The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2028-13a

Joint ICTP/IAEA Workshop on Atomic and Molecular Data for Fusion

20 - 30 April 2009

Plasma-Wall Interaction in Magentic Fusion
Personal Research Interests/Latest Work

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Thomas Schwarz-Selinger

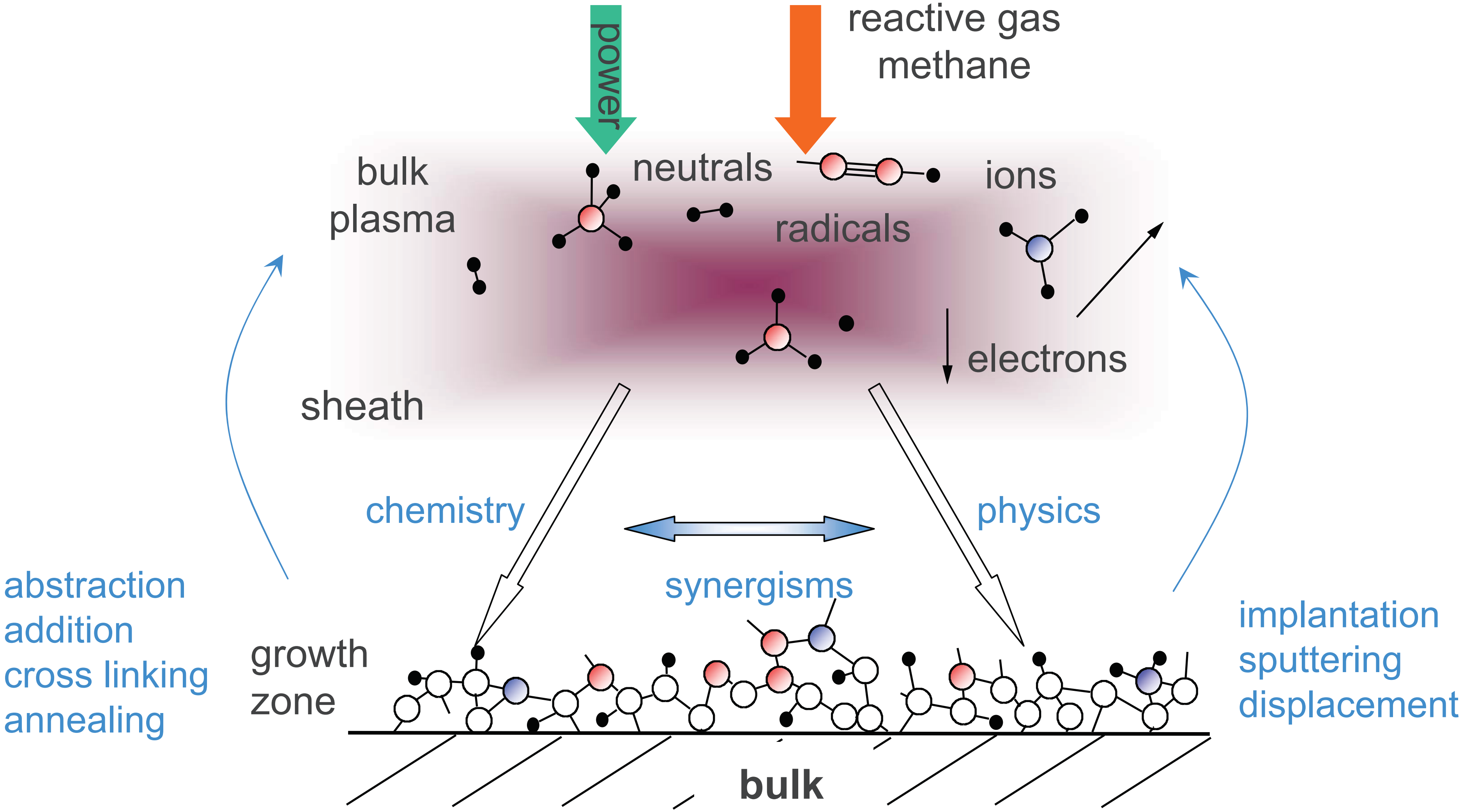
Max-Planck-Institut for Plasmaphysics, Garching
Material Science Division
Reactive Plasma Processes

personal research interests / latest work

Plasma-Wall-Interaction at low Particle Energies: Deposition, Erosion and Hydrogen Retention of Amorphous, Hydrogenated Carbon Thin Films (a-C:H)

model studies
with lab experiments
for Divertor conditions
(meV- 100 eV)

my focus: growth, stability and erosion of a-C:H films

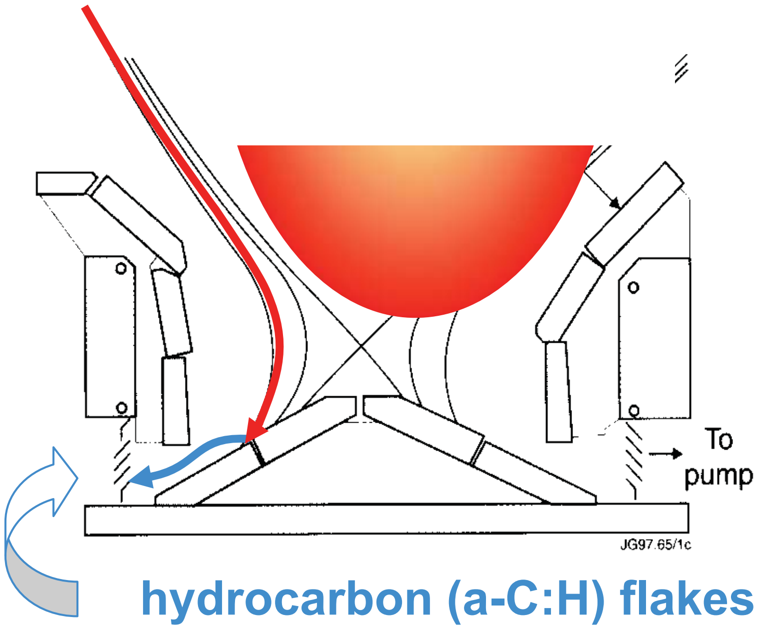


growth and erosion of hydrogenated, amorphous carbon

Motivation:

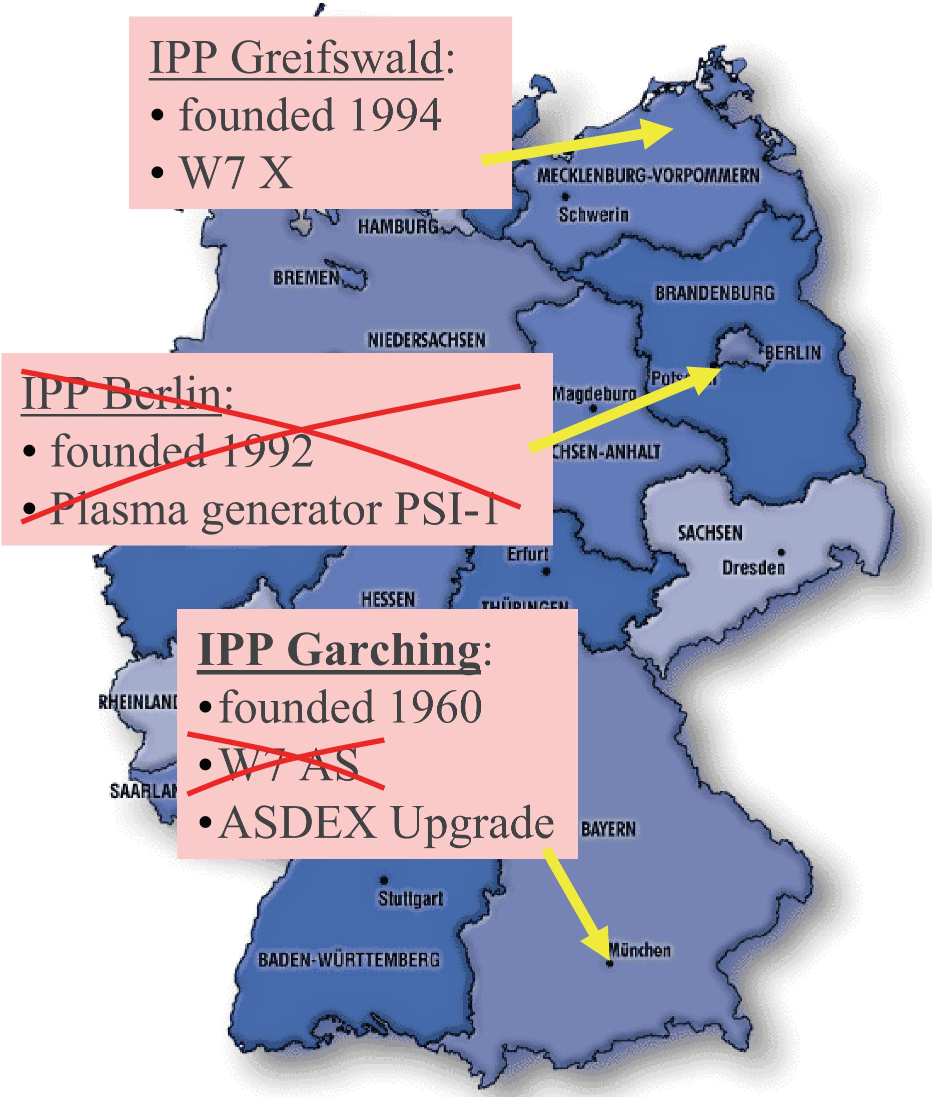
Tritium Redeposition

JET Divertor



hydrocarbon (a-C:H) flakes (later a-C:T)

Max-Planck-Institut für Plasmaphysik (IPP), Garching, Germany



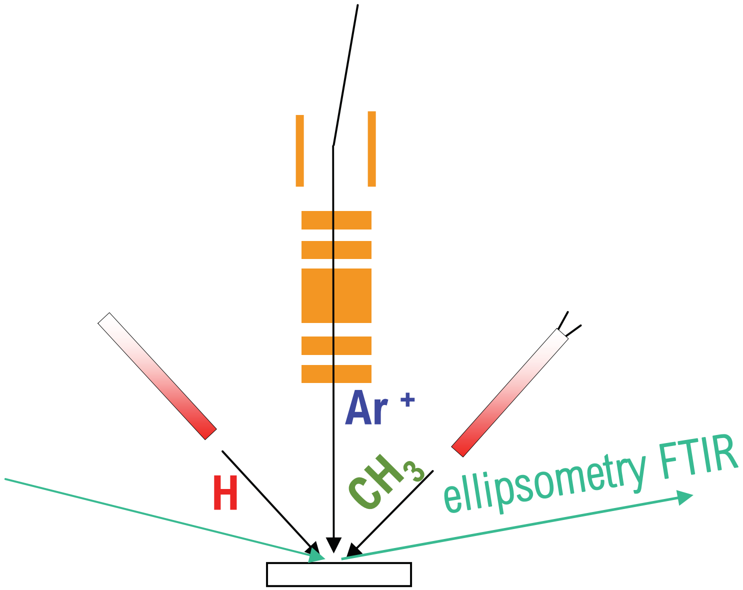
aim of research: Investigate basic conditions for a fusion power plant that generates energy similar like the sun from fusion of atomic nuclei

Garching:

- Tokamak:
  ASDEX Upgrade
- ~~Stellarator:~~
  ~~Wendelstein W7-AS~~
- Plasma Heating
- Theory
- Plasma Wall Interaction

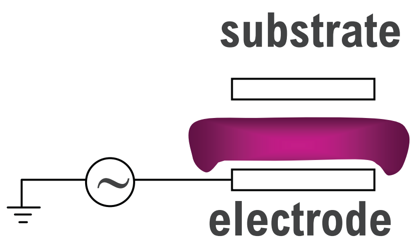
film growth and erosion studies: two approaches

1. quantified beam experiments



+ "easy" interpretation
+ isolation of microscopic mechanism
– "artificial plasma"

2. plasma experiments



ECR
cc-rf plasma
pulsed ICP

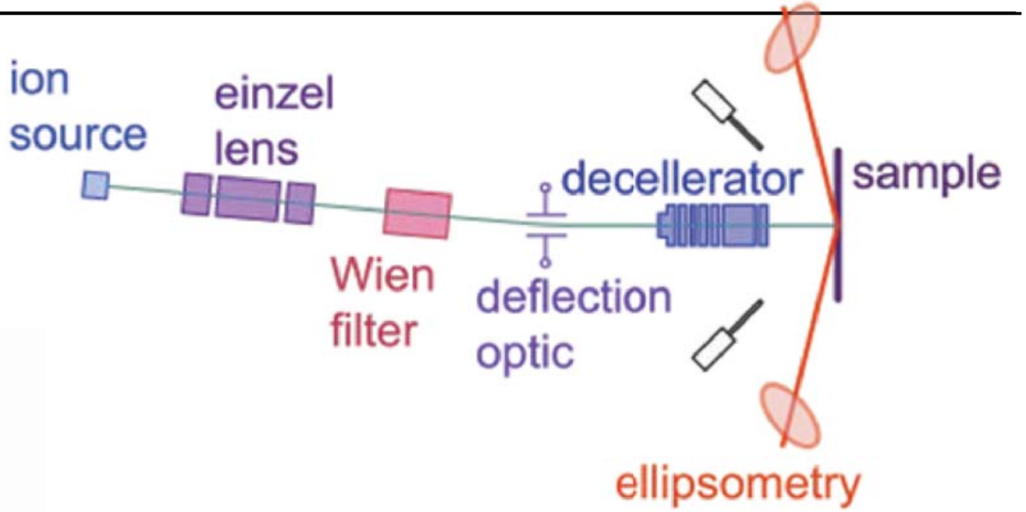
diagnostics: ellipsometry
FTIR
QMS, PM, RFA
cavities…

+ real life
– interpretation ambiguous
complex particle zoo
quantification of fluxes?
➢ modelling of fluxes

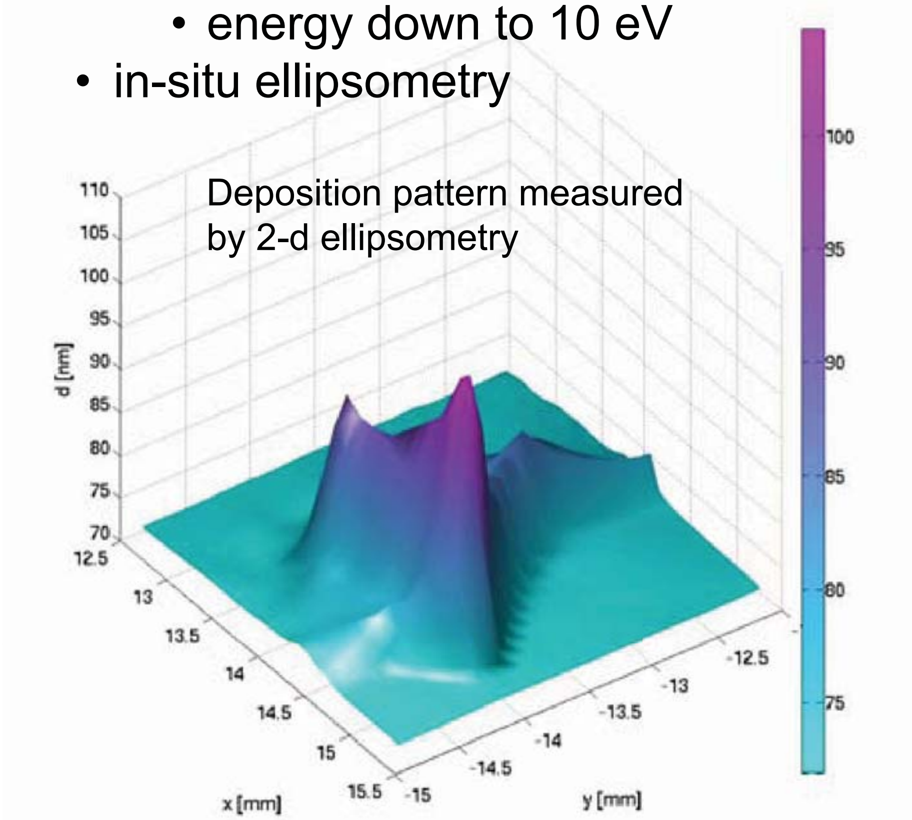
sticking coefficients of hydrocarbons at low energy

PhD work Klaus Tichmann

Setup:
- ion gun
    - mass selected ions
    - energy down to 10 eV
- in-situ ellipsometry



Deposition pattern measured by 2-d ellipsometry

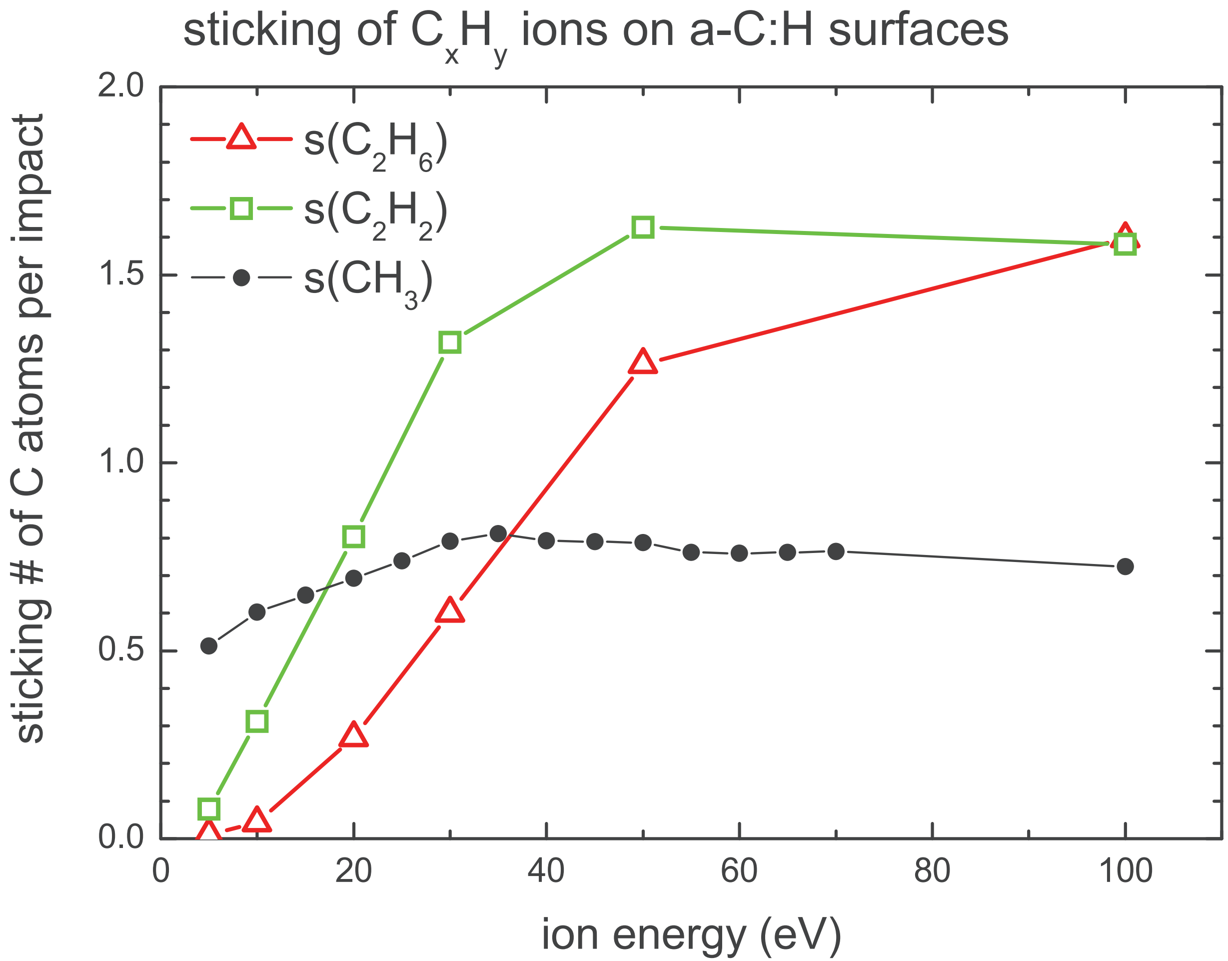


First experiment:
- 150 eV CH_3^+ ions on a-C:H surface
- measurement of sample current
  → number of impinging carbon atoms
- 2D ellipsometry of grown surface
  → number of deposited carbon atoms

→ sticking probability of selected ion
→ in this case: about 1
(still subject to large uncertainty)

sticking coefficients of hydrocarbons at low energy

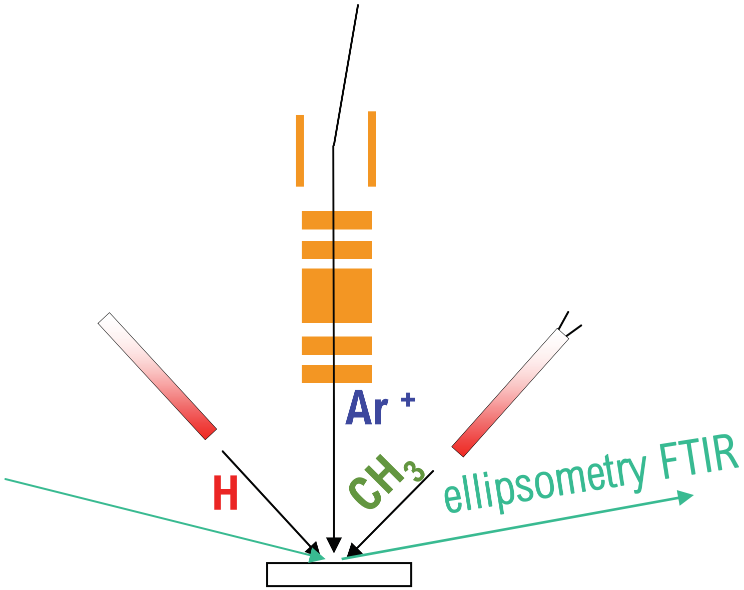
MD simulations with HCParCas Code (K. Tichmann, U. von Toussaint)



- Bombardment of a-C:H films with C_xH_y ions
- Determination of sticking coefficients
- Comparision with well definded experiments
- Other data from MD: reflection coeff. refl. species energy of species

film growth and erosion studies: two approaches

1. quantified beam experiments



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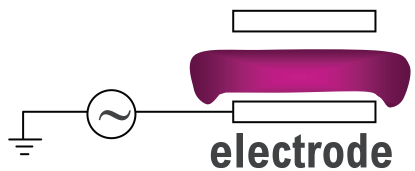

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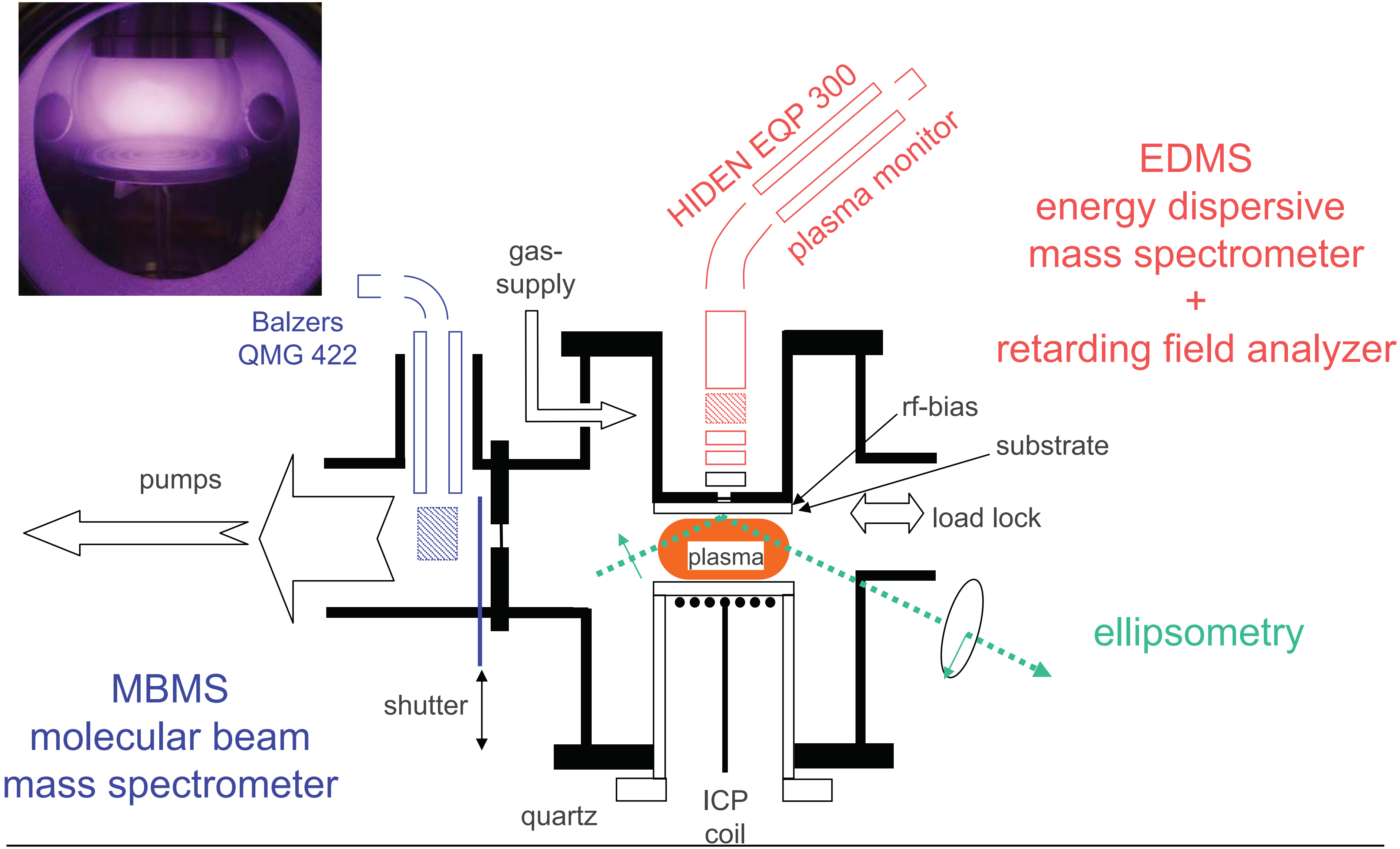
plasma chemistry of CxHy plasmas

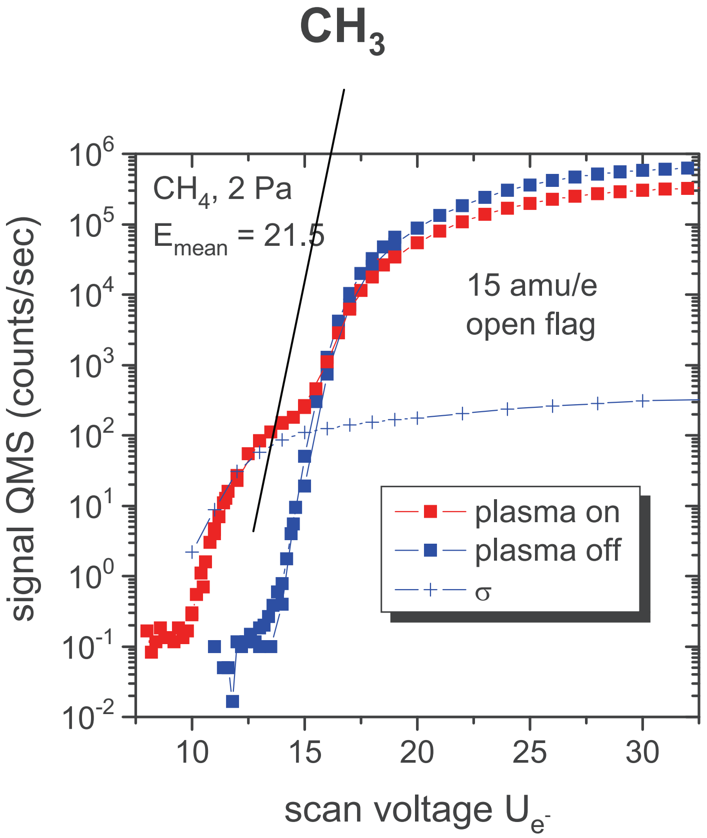


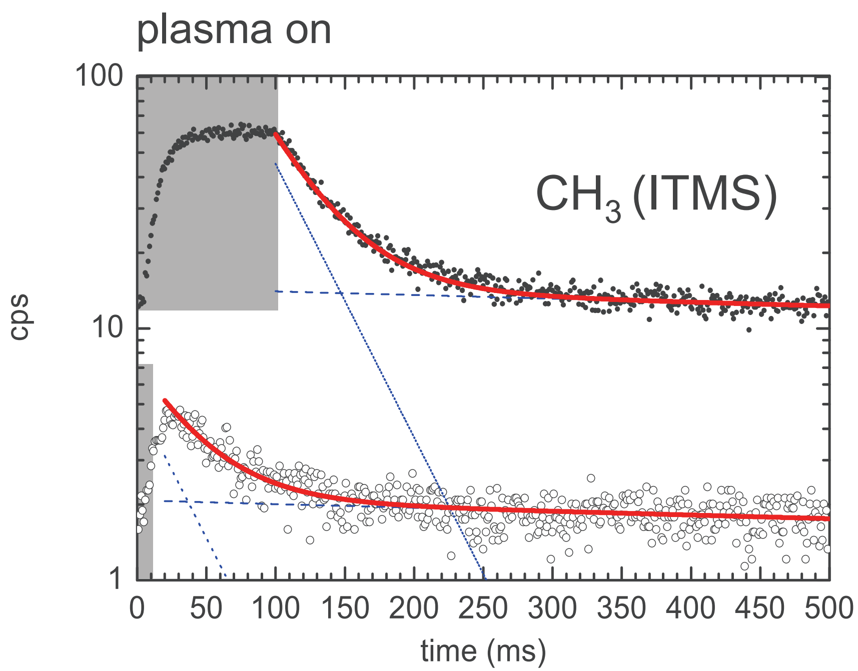
plasma chemistry of CxHy plasmas (Dipl. work M.Pietzka + PhD work M.Sode)

aim: time resolved measurements of

- ions,
- neutrals and
- radicals to

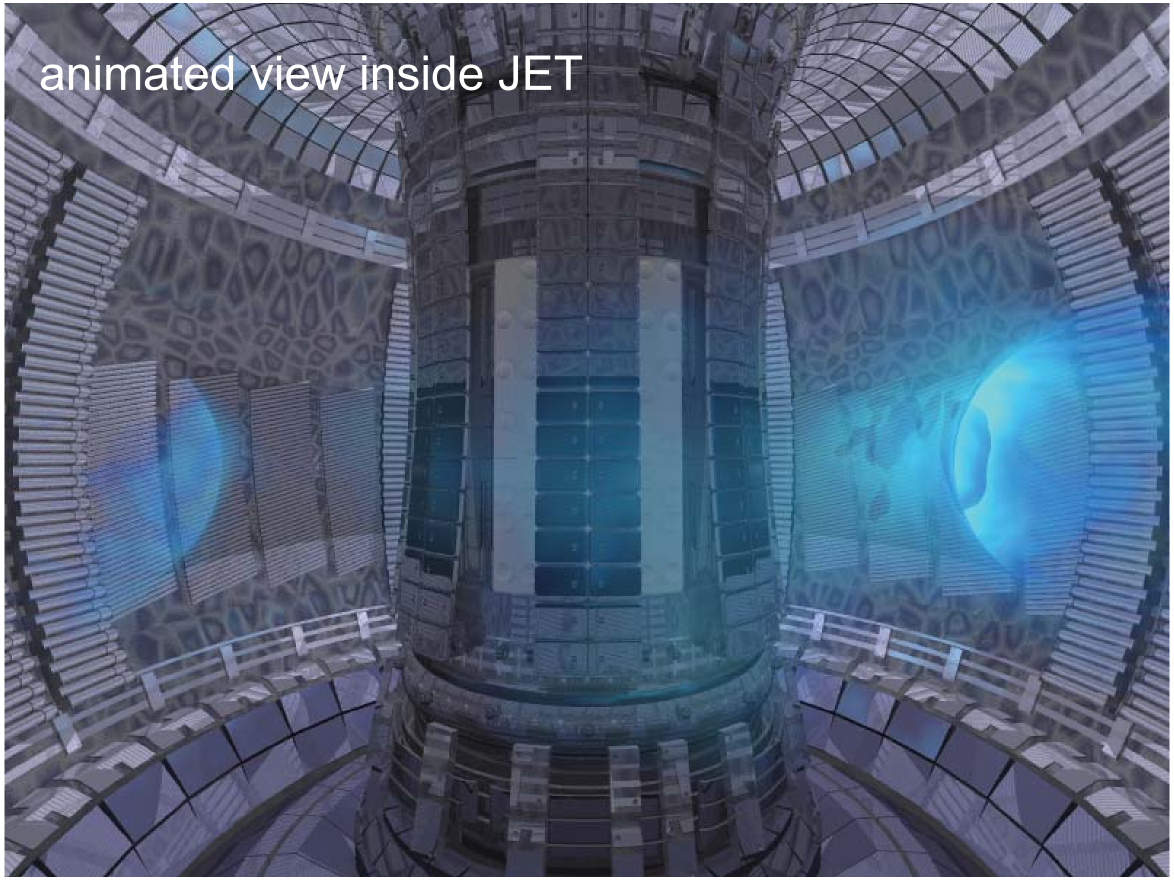
- verify input parameters of plasma boundary codes





challenge for film removal: gaps everywhere

plasma exposed surface ≈ remote surfaces



EU Prototype of Inner Vertical Target with CfC & W Armour

erosion of carbon in tile gap structures by oxygen plasmas

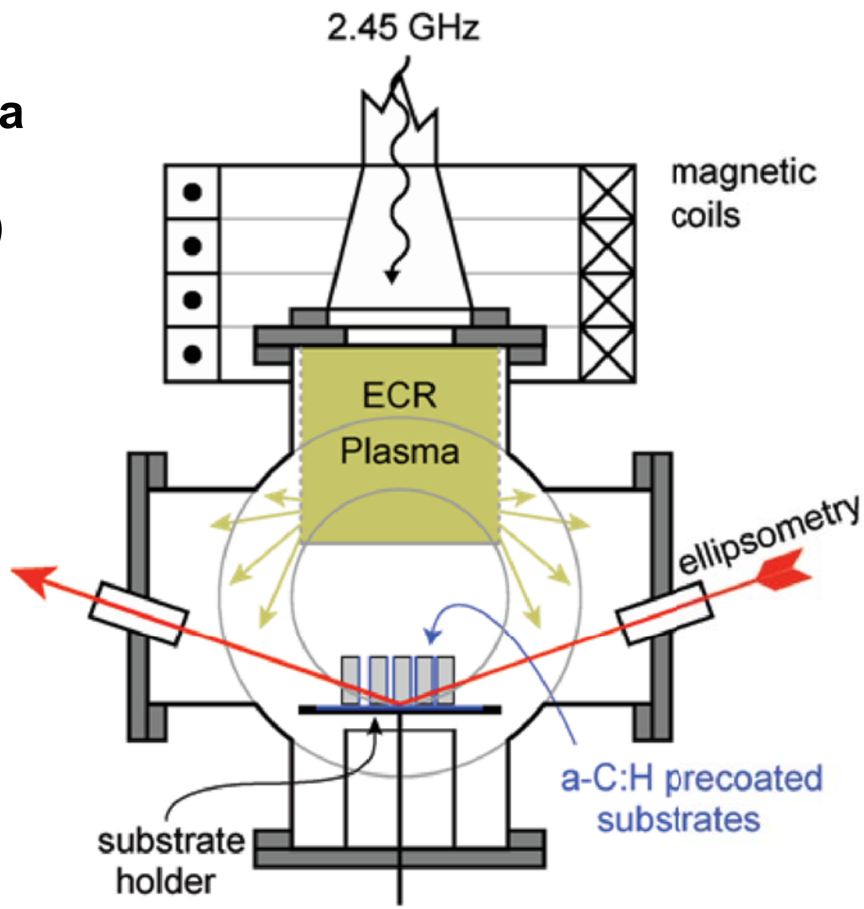
model system for redeposited films: amorphous, hydrogenated carbon (a-C:H)

different oxygen plasmas at p ≈ 1 Pa

- **ECR afterglow (thermal energies)**

  ECR plasma (ion energy ≈ 15 eV)

  CCP mode (ion energy ≈ 300 eV)

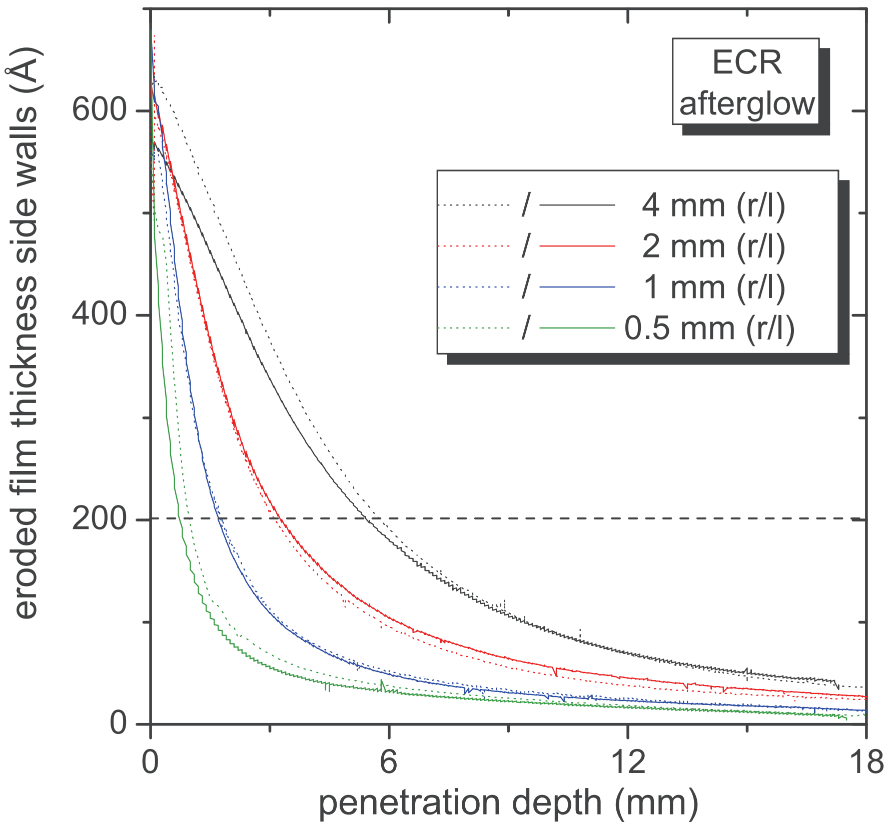


analysis by ellipsometry

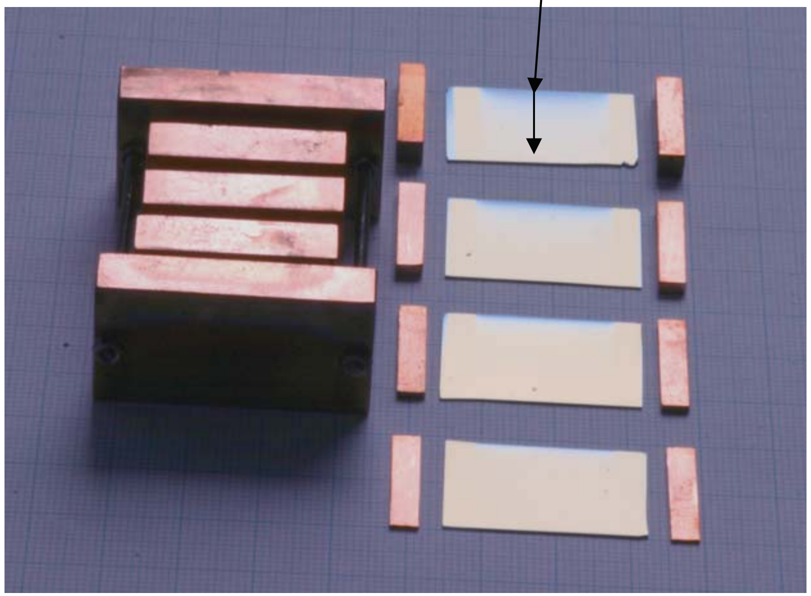
- **before exposure 2D scan**
- **during exposure locally**
- **ex-situ 2D scan of all surfaces**

erosion in ECR oxygen afterglow (thermal particle energies)

side wall erosion drops faster for smaller gaps !



ellipsometry



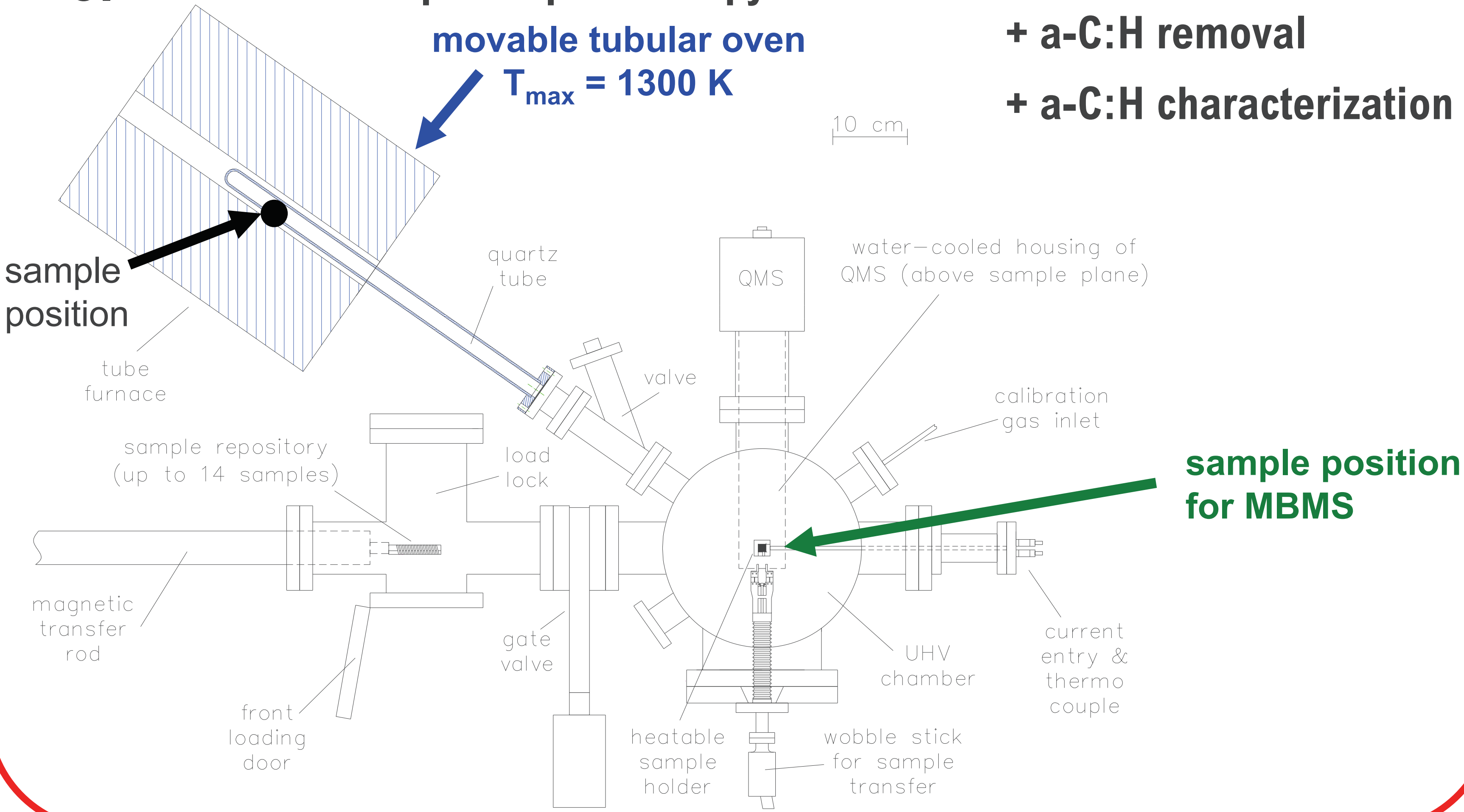
p = 0.5 Pa,
P_{MW} = 75 Watt
t = 5740 min

film characterization

3. Thermal desorption spectroscopy

+ a-C:H removal

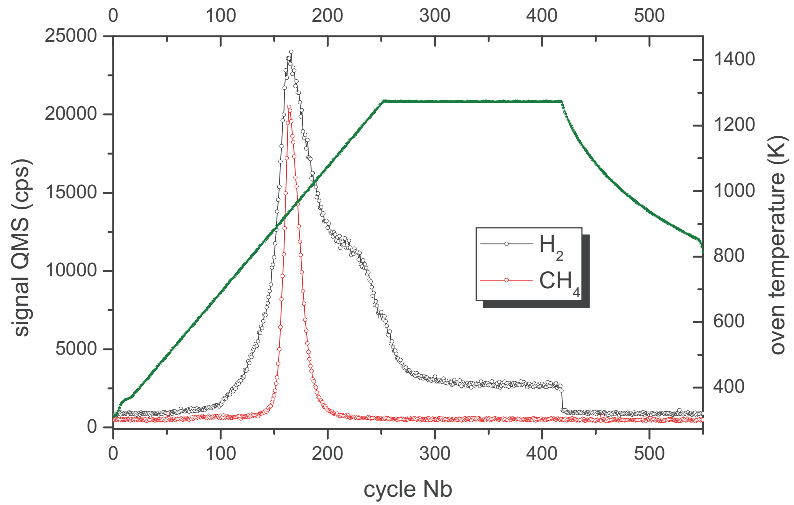
+ a-C:H characterization

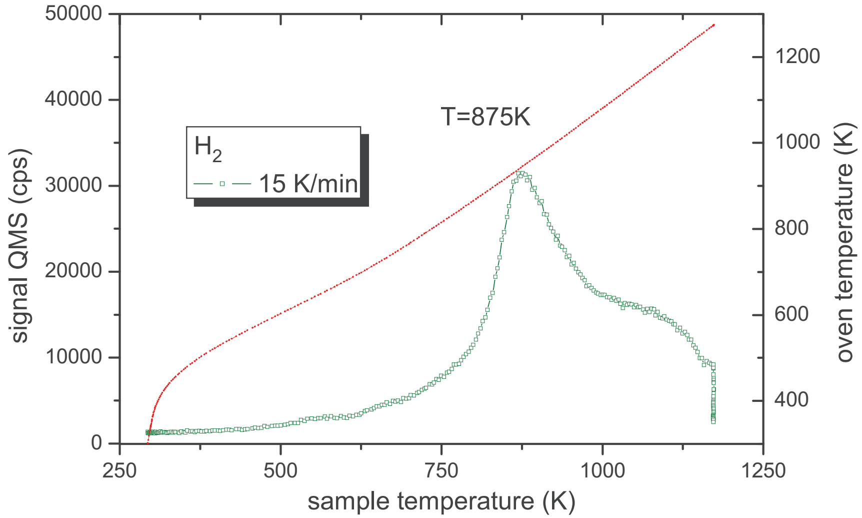


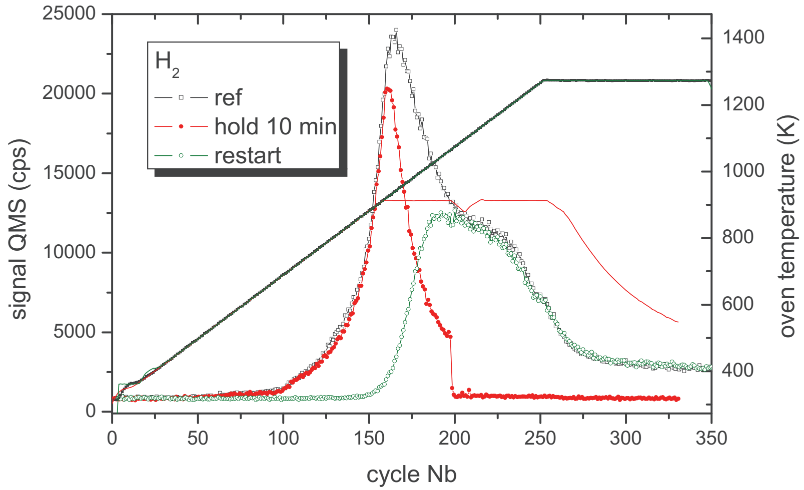
Thermal desorption of amourphous hydrogenated carbon thin films

T. Dürbeck, T. Schwarz-Selinger, U. von Toussaint, W. Jacob

- species monitoring with QMS
- linear T ramp from RT to 1300 K
- different hold temperatures
- different hold times
- different ramps (3 to 40 K/min)

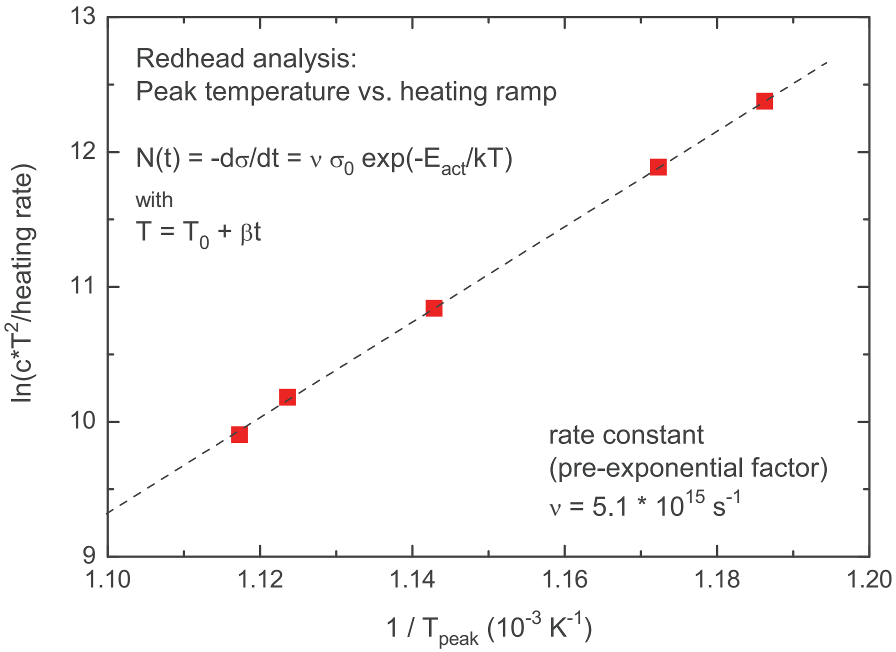


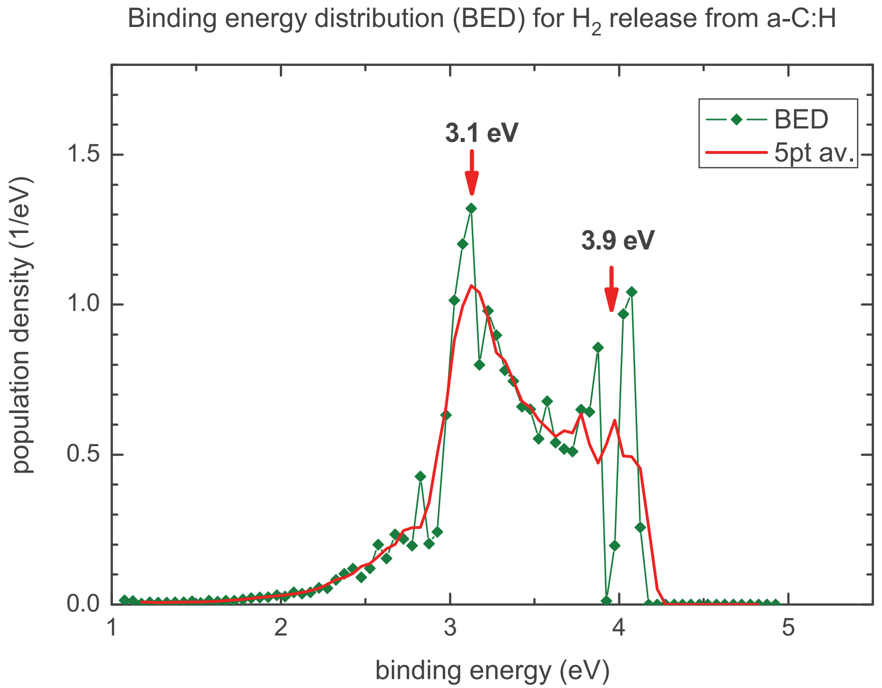




Variation of T ramp: Redhead analysis of TDS spectra

T. Dürbeck, T. Schwarz-Selinger, U. von Toussaint, W. Jacob





Determination of pre-exponential factor and **binding energy distribtion (BED)**
[one BED explains all results for the different ramps from 3 K/min up to 40 K/min]

Diffusion does not seem to play a dominant role in thermal decomposition of a-C:H.