A new high performance micro wave plasma source

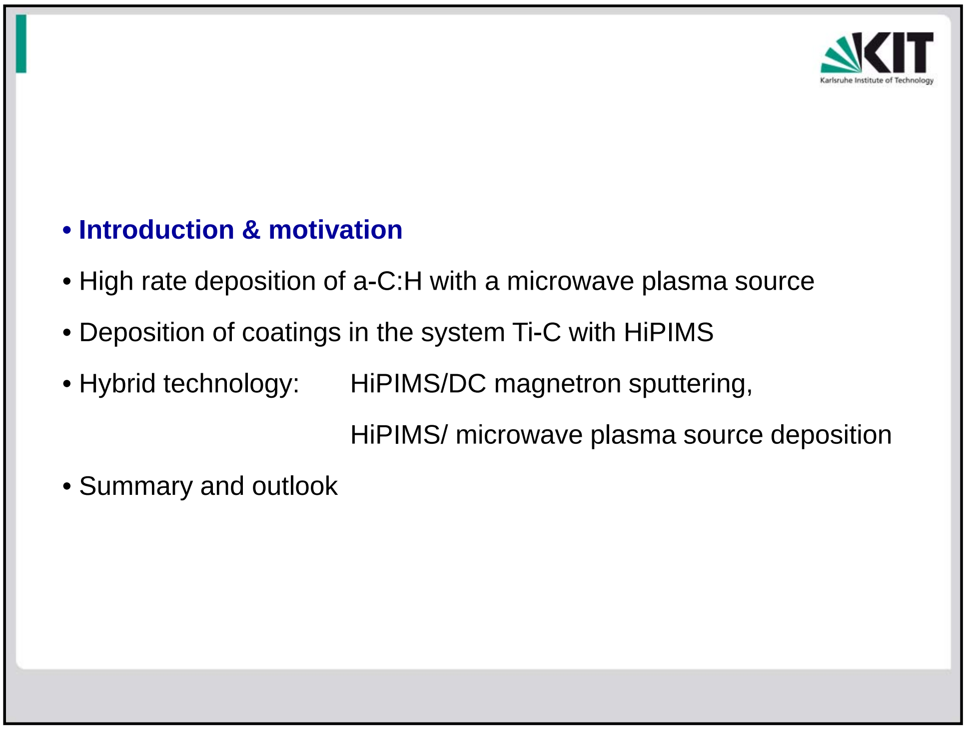
S. Ulrich, J. Ye, M. Stüber, H. Leiste

robeko in-house exibition & workshop plasmatechnology, 30th September 2015

Institute for Applied Materials (IAM-AWP), Department of Composites and Thin Films

Outline

- Introduction & motivation
- High rate deposition of a-C:H with a microwave plasma source
- Deposition of coatings in the system Ti-C with HiPIMS
- Hybrid technology: HiPIMS/DC magnetron sputtering,
  HiPIMS/ microwave plasma source deposition
- Summary and outlook



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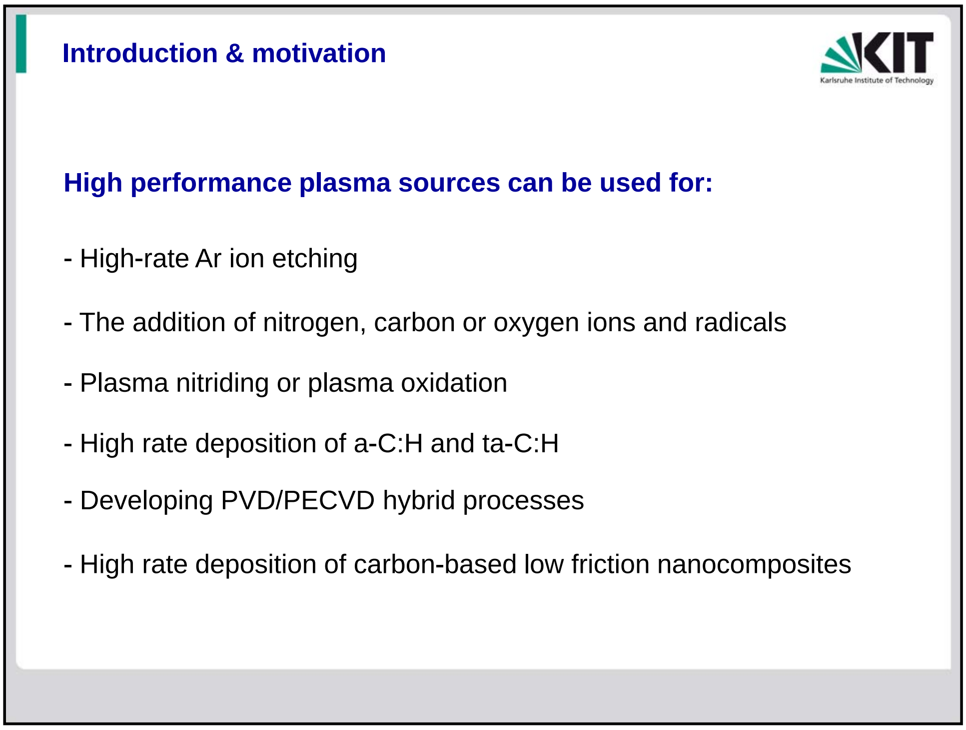


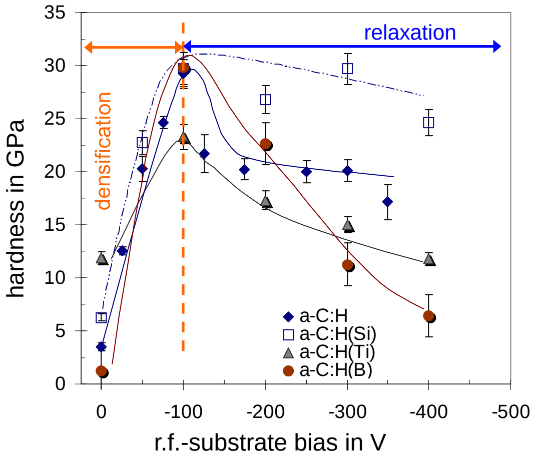
Introduction & motivation

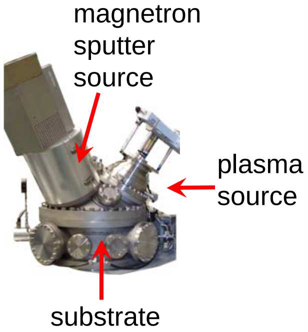
High performance plasma sources can be used for:

- High-rate Ar ion etching
- The addition of nitrogen, carbon or oxygen ions and radicals
- Plasma nitriding or plasma oxidation
- High rate deposition of a-C:H and ta-C:H
- Developing PVD/PECVD hybrid processes
- High rate deposition of carbon-based low friction nanocomposites

Introduction & motivation

Modified a-C:H coatings produced by a PECVD/PVD hybrid process





S. Ulrich, H. Holleck, H. Leiste, L. Niederberger, E. Nold, K. Sell, M. Stüber, J. Ye, C. Ziebert, P. Pesch, S. Sattel, Nano-scale, multi-functional coatings in the material system B-C-N-H, Surf. Coat. Technol. 200 1-4 (2005) 7-13

- Independent particle fluxes forming a-C:H and adding Si, Ti or B

Introduction & motivation

HiPIMS

Pulsing allows us to use high peak power while keeping the average power relatively low, making it easy on power grid demands while reaching technologically interesting plasma states.

Advantages:

- film forming particles: ions
- control of growth process
- interface design is possible
- high adhesion
- compact morphology

Disadvantiges:

- redeposition process on target
- low growth rate
- arcing poisoning problems

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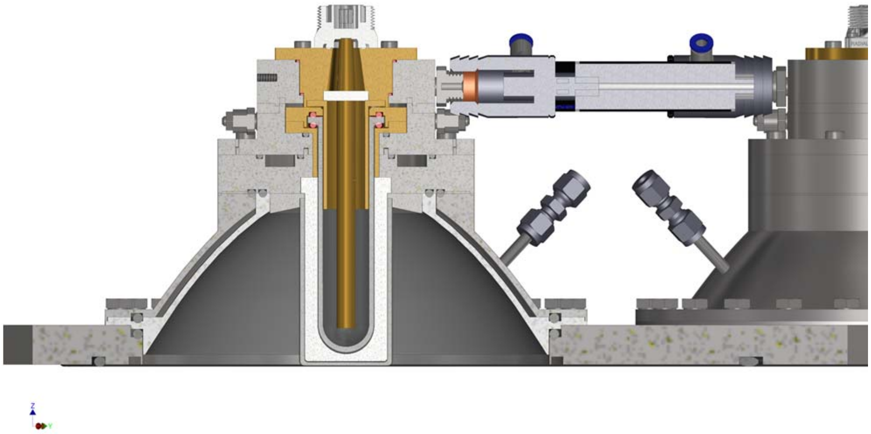
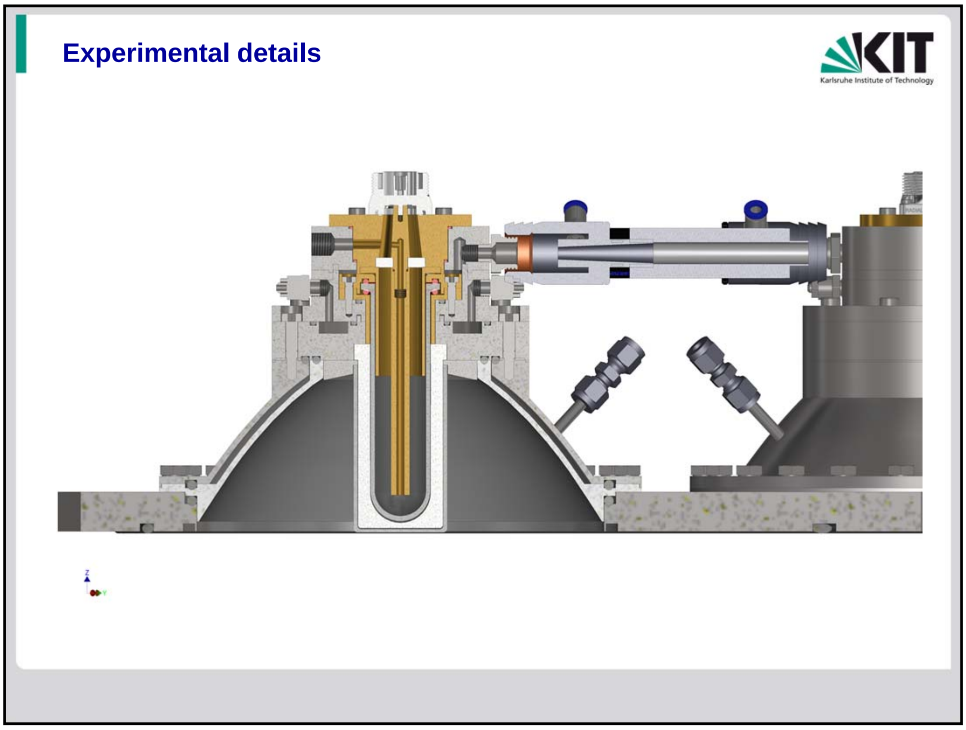
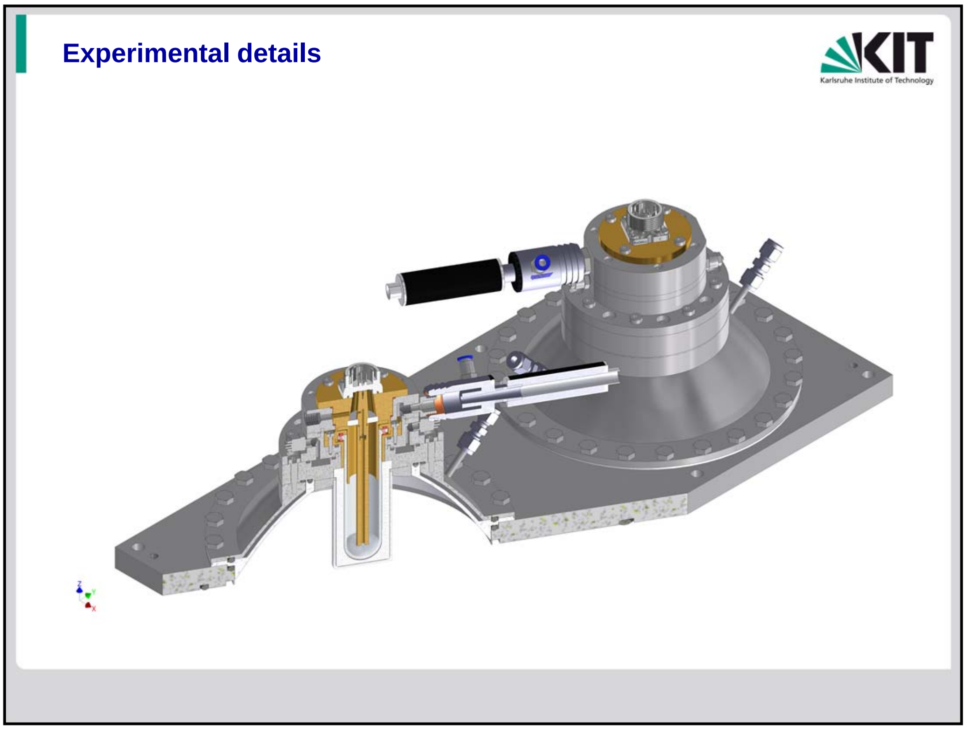
Experimental details





Experimental details



Experimental details

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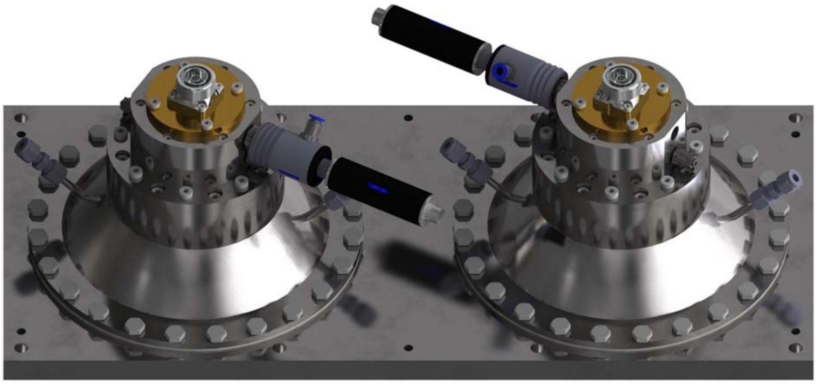

Experimental details

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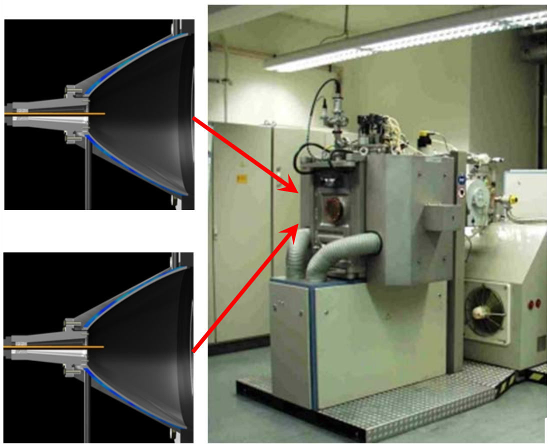
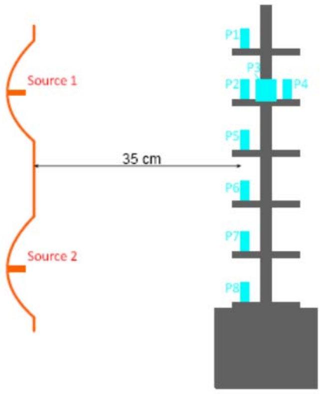
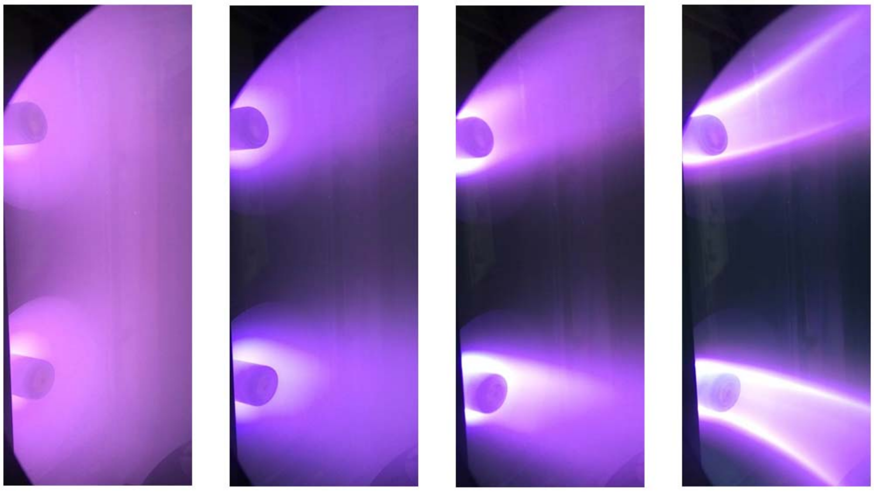
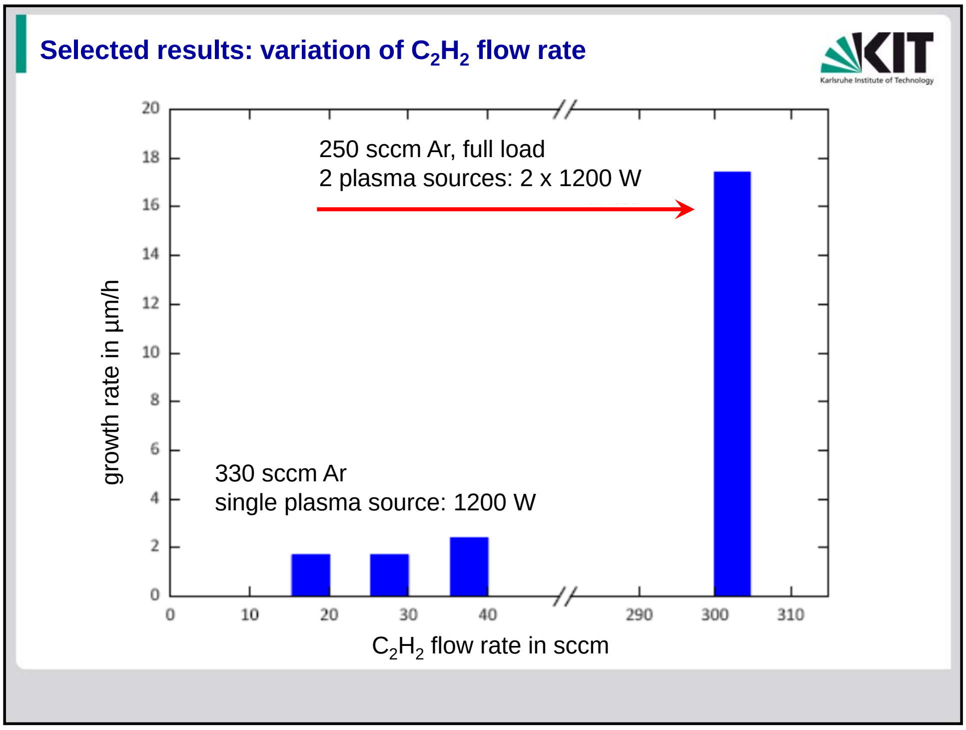




Developments in PVD/PECVD coatings for automotive applications
R. Tietema, R. Jacobs, D. Doerwald, I. Kolev, J. Landsbergen
IHI Hauzer Techno Coating BV, AEPSE, 22-WS-6

Experimental details

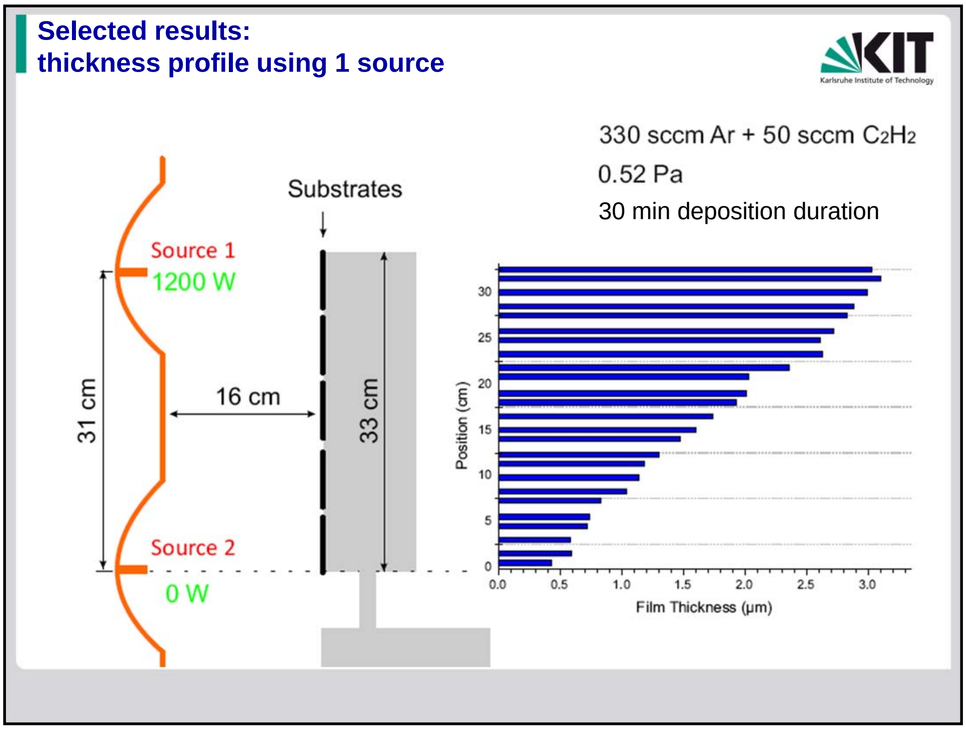




Selected results: variation of C_2H_2 flow rate

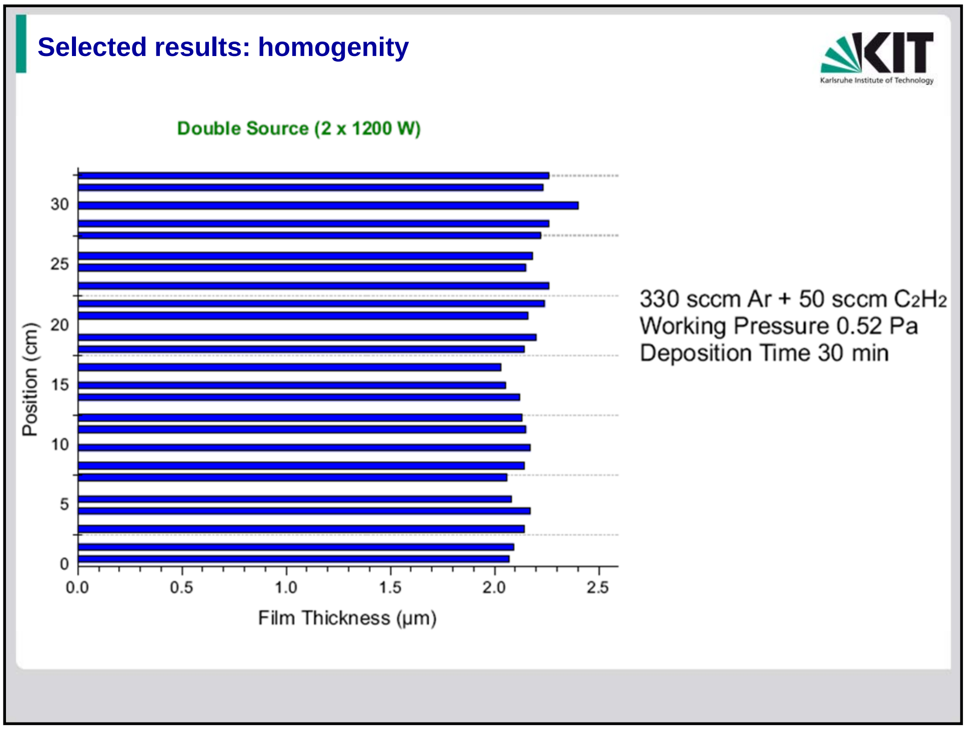
250 sccm Ar, full load
2 plasma sources: 2 x 1200 W

330 sccm Ar
single plasma source: 1200 W



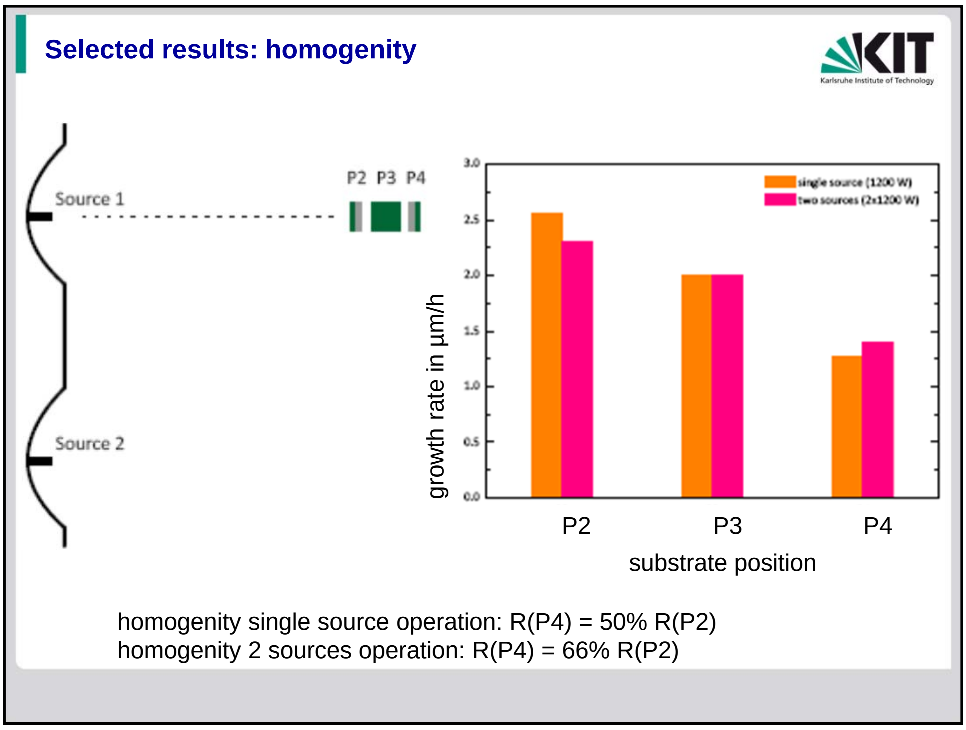
Selected results:
thickness profile using 1 source

330 sccm Ar + 50 sccm C_2H_2
0.52 Pa
30 min deposition duration



Selected results: homogenity

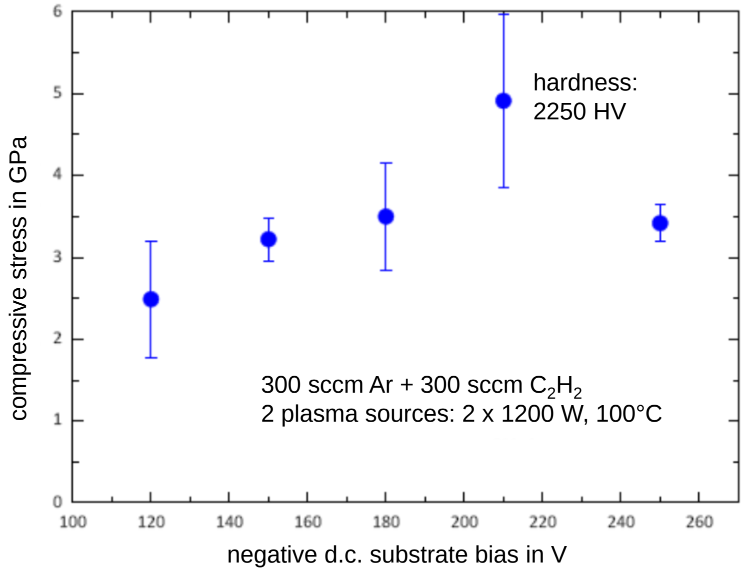
330 sccm Ar + 50 sccm C_2H_2
Working Pressure 0.52 Pa
Deposition Time 30 min



Selected results: homogenity

homogenity single source operation: R(P4) = 50% R(P2)
homogenity 2 sources operation: R(P4) = 66% R(P2)

Selected results: residual stress



hardness:
2250 HV

300 sccm Ar + 300 sccm C_2H_2
2 plasma sources: 2 x 1200 W, 100°C

Selected results: high growth rate

-Deposition with **single plasma source**
(new BN-part attached on antenna): 1 x 1.4kW

-Gas: **500 sccm C_2H_2 + 15 sccm Ar**

-Pressure: (a) before deposition 1.2 x 10^{-2} mbar,
(b) during deposition (plasma on) **5.4 x 10^{-3} mbar**

-Without substrate bias, no substrate rotation during deposition

-**Distance** between substrate and plasma-source: ca. **20 cm**

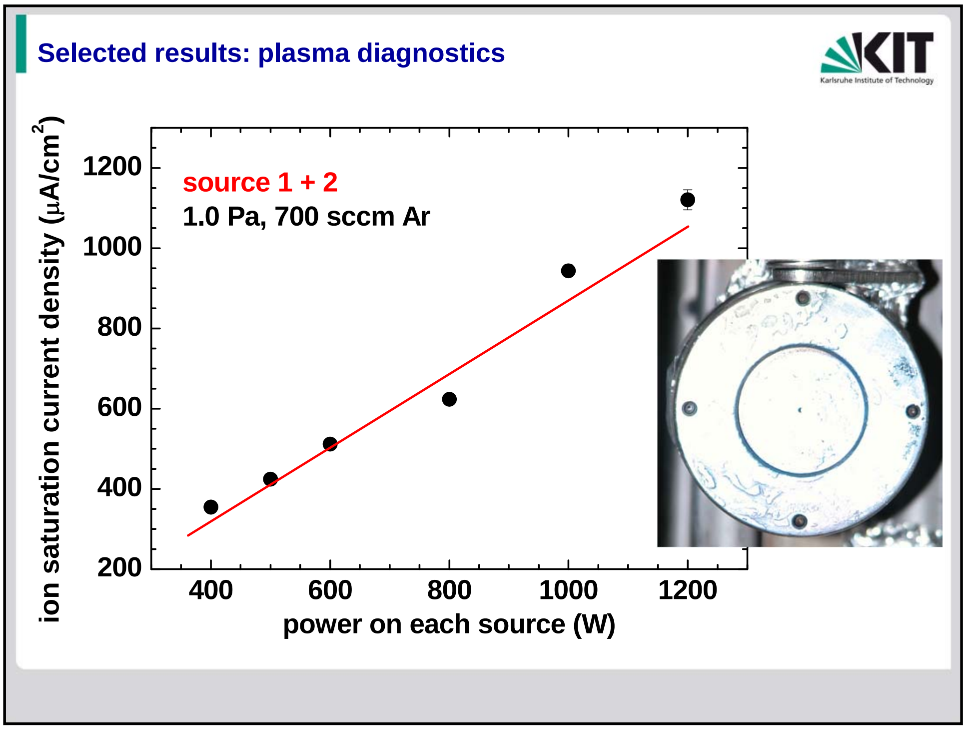
-Deposition time: 28 min

-Film thickness: 16.7 µm

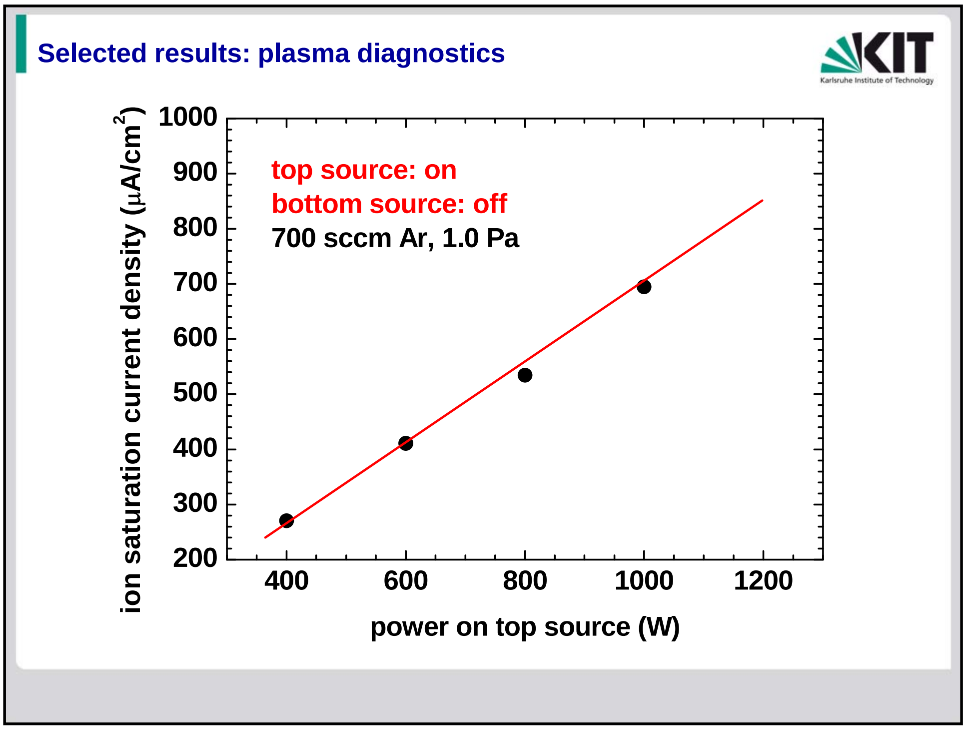
-Chamber temperature: 47° C in the end of deposition

-Muegge 3-stub tuner: no need for adjustment during deposition,
power refection kept at 0 - 2%.
Tuner temperature 32° C in the end of deposition

-**Deposition rate: 35.8 µm/h**



Selected results: plasma diagnostics



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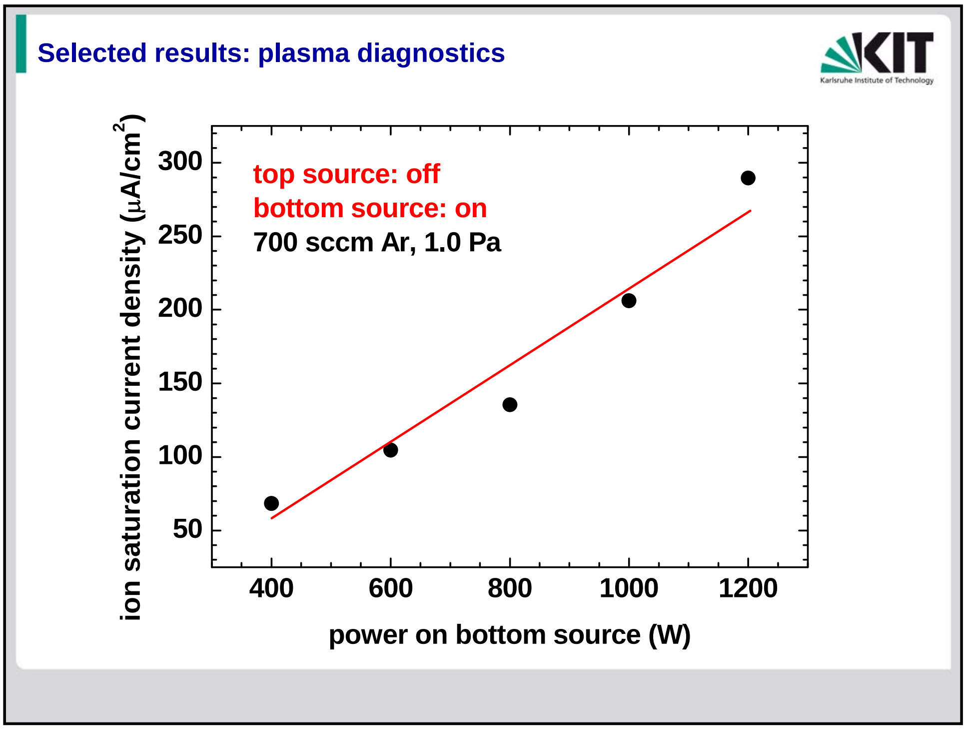

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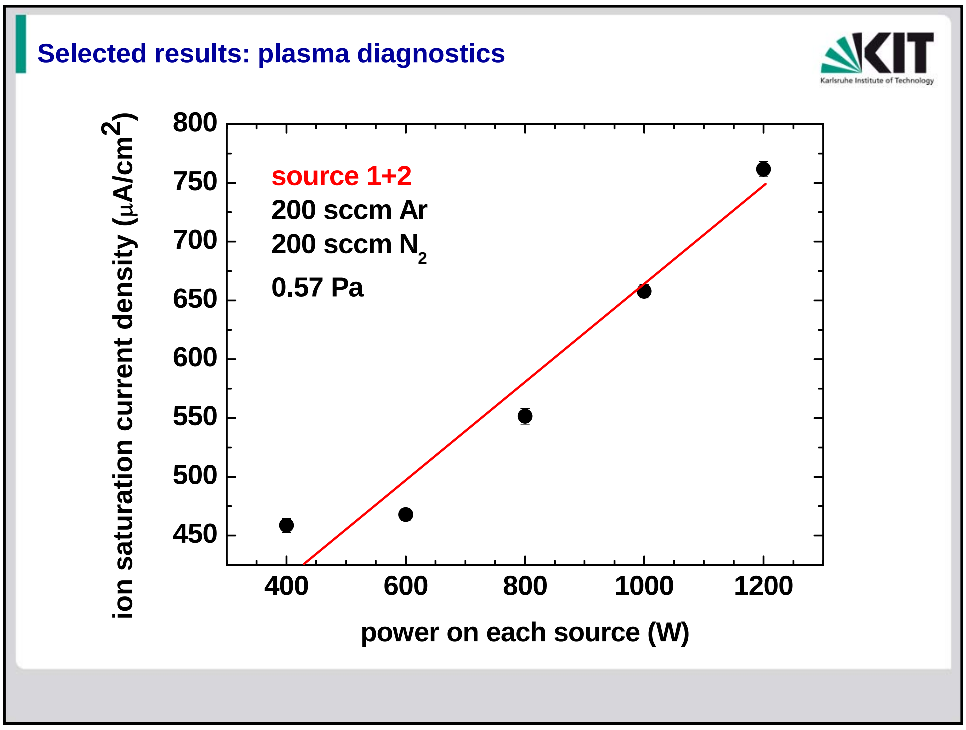

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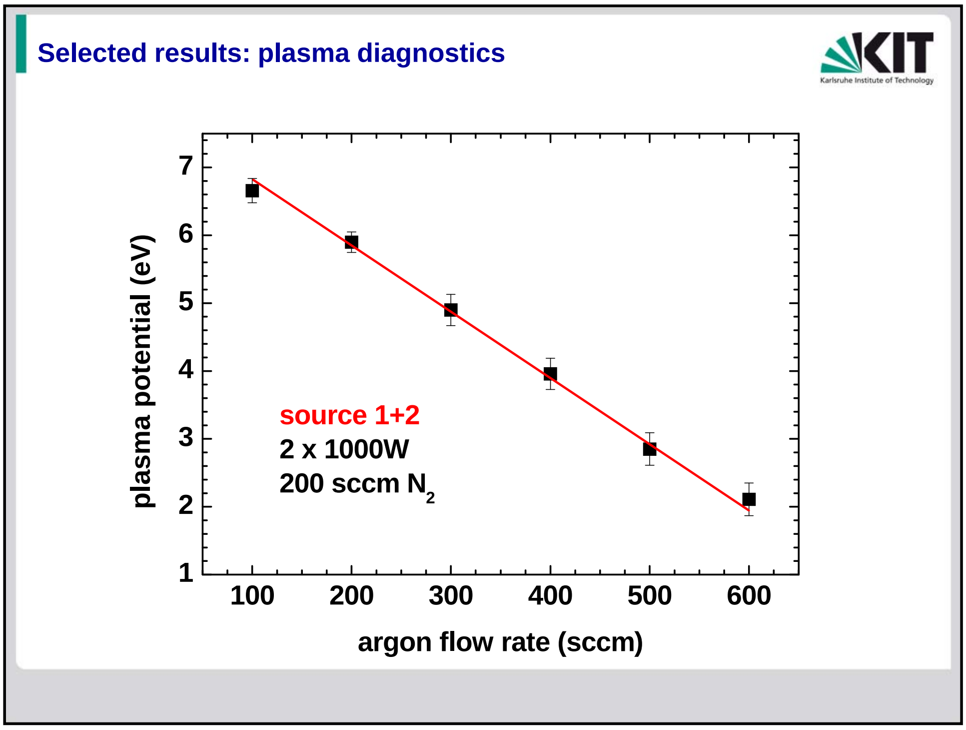

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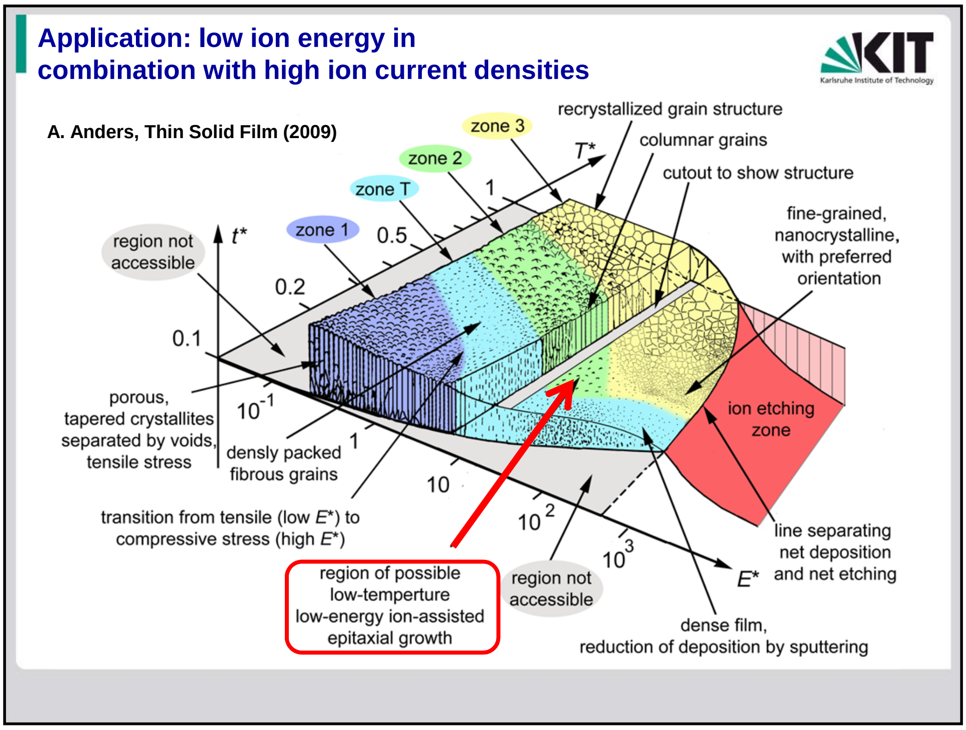

Application: low ion energy in combination with high ion current densities

A. Anders, Thin Solid Film (2009)

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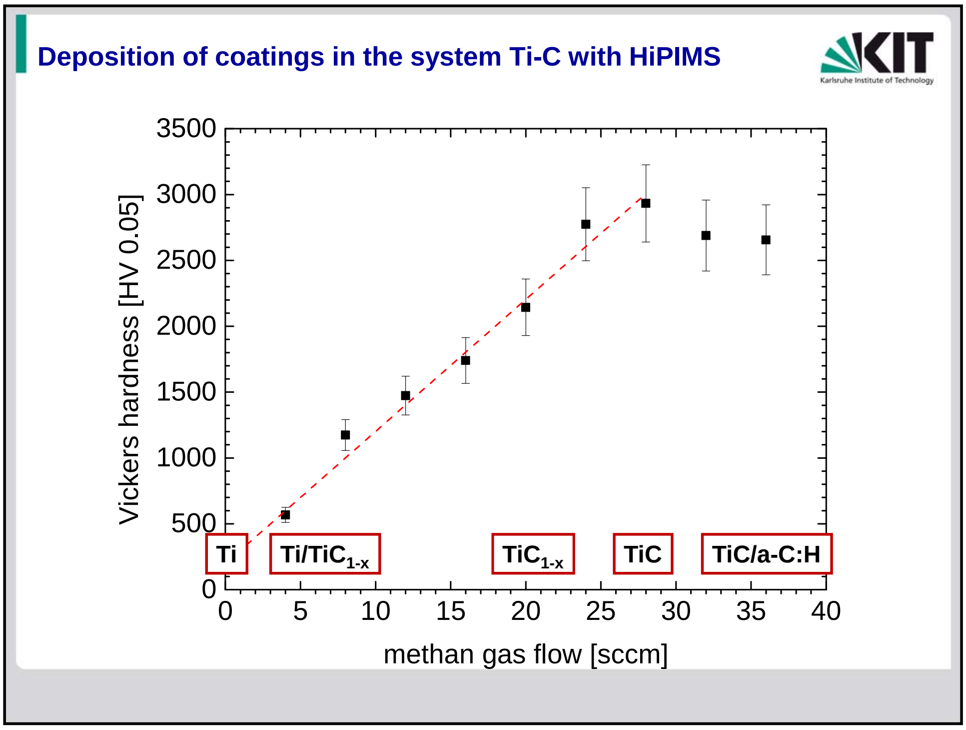
Deposition of coatings in the system Ti-C with HiPIMS

CABINET MELEC
DUAL – CHANNEL
DC PULSE POWER SUPPLY SET
A: +/1000V / +/- 500A ; 5 kW DC power
B: +/-1000V /+/- 500A; 5 kW DC power
4 channel measurement 2 x U(t); 2 x I(t)
Diode module using DC – HiPIMS (UP)

PVD Hauzer
Ti-target
planar magnetron
dimension: 125 mm x 406 mm
area: 507,5 cm²

5 kW DC AVERAGE CONST

HiPIMS : DC = 100% : 0%



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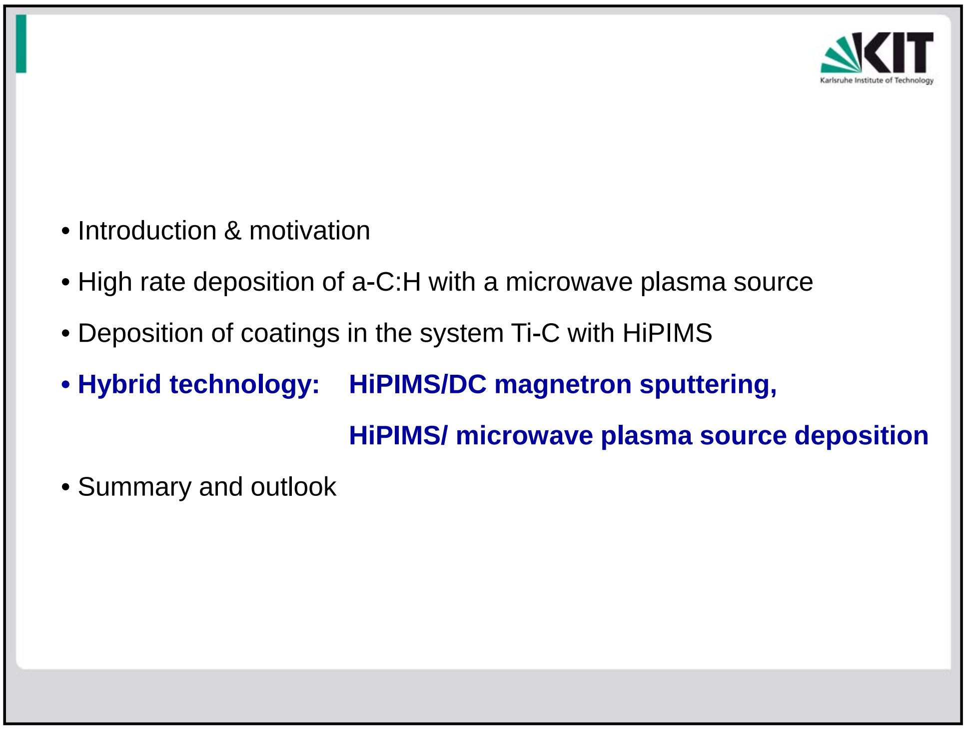

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Hybrid technology: HiPIMS/DC magnetron sputtering

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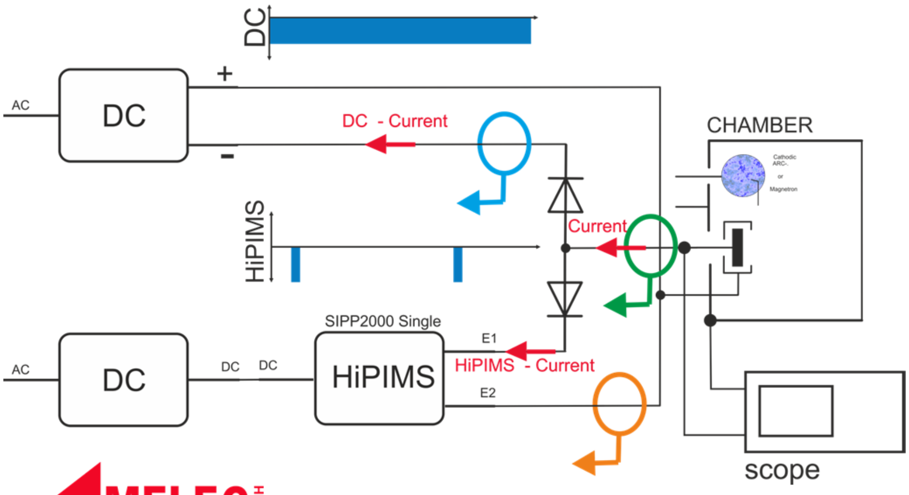
5 kW DC AVERAGE CONST

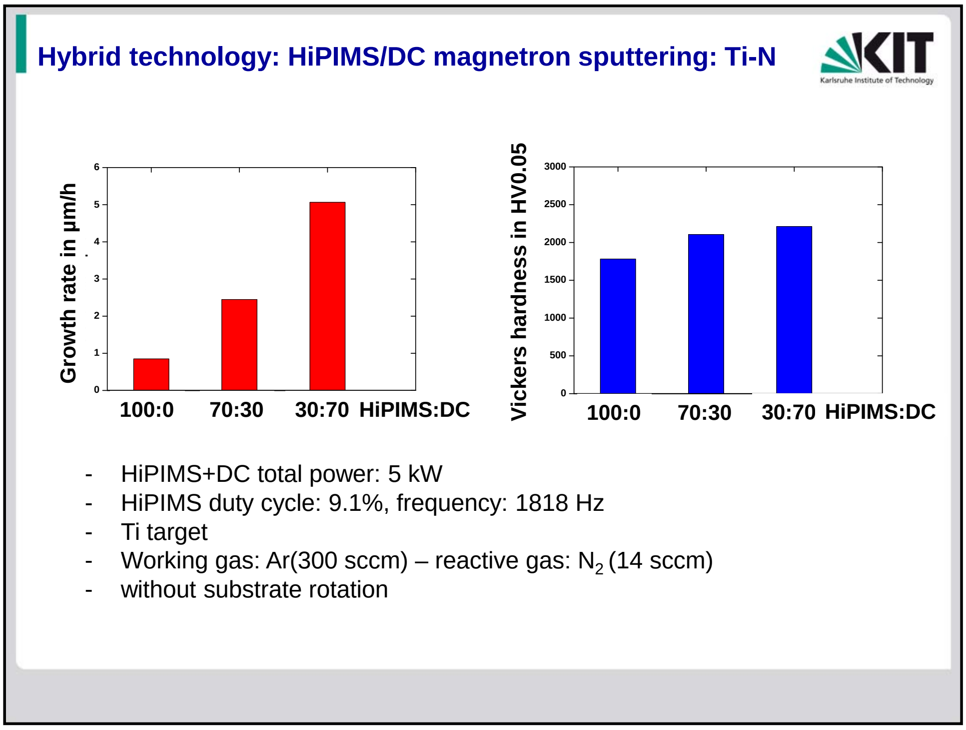
HiPIMS : DC = 100% : 0%
HiPIMS : DC = 70% : 30%
HiPIMS : DC = 30% : 70%

Hybrid technology: HiPIMS/DC magnetron sputtering



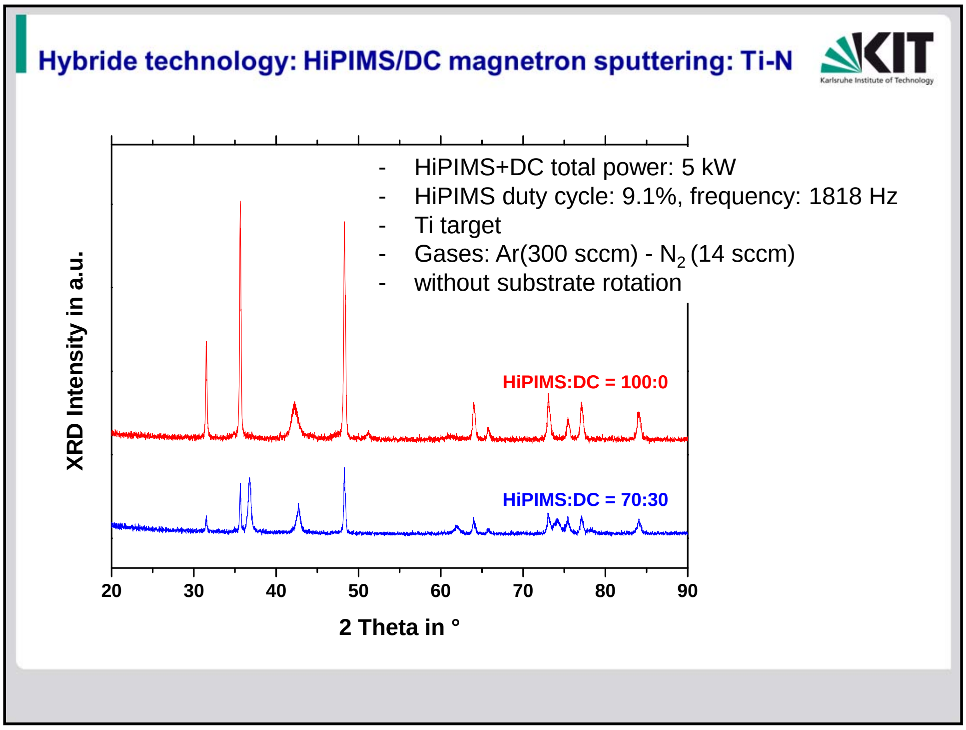
THE HIGH PULSE POWER COMPANY

M. Mark, G. Mark: Pluse textbook



Hybrid technology: HiPIMS/DC magnetron sputtering: Ti-N

- HiPIMS+DC total power: 5 kW
- HiPIMS duty cycle: 9.1%, frequency: 1818 Hz
- Ti target
- Working gas: Ar(300 sccm) – reactive gas: N_2 (14 sccm)
- without substrate rotation



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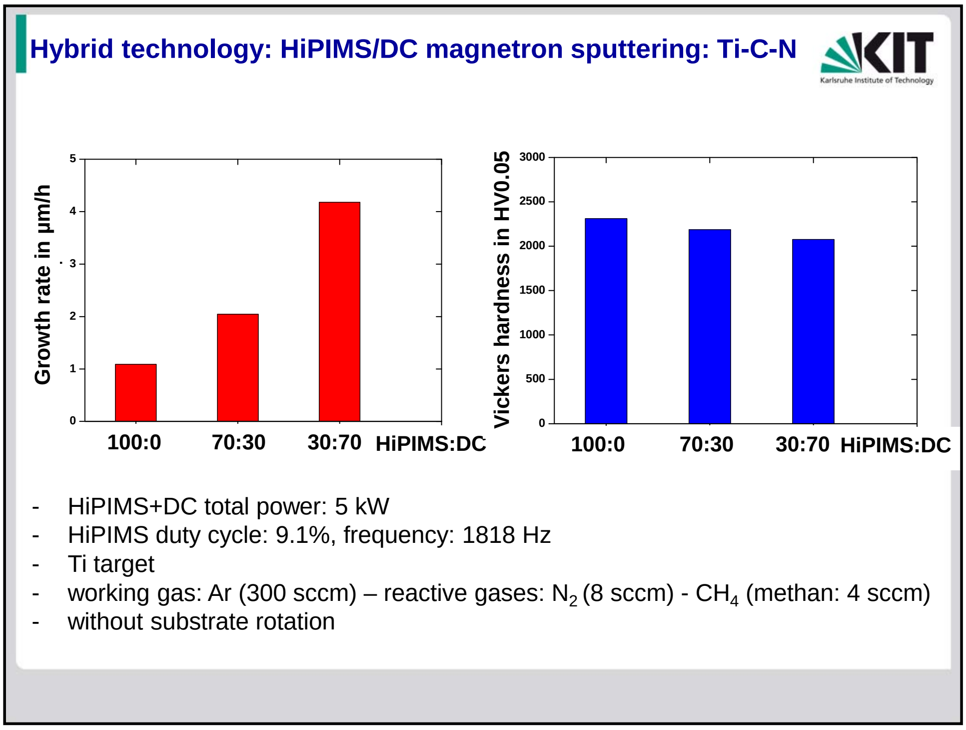
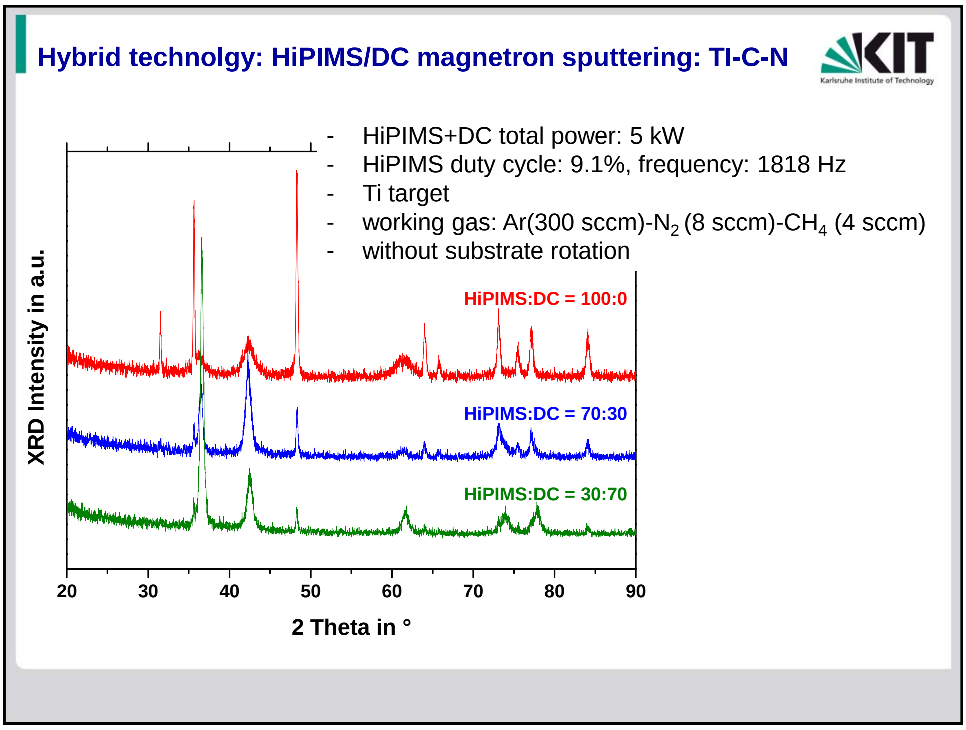


Hybrid technology: HiPIMS/DC magnetron sputtering: Ti-C-N

- HiPIMS+DC total power: 5 kW
- HiPIMS duty cycle: 9.1%, frequency: 1818 Hz
- Ti target
- working gas: Ar (300 sccm) – reactive gases: N_2 (8 sccm) - CH_4 (methan: 4 sccm)
- without substrate rotation



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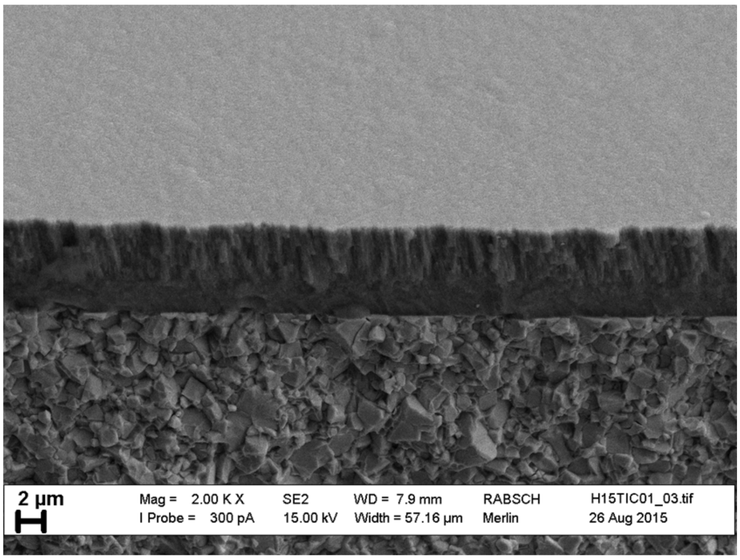
Hybrid technolgy: HiPIMS/ micro wave plasma source Ti-C



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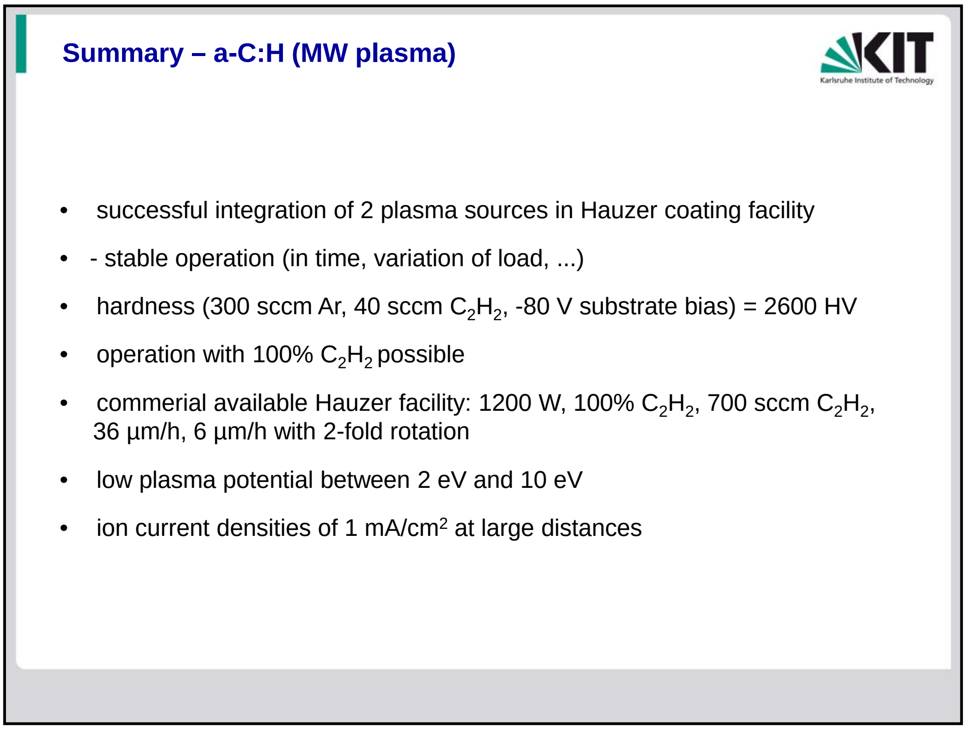
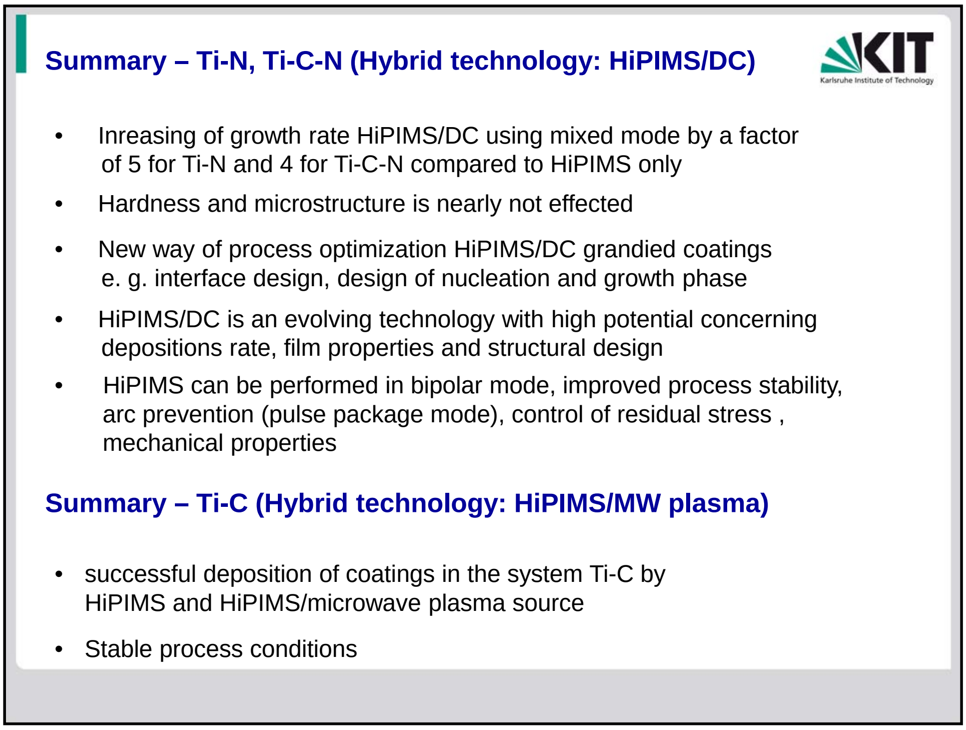


Summary – a-C:H (MW plasma)

- successful integration of 2 plasma sources in Hauzer coating facility
- \- stable operation (in time, variation of load, ...)
- hardness (300 sccm Ar, 40 sccm C_2H_2, -80 V substrate bias) = 2600 HV
- operation with 100% C_2H_2 possible
- commerial available Hauzer facility: 1200 W, 100% C_2H_2, 700 sccm C_2H_2, 36 µm/h, 6 µm/h with 2-fold rotation
- low plasma potential between 2 eV and 10 eV
- ion current densities of 1 mA/cm^2 at large distances



Summary – Ti-N, Ti-C-N (Hybrid technology: HiPIMS/DC)

- Inreasing of growth rate HiPIMS/DC using mixed mode by a factor of 5 for Ti-N and 4 for Ti-C-N compared to HiPIMS only
- Hardness and microstructure is nearly not effected
- New way of process optimization HiPIMS/DC grandied coatings e. g. interface design, design of nucleation and growth phase
- HiPIMS/DC is an evolving technology with high potential concerning depositions rate, film properties and structural design
- HiPIMS can be performed in bipolar mode, improved process stability, arc prevention (pulse package mode), control of residual stress , mechanical properties

Summary – Ti-C (Hybrid technology: HiPIMS/MW plasma)

- successful deposition of coatings in the system Ti-C by HiPIMS and HiPIMS/microwave plasma source
- Stable process conditions

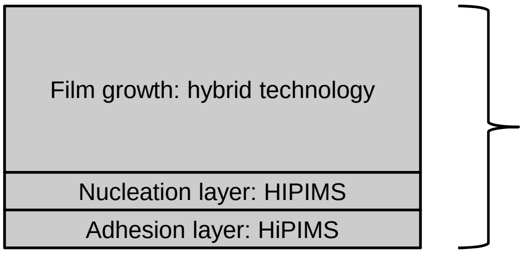
Outlook

Hybrid technology:

HiPIMS/DC magnetron sputtering + MW plasma source deposition

for carbon based coating systems

New coating concepts when HiPIMS is involved



Film growth: hybrid technology

Nucleation layer: HIPIMS

Adhesion layer: HiPIMS

3 layer systems

or

multilayer of this 3 layer system

Many thanks …

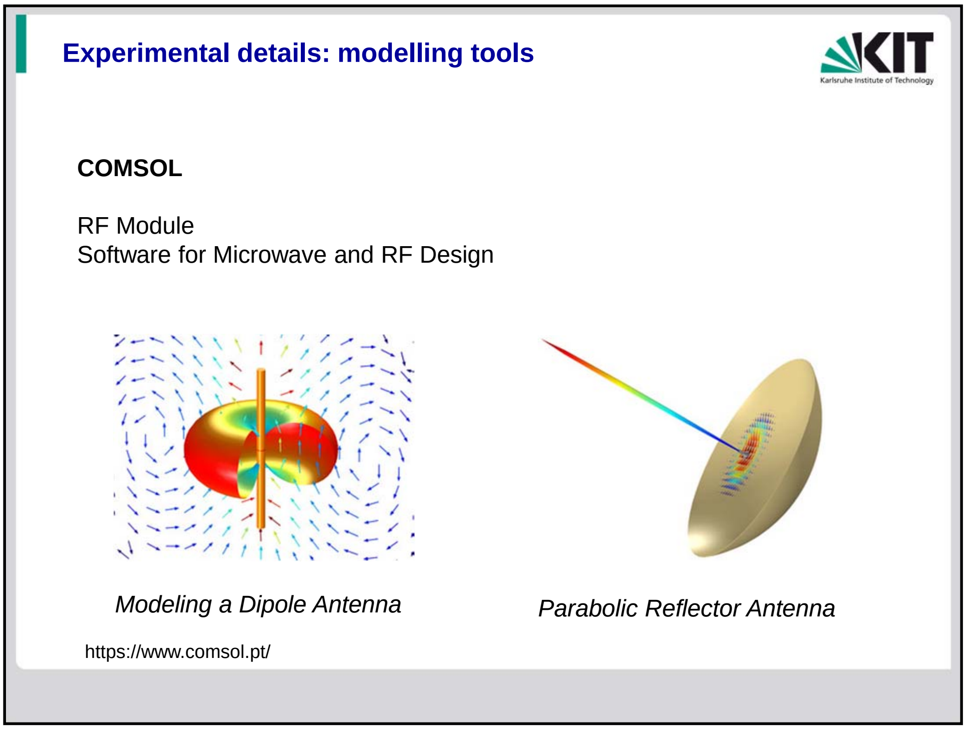
… to my co-workers J. Ye, M. Stüber and H. Leiste

… to my technical stuff: S. Schweiger, B. Rabsch, K. Erbes

… to our distribution partner robeko

… and Rolf Schäfer for the invitation

Thank you very much
for your attention!



Experimental details: modelling tools

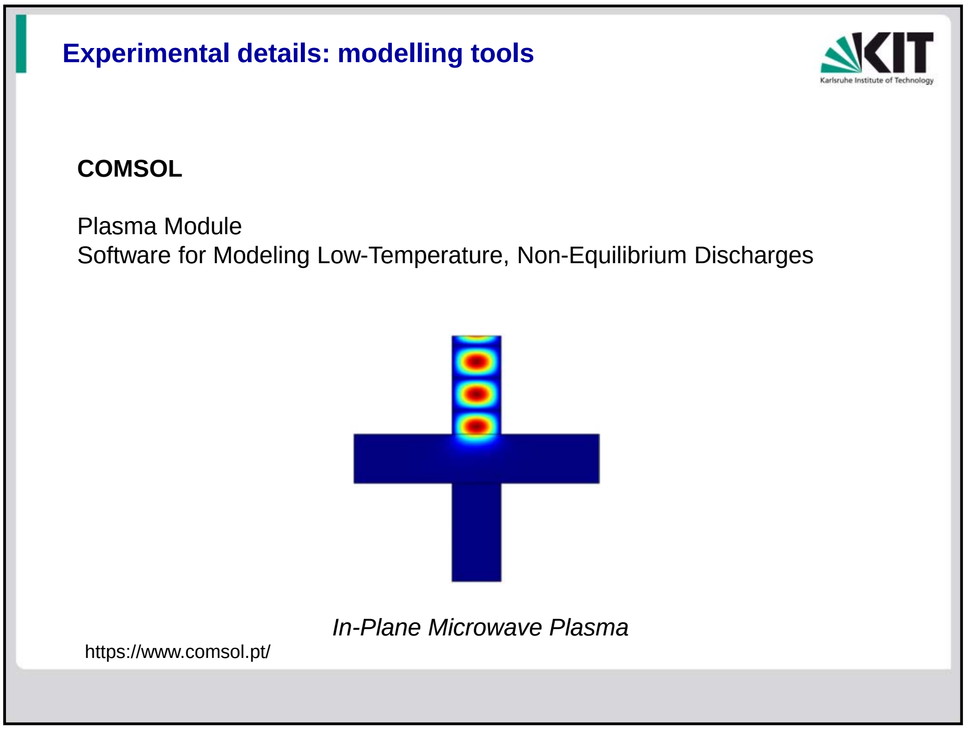
COMSOL

RF Module
Software for Microwave and RF Design

Modeling a Dipole Antenna

Parabolic Reflector Antenna

https://www.comsol.pt/



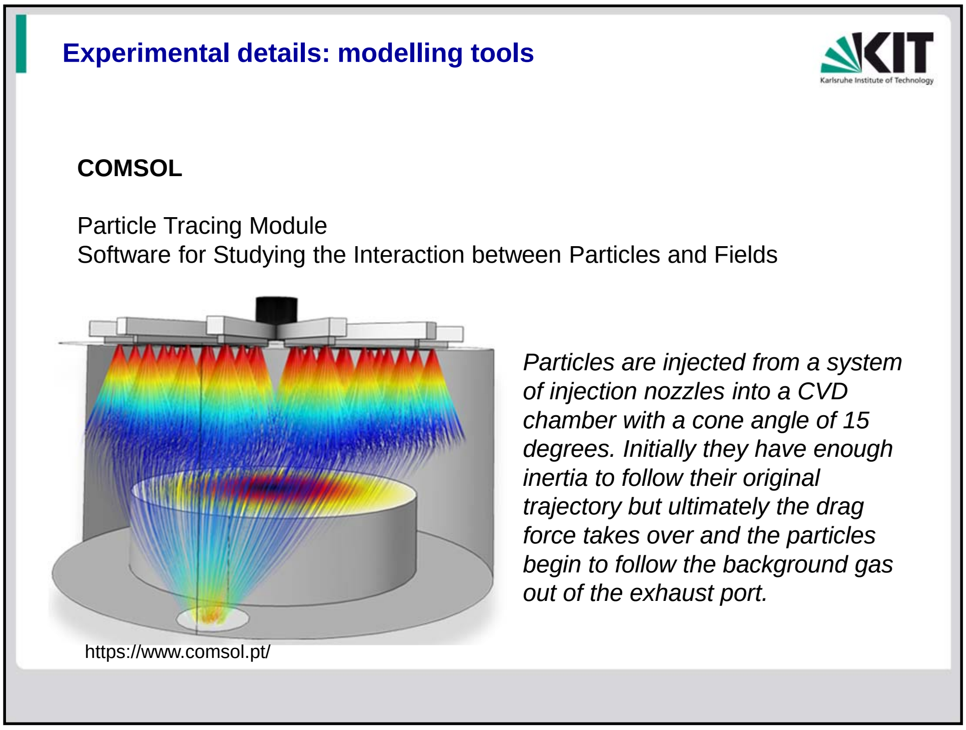
Experimental details: modelling tools

COMSOL

Plasma Module
Software for Modeling Low-Temperature, Non-Equilibrium Discharges

In-Plane Microwave Plasma

https://www.comsol.pt/



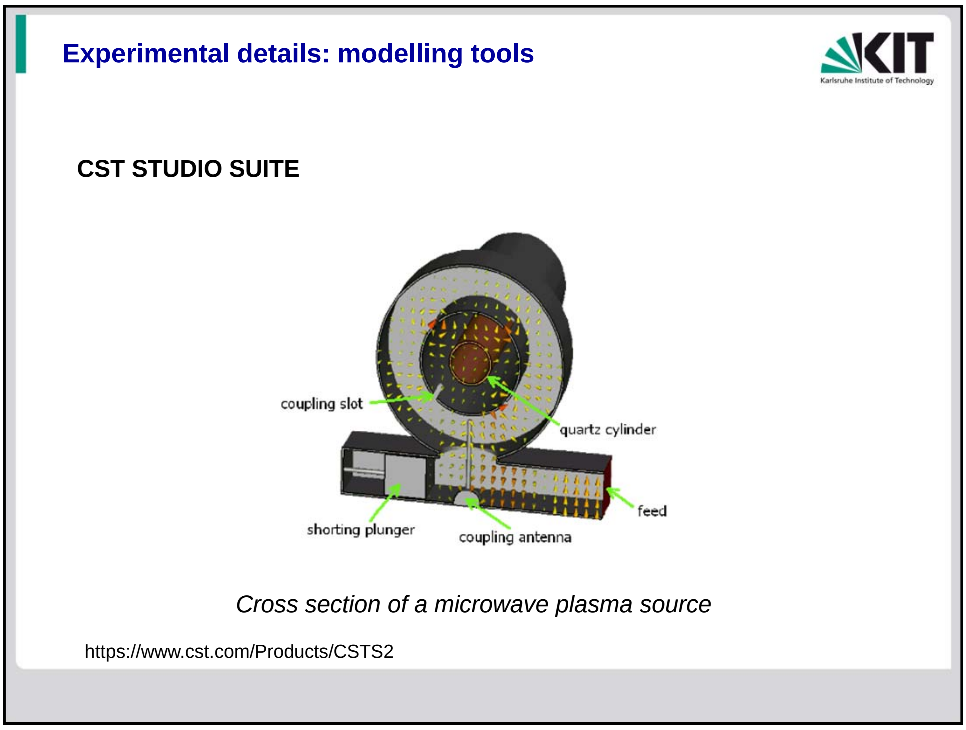
Experimental details: modelling tools

COMSOL

Particle Tracing Module
Software for Studying the Interaction between Particles and Fields

Particles are injected from a system of injection nozzles into a CVD chamber with a cone angle of 15 degrees. Initially they have enough inertia to follow their original trajectory but ultimately the drag force takes over and the particles begin to follow the background gas out of the exhaust port.

https://www.comsol.pt/



Experimental details: modelling tools

CST STUDIO SUITE

Cross section of a microwave plasma source

https://www.cst.com/Products/CSTS2