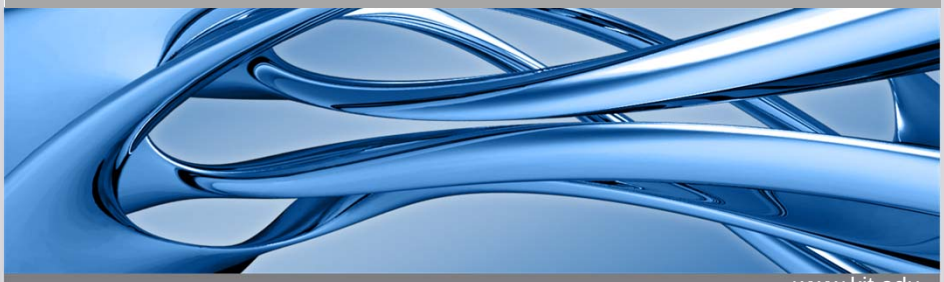
Entwicklung einer Hochleistungsmikrowellenplasmaquelle und Integration derselben in eine industrielle Beschichtungsanlage

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

19. März 2015 , BÜHLER Alzenau GmbH, 63755 Alzenau

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



www.kit.edu

outline

- introduction & motivation
- experimental details
- selected results
- summary and outlook

AG »Neuartige Plasmaquellen und -prozesse«
19. März 2015
BÜHLER Alzenau GmbH, 63755 Alzenau

- **introduction & motivation**
- experimental details
- selected results
- summary and outlook

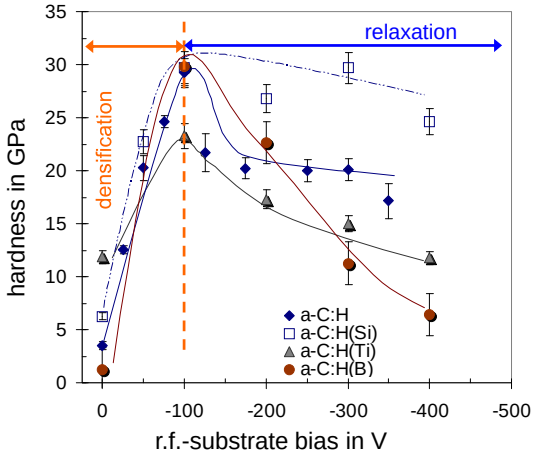
Introduction & motivation

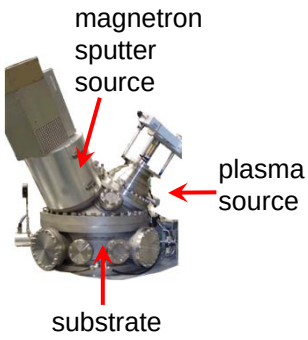
High performance plasma sources can be used for:

- 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



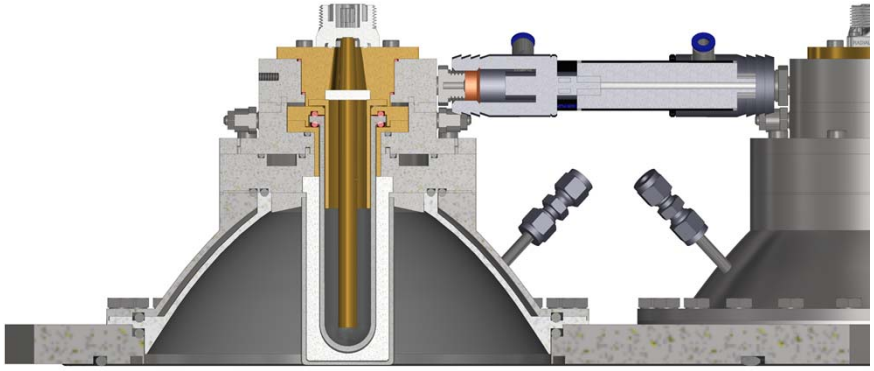


S. Ulrich, H. Holleck, H. Leiste, L. Niederberger, E. Nold, K. Sell, M. Stüber, J. Ye, C. Ziebert, P. Pesch, S. Sattel, Nano-scale, multi-functional coatings in the material system B-C-N-H, Surf. Coat. Technol. 200 1-4 (2005) 7-13

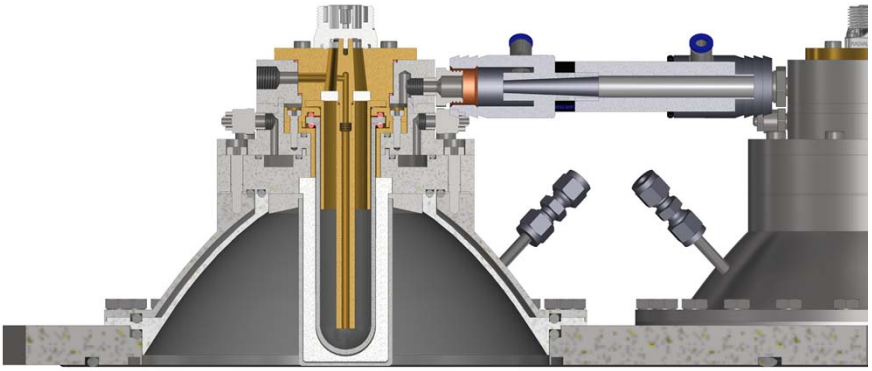
- Independent particle fluxes forming a-C:H and adding Si, Ti or B

- introduction & motivation
- **experimental details**
- selected results
- summary and outlook

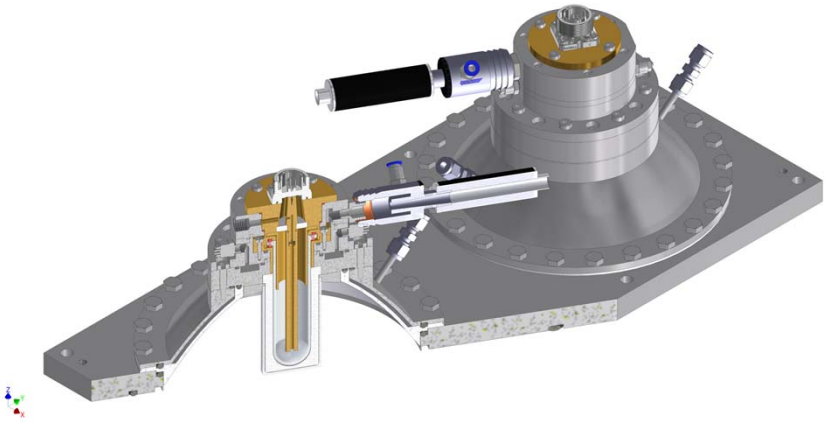
Experimental details



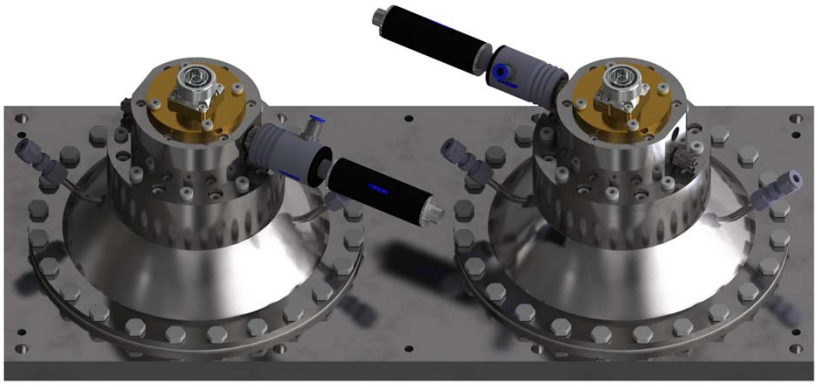
Experimental details



Experimental details

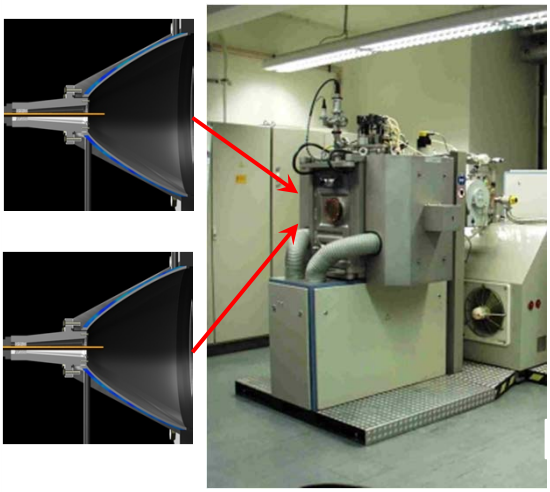


Experimental details



Experimental details

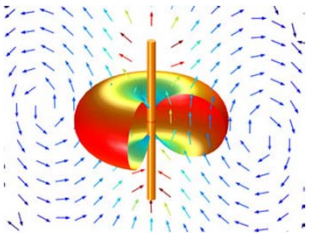
Experimental details



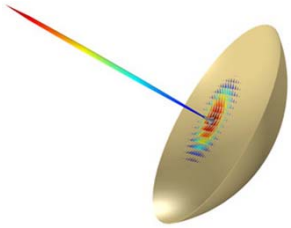
Experimental details: modelling tools

COMSOL

RF Module
Software for Microwave and RF Design



Modeling a Dipole Antenna



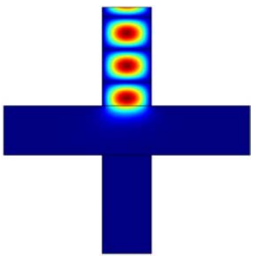
Parabolic Reflector Antenna

https://www.comsol.pt/

Experimental details: modelling tools

COMSOL

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



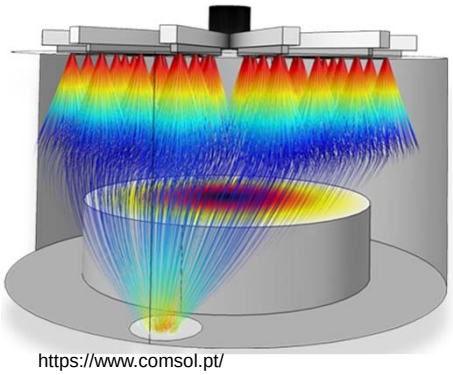
In-Plane Microwave Plasma

https://www.comsol.pt/

Experimental details: modelling tools

COMSOL

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

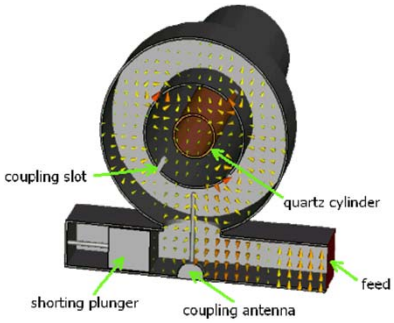


Particles are injected from a system of injection nozzles into a CVD chamber with a cone angle of 15 degrees. Initially they have enough inertia to follow their original trajectory but ultimately the drag force takes over and the particles begin to follow the background gas out of the exhaust port.

https://www.comsol.pt/

Experimental details: modelling tools

CST STUDIO SUITE

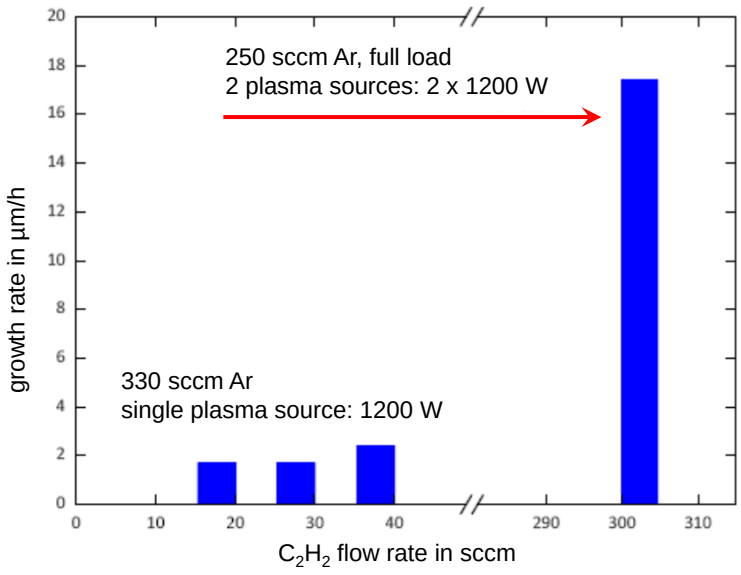


Cross section of a microwave plasma source

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

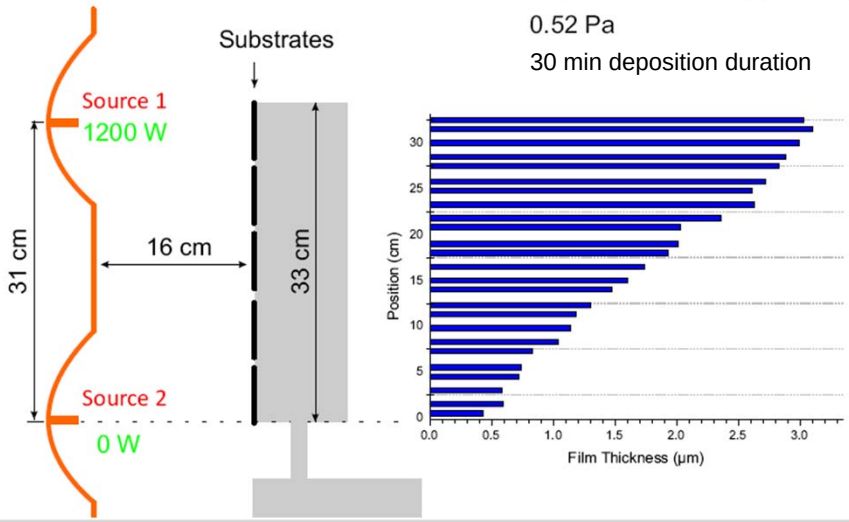
- introduction & motivation
- experimental details
- **selected results**
- summary and outlook

Selected results: variation of C_2H_2 flow rate

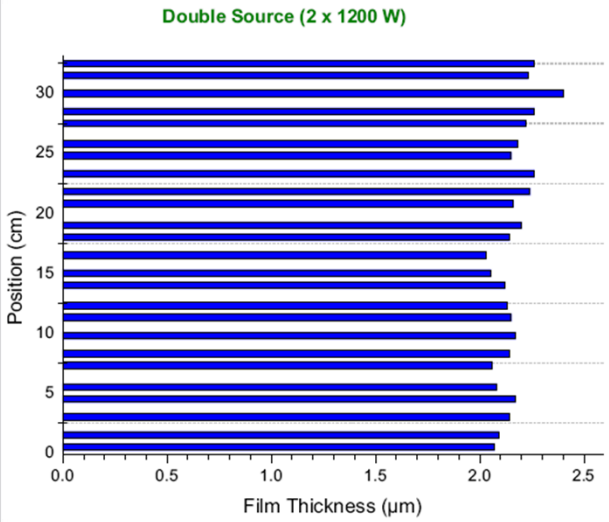


Selected results: thickness profile using 1 source

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

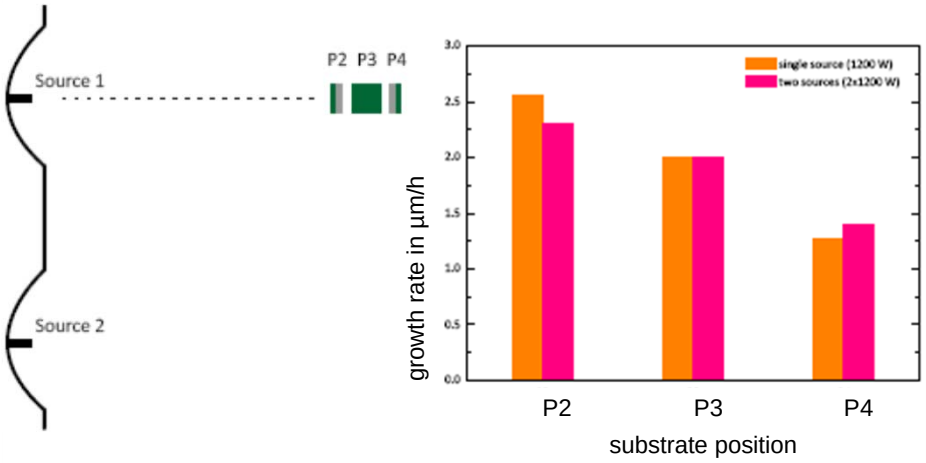


Selected results: homogenity



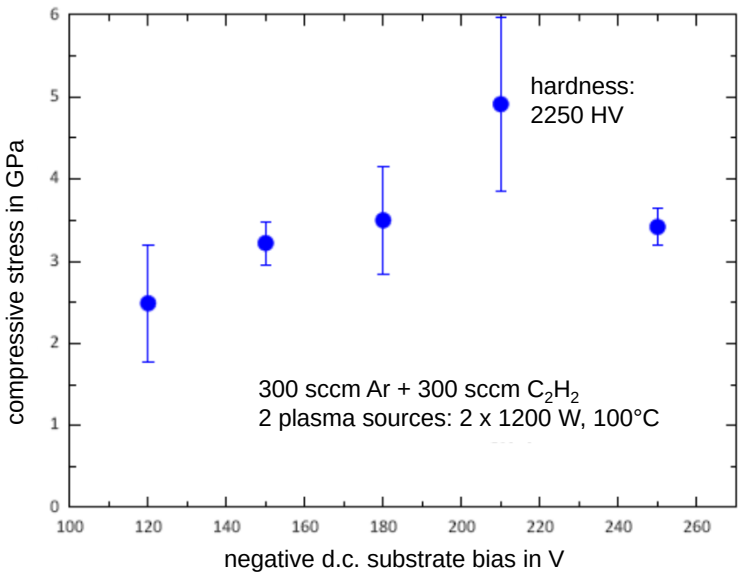
330 sccm Ar + 50 sccm C_2H_2
Working Pressure 0.52 Pa
Deposition Time 30 min

Selected results: homogenity



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

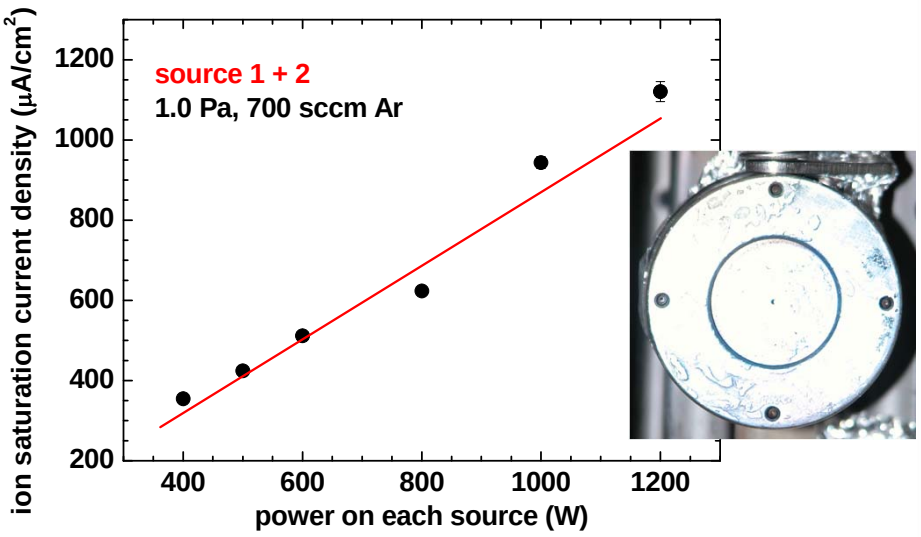
Selected results: residual stress



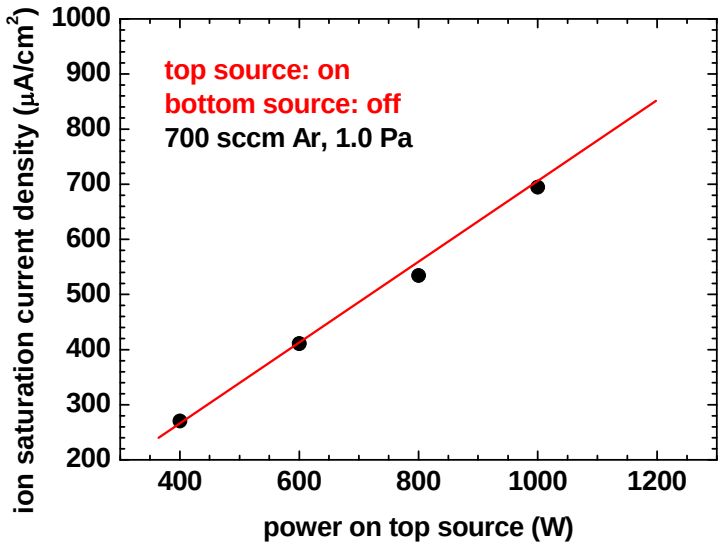
Selected results: high growth rate

-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**

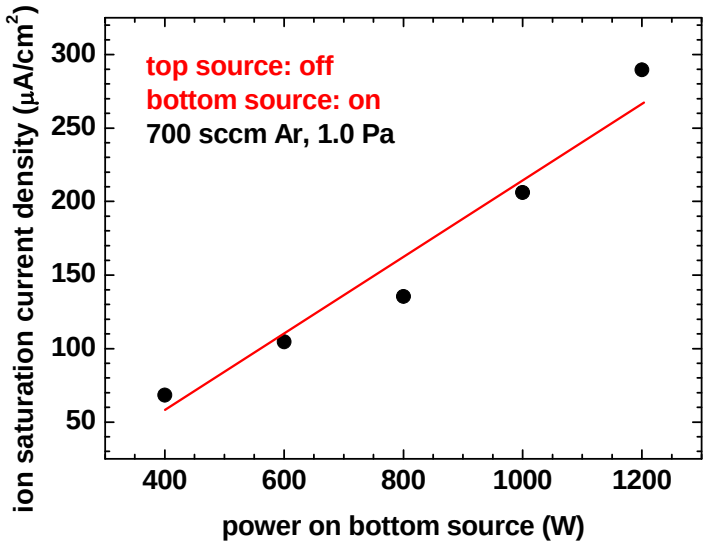
Selected results: plasma diagnostics



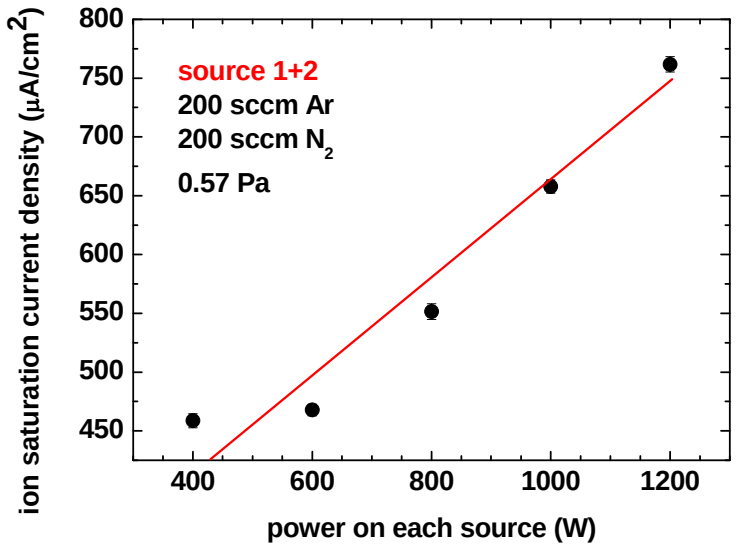
Selected results: plasma diagnostics



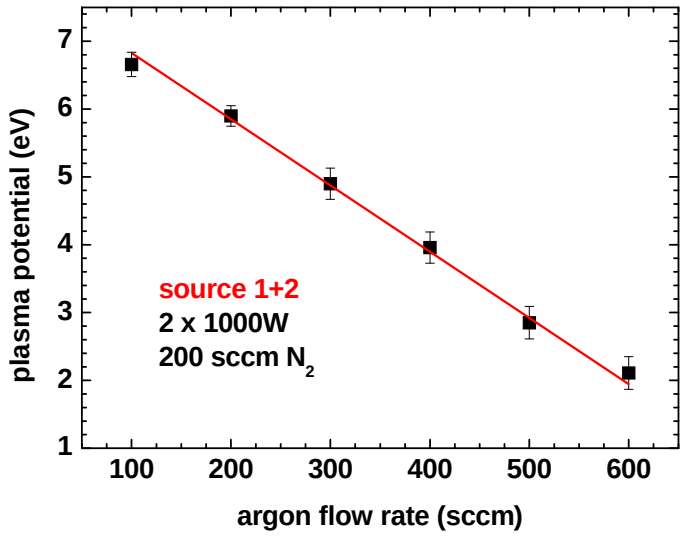
Selected results: plasma diagnostics



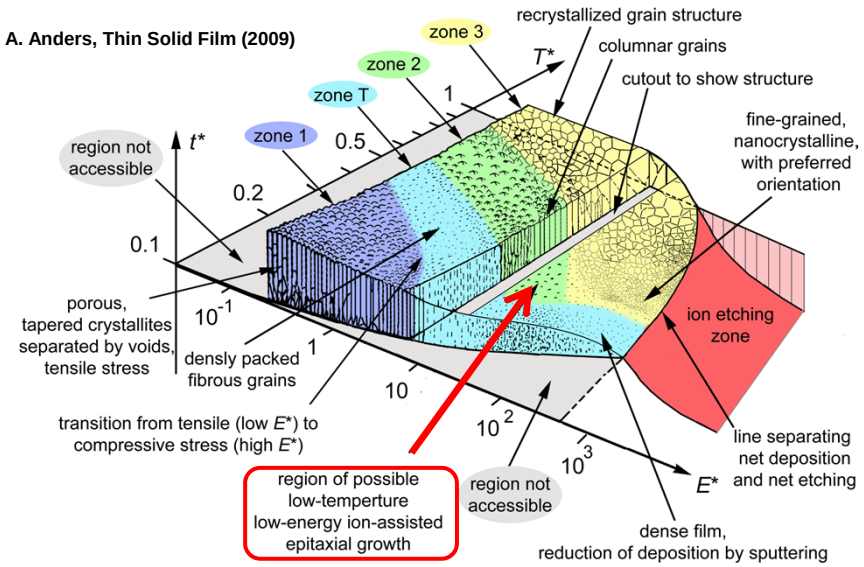
Selected results: plasma diagnostics



Selected results: plasma diagnostics



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



- introduction & motivation
- experimental details
- selected results
- **summary and outlook**

Summary

- 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

Outlook

- future development of an oblong plasma source

Many thanks …

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

… to our distribution partners

… Dr. Cord, Singulus Technologies AG, and the whole inplas team for the invitation

Thank you very much for your attention!

Distribution partners:

Hauzer TECHNO COATING PVD / PACVD TECHNOLOGY

robeko rolf schäfer beschichtungskomponenten