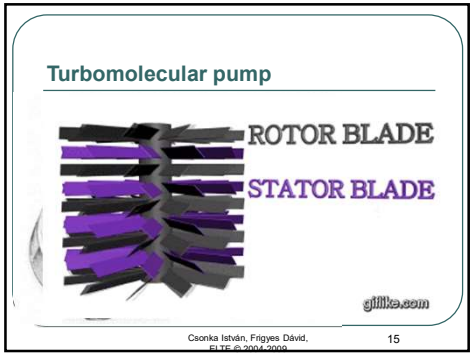

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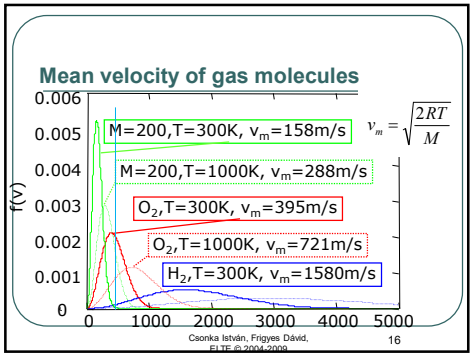

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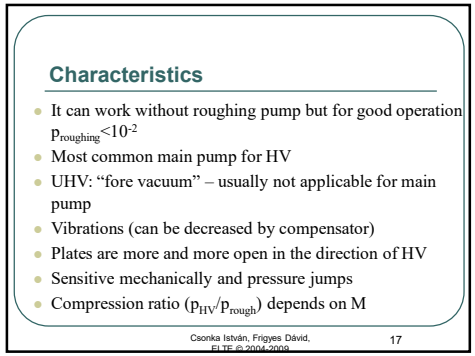

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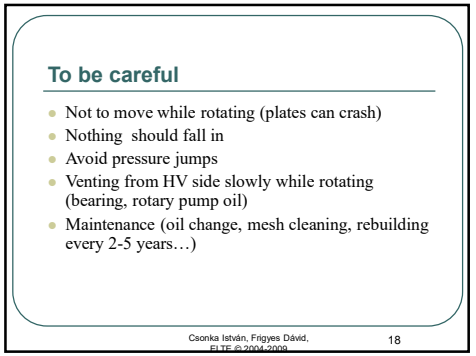
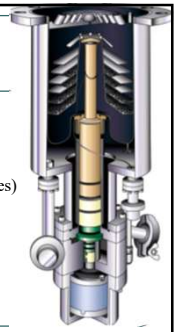


18

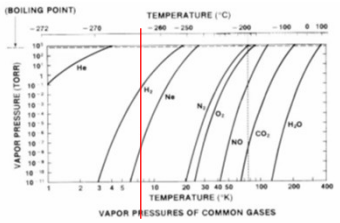
Cryopump

- Trapping pump
- Gases are captured on cooled surfaces:
  - Cryocondensation (heavy gases)
  - Cryosorption (He, H_2, Ne)
- Working principle ~ fridge refrigerant: He (~10-20K)



19

Vapor pressures



VAPOR PRESSURES OF COMMON GASES

20

Characteristics

- It needs to be periodically regenerated: heating up to room temperature in N_2 flow
- There should be molecular sieve between the roughing pump and the cryopump (contamination); it also needs to be regenerated (practically together with cryo regeneration)

21

UHV-pumps

- Gas load is low, thus no high pumping speed is needed – but no backflow allowed
- Main background gas is H_2
- The pump must tolerate baking
- These pumps can be used in HV as well but are typical in UHV

22

Titanium sublimation pump (TSP)

- A Ti-source is heated (>1300K), a monolayer is created in the surrounding surfaces
- The layer is extremely reactive producing non-volatile compounds from gas molecules
- Pumping speed (l/s):

	H_2	N_2	O_2	CO	CO_2	H_2O
300K	20	30	60	60	50	20
70K	65	65	70	70	60	90

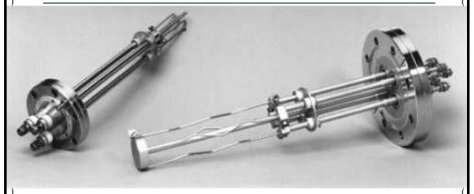
23

TSP-characteristics

- Ti-source is a sphere or filament
- Can be switched on in atmosphere but works only in UHV (monolayer speed)
- Effective for N_2, O_2, H_2, CO, CO_2, H_2O; moderately for methane, noble gases
- When the surface is coated, a new one is created (usually automated from vacuum gauge)
- No maintenance needed, Ti-source is to be replaced when needed (usually not so often)

24

A titánszublimációs szivattyú



25

Non-evaporable getter (NEG)

- Zr-V-Fe alloy
- Most effective for O_2, N_2 and CO, capacity for H_2 is independent of other gases
- Regeneration when saturated (350°C, inert gas)
- Replacement after several cycles

26

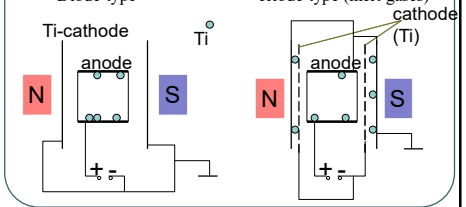
Ion (Getter) Pump

- Electrons forced on a spiral trajectory (high voltage, strong magnet)
- The electrons ionize gas molecules
- + ions impact the cathode (–A + ionok a katódba (-pole)
  - Captured in the chatode
  - Sputter the cathode material (getter effect)
  - Some gases (H_2) directly captured in the cathode

27

Geometrical arrangement

- Diode-type
- Triode-type (inert gases)



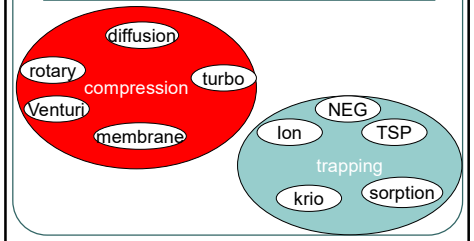
28

Characteristics

- Self-regulating: higher pressure→higher sputtering
- Ion current shows the pressure (~gauge, orders of magnitude)
- $p<10^{-2}$ (better: 10^{-5}) before switching (discharge/pumping speed)
- Lifetime depends on mean pressure, but works fast and takes long if no leaks
- Works in HV as well (Huygens-probe GC-MS, Titan, Saturns's moon)

29

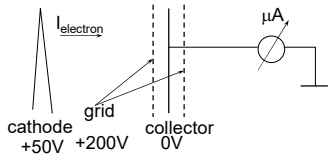
Summary of pumps



30

Hot cathode gauges

- ~electron impact ion source; triode-type ion pump

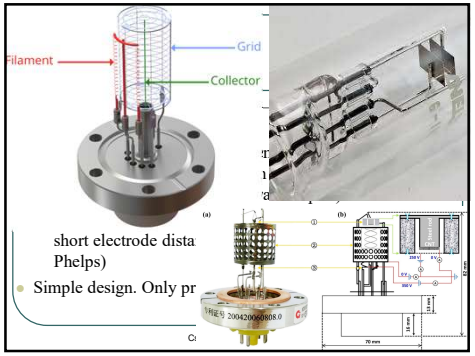


31

Main characteristics

- Wide pressure range ($10^{-2}..10^{-12}$ – range switch) – limiting factors:
  - X-ray limit (low pressure: bremsstrahlung/ braking radiation → photoemission on the collector): to lower the limit: fine wire collector (Bayard-Alpert)
  - High pressure: recombination is probable: to lower it: short electrode distance (higher free path) (Schulz-Phelps)
- Simple design. Only problem: filament can burn out… degas

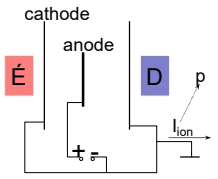
32



33

Cold cathode gauges

Penning-gauge



- ~ small diode ion pump – not accidental coincidence
- $p>10^{-8}$
- Nofilament, no burnout
- Smaller accuracy: 50%
- Magnet can cause problems

34

Residual nitrogen analyzer

- Cold cathode gauge + optical elements (light-filter, photon detector)
- Total pressure + N_2-pressure reading
- Useful in distinguishing between holes, virtual holes, outgassing, hole searching

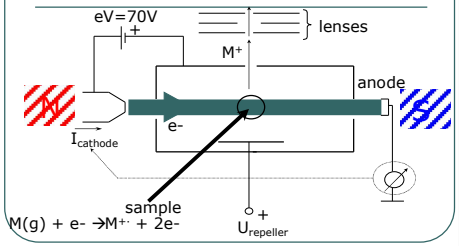
35

Residual Gas Analyser (RGA)

- Small quadrupole mass spectrometer
- Open, room-temperature ion source
- Spectrum is usually recorded in a logartithmic scale
- Usually connected to computer, the partial pressure scale (calibration!, electron impact cross sections differ)

36

Design of the ion source



37

Characteristics

- One can check what is inside vacuum
- Hole searching
- More than a pressure gauge, less than a mass spectrometer (lower price, lower performance)
  - No tricks with sample inlet
  - Mass range: 100-200-300
  - Low resolution

38