Karlsruhe Institute of Technology

AEPSE 2015

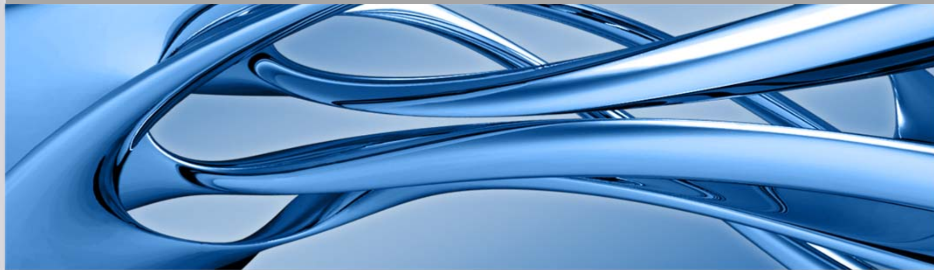
IAM Institute for Applied Materials

New HiPIMS – microwave plasma source – hybrid technology for tribological and protective coatings

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

AEPSE 2015, Ramada Plaza Hotel, Room B, Jeju, Korea, 24th September 2015

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



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Outline

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- 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

AEPSE 2015

The 10th Asian-European International Conference on Plasma Surface Engineering

September 20-24, 2015 I Ramada Plaza Jeju Hotel, Jeju Island, Korea

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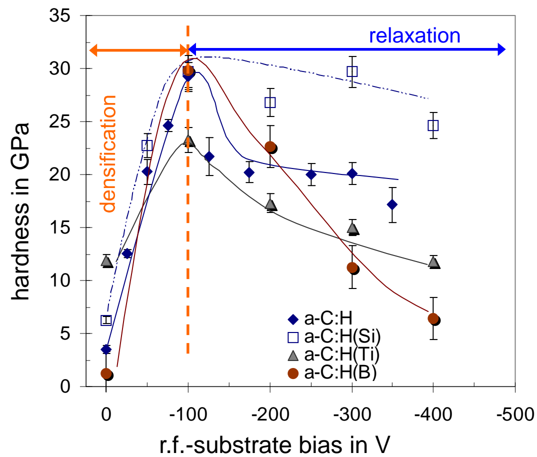
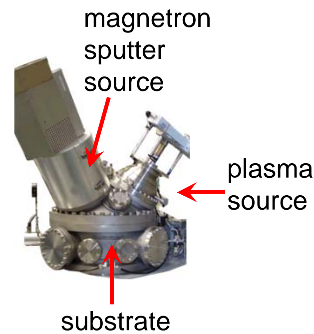
High performance plasma sources can be used for:

- 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

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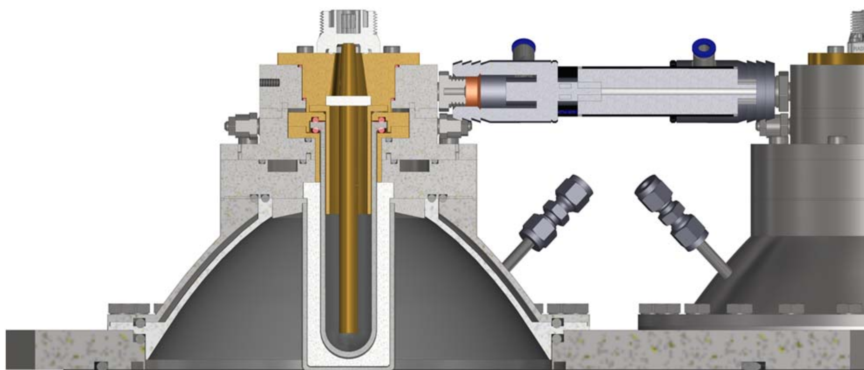
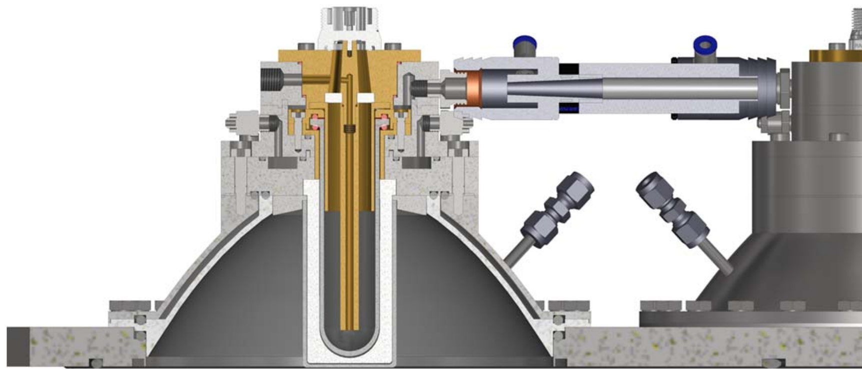


Experimental details



Experimental details

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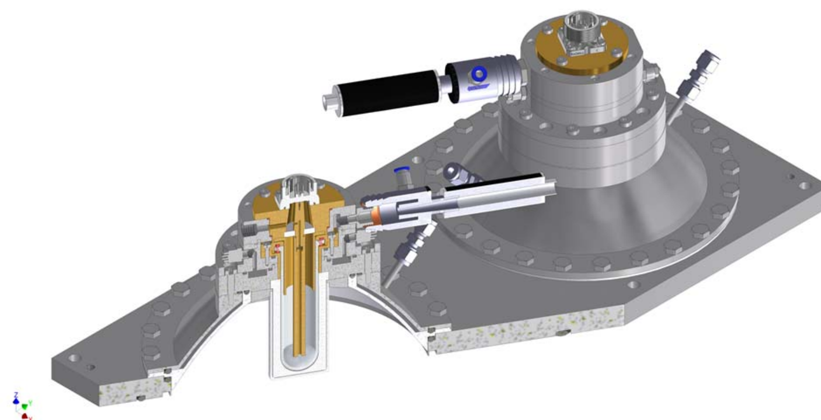
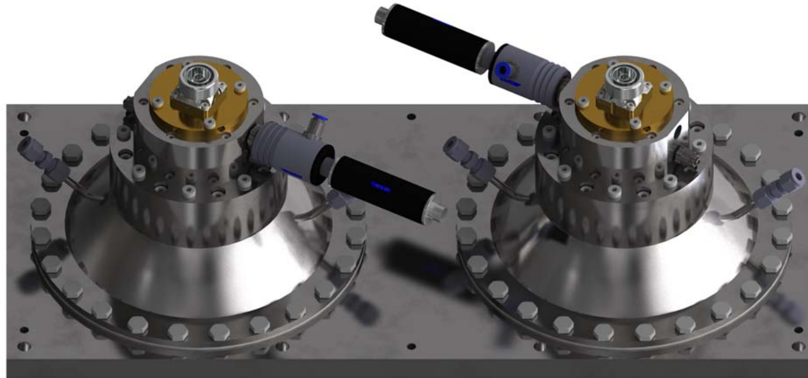


Experimental details



Experimental details

Experimental details

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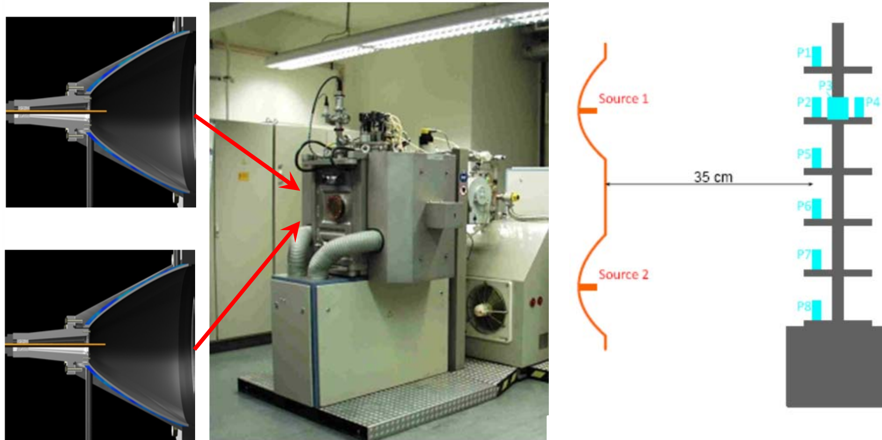

Developments in PVD/PECVD coatings for automotive applications
R. Tietema, R. Jacobs, D. Doerwald, I. Kolev, J. Landsbergen
IHI Hauzer Techno Coating BV, AEPSE, 22-WS-6

Experimental details

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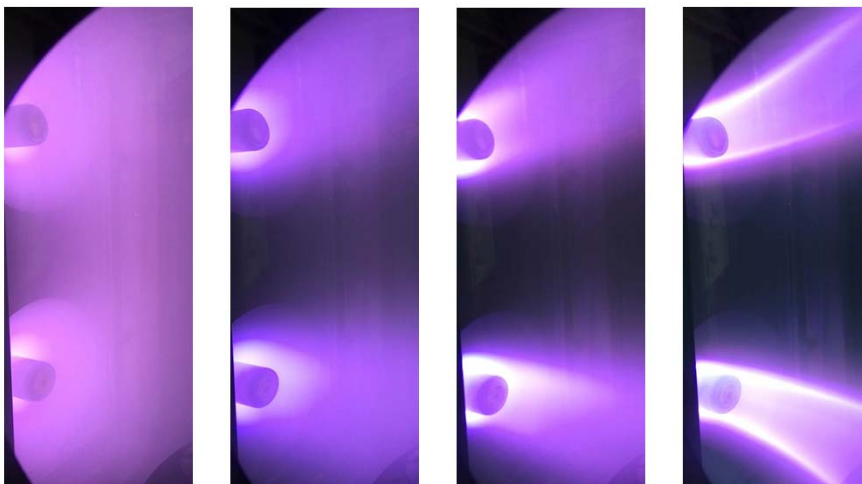

Selected results: variation of C_2H_2 flow rate

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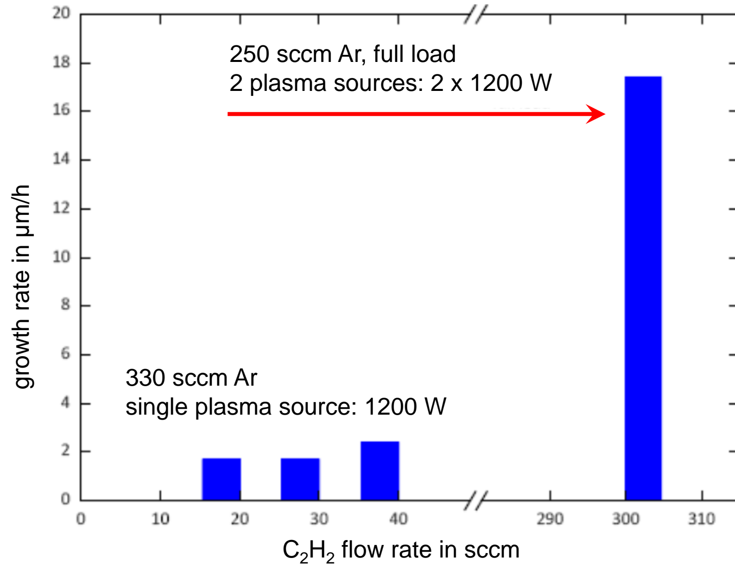

Selected results: thickness profile using 1 source

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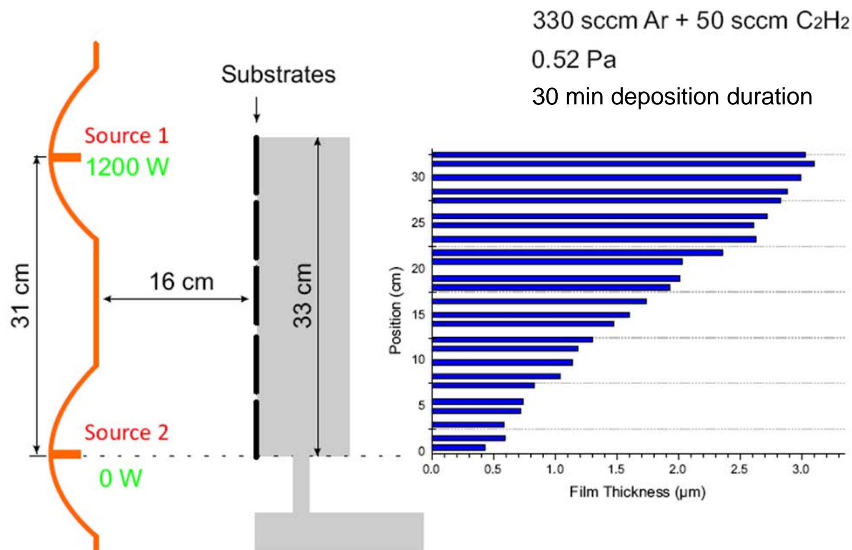
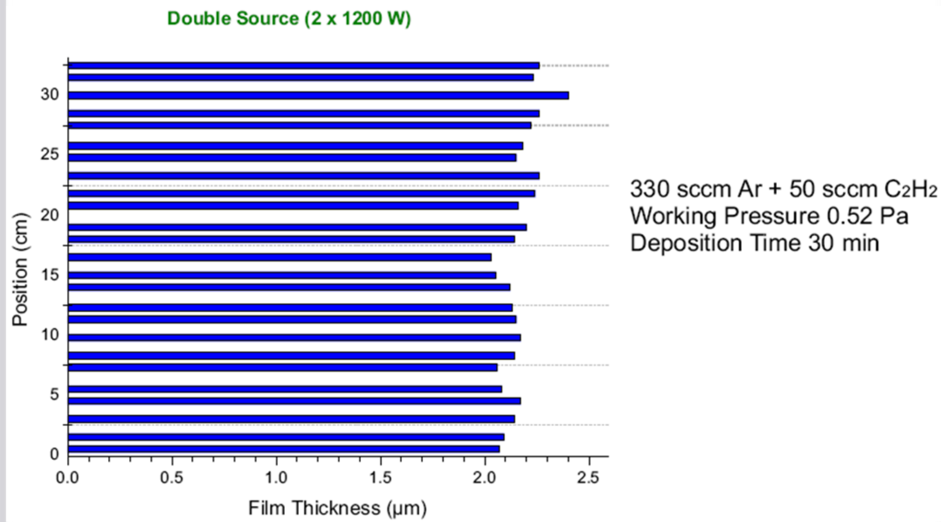
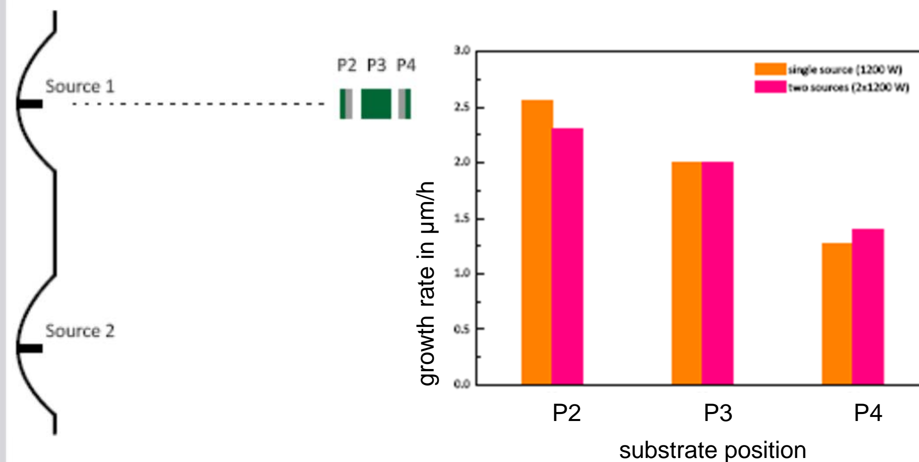


Selected results: homogenity



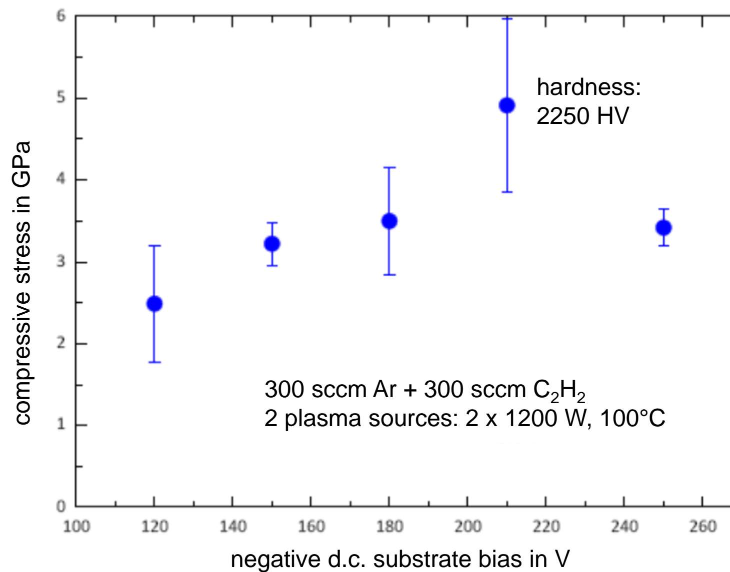
330 sccm Ar + 50 sccm C_2H_2
Working Pressure 0.52 Pa
Deposition Time 30 min

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

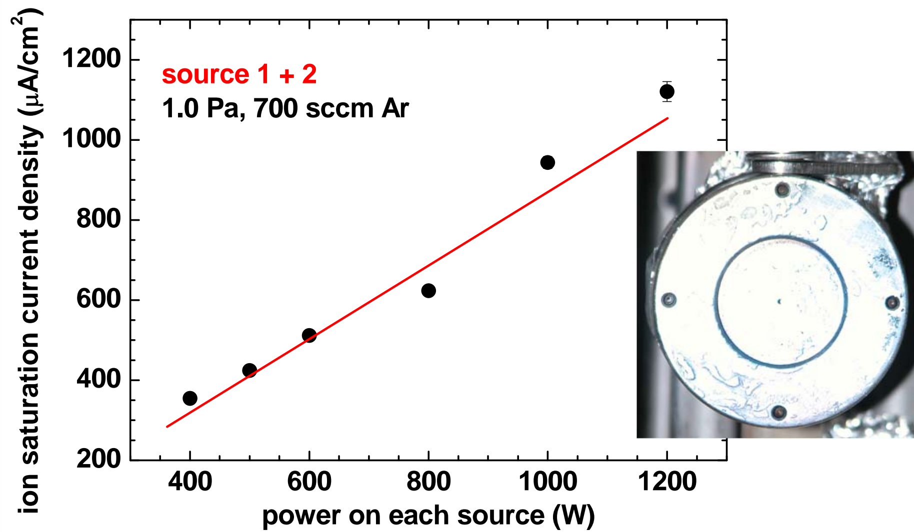
-Chamber temperature: 47° C in the end of deposition

-Muegge 3-stub tuner: no need for adjustment during deposition, power refection kept at 0 - 2%.

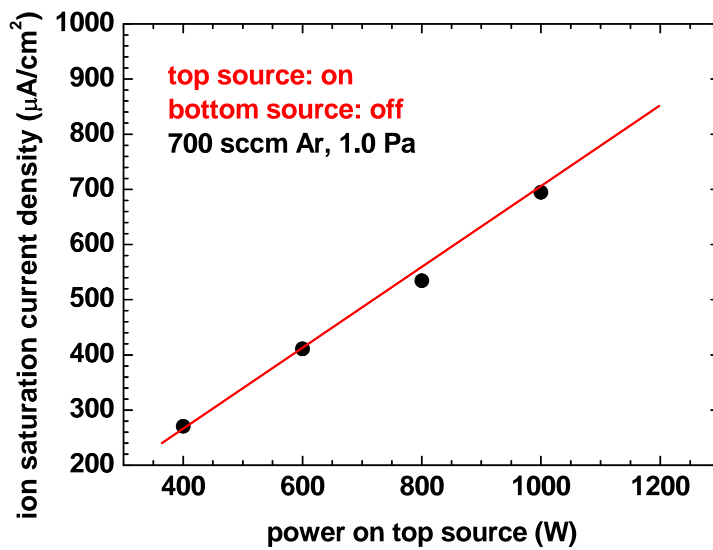
Tuner temperature 32° C in the end of deposition

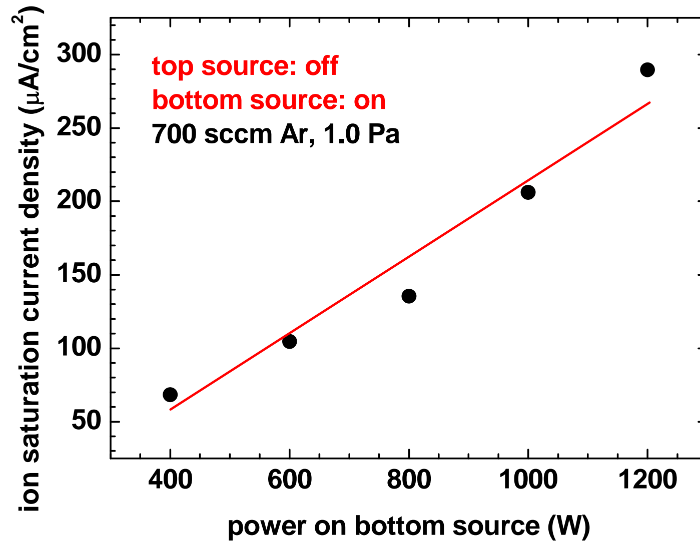
-**Deposition rate: 35.8 µm/h**

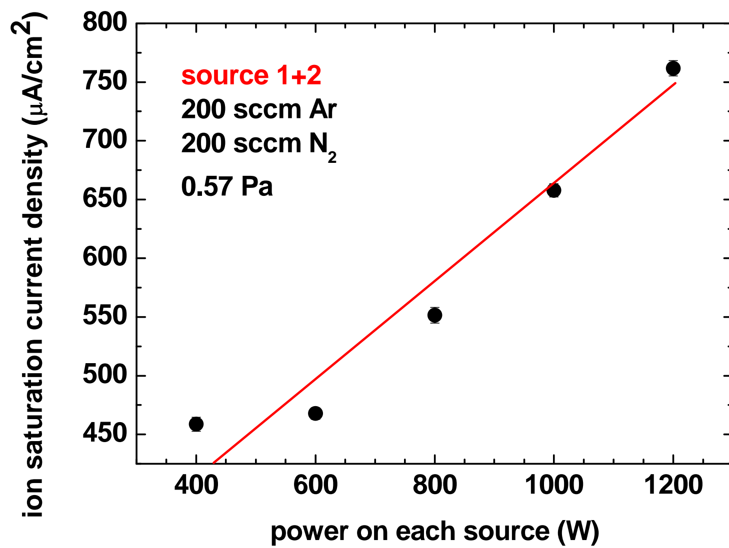
Selected results: plasma diagnostics



Selected results: plasma diagnostics




Selected results: plasma diagnostics
KIT
top source: off
bottom source: on
700 sccm Ar, 1.0 Pa
ion saturation current density (µA/cm²)
300
250
200
150
100
50
400
600
800
1000
1200
power on bottom source (W)


Selected results: plasma diagnostics
KIT
source 1+2
200 sccm Ar
200 sccm N₂
0.57 Pa
ion saturation current density (µA/cm²)
800
750
700
650
600
550
500
450
400
600
800
1000
1200
power on each source (W)

Selected results: plasma diagnostics

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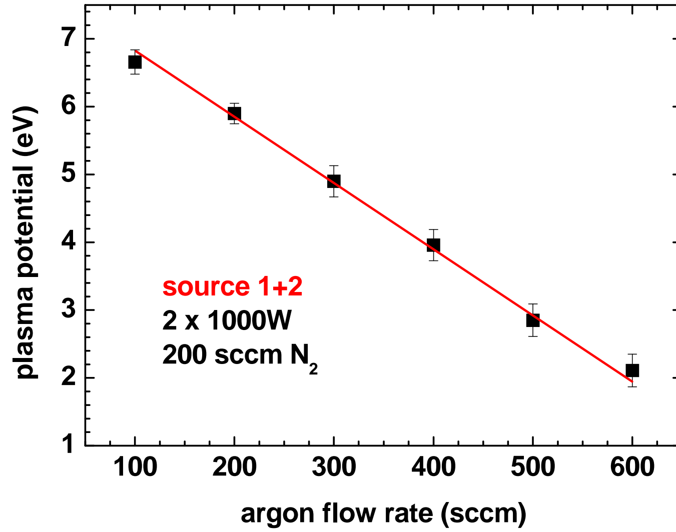

Application: low ion energy in combination with high ion current densities

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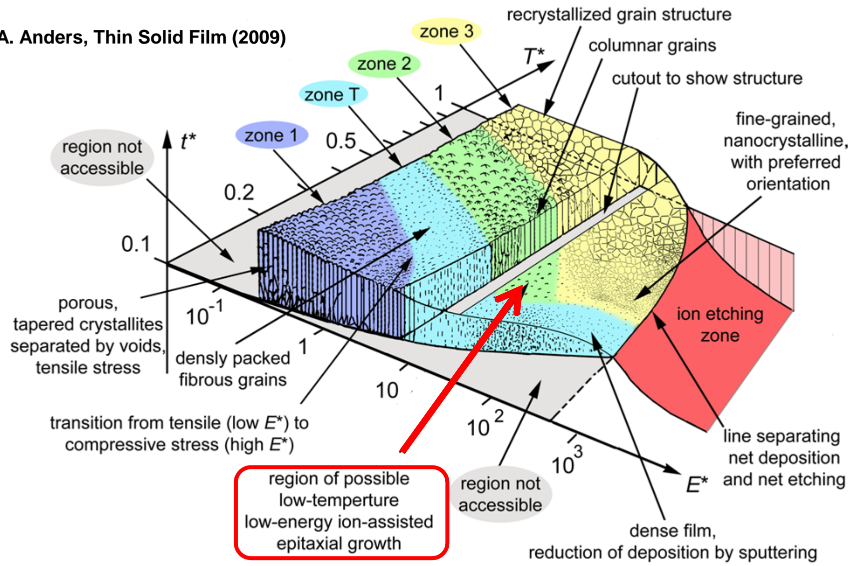

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Deposition of coatings in the system Ti-C with HiPIMS

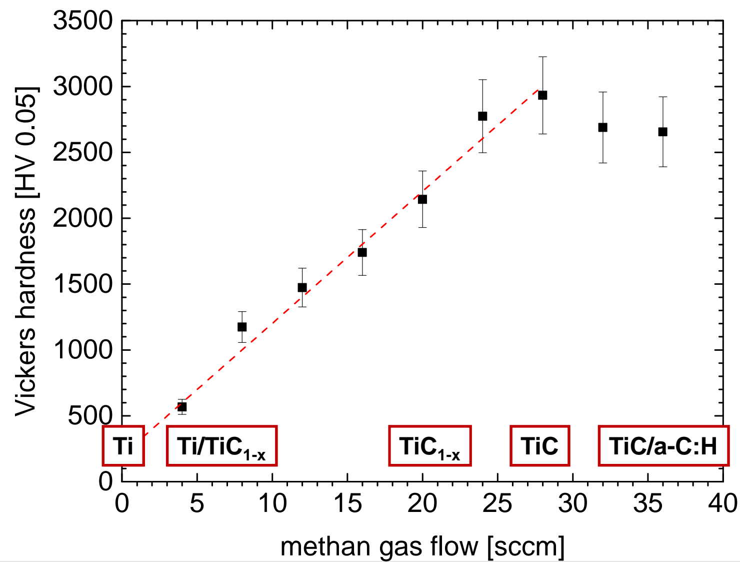
CABINET MELEC
DUAL – CHANNEL
DC PULSE POWER SUPPLY SET
A: +/1000V / +/- 500A ; 5 kW DC power
B: +/-1000V /+/- 500A; 5 kW DC power
4 channel measurement 2 x U(t); 2 x I(t)
Diode module using DC – HiPIMS (UP)

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%

Deposition of coatings in the system Ti-C with HiPIMS



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Hybrid technology: HiPIMS/DC magnetron sputtering

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dimension: 125 mm x 406 mm
area: 507,5 cm²

5 kW DC AVERAGE CONST

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

Hybrid technology: HiPIMS/DC magnetron sputtering

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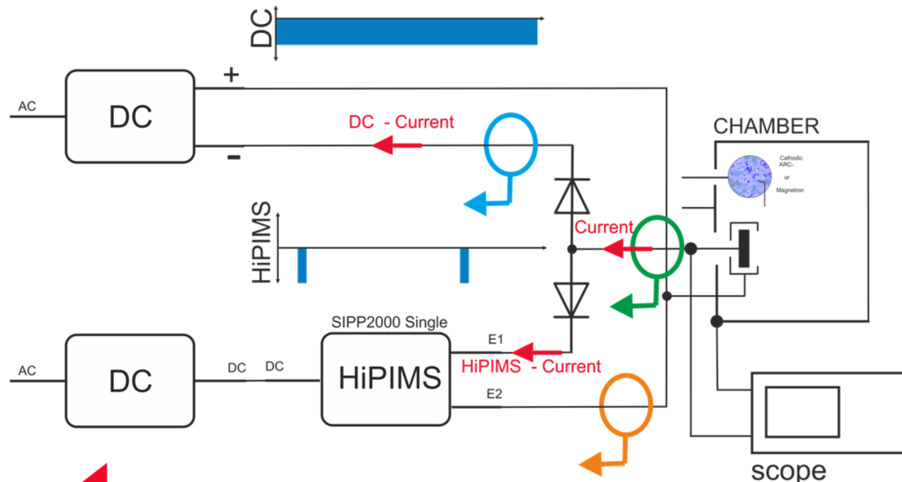

MELEC GmbH THE HIGH PULSE POWER COMPANY

M. Mark, G. Mark: Pluse textbook

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

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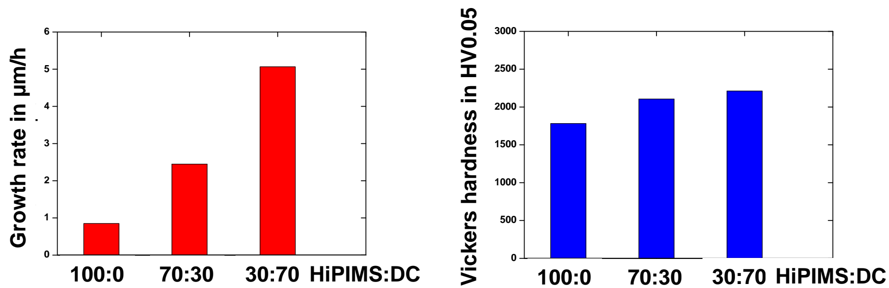

- HiPIMS+DC total power: 5 kW
- HiPIMS duty cycle: 9.1%, frequency: 1818 Hz
- Ti target
- Working gas: Ar(300 sccm) – reactive gas: N_2 (14 sccm)
- without substrate rotation

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

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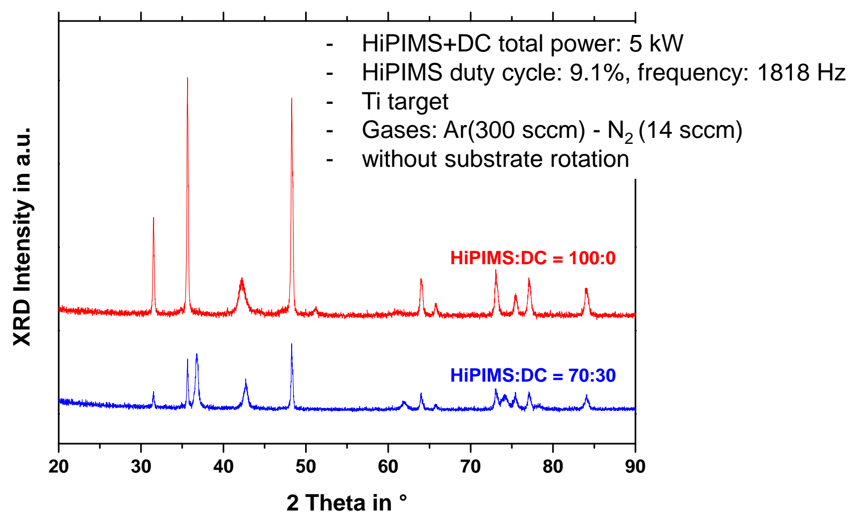
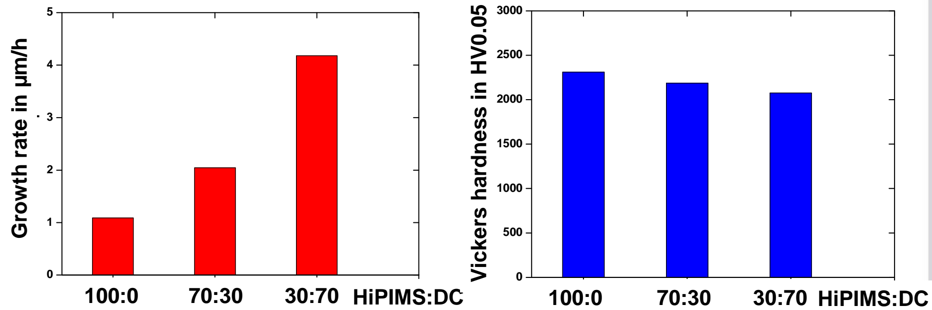


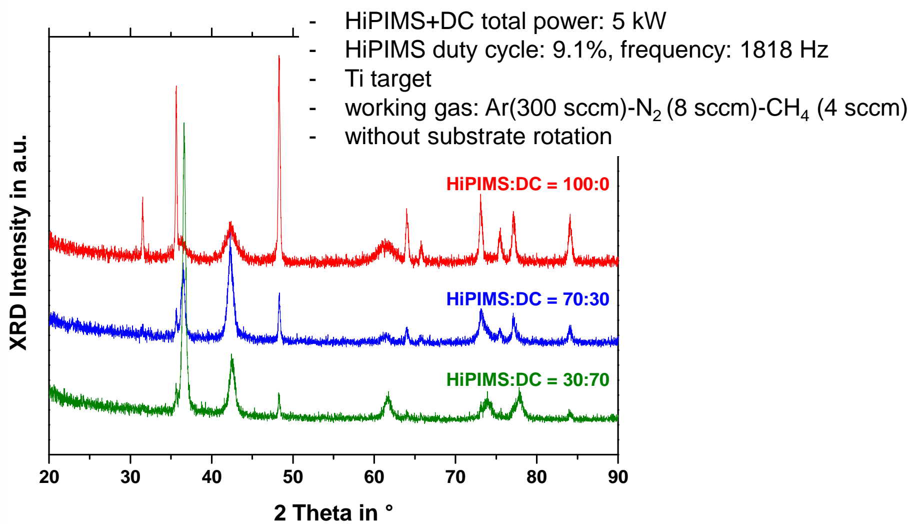
Hybrid technology: HiPIMS/DC magnetron sputtering: Ti-C-N



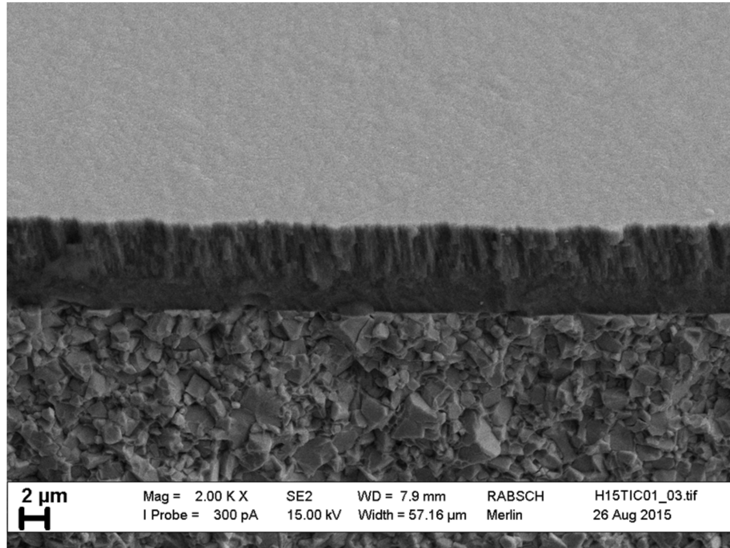
- HiPIMS+DC total power: 5 kW
- HiPIMS duty cycle: 9.1%, frequency: 1818 Hz
- Ti target
- working gas: Ar (300 sccm) – reactive gases: N_2 (8 sccm) - CH_4 (methan: 4 sccm)
- without substrate rotation

Hybrid technolgy: 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)-N_2 (8 sccm)-CH_4 (4 sccm)
- without substrate rotation



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

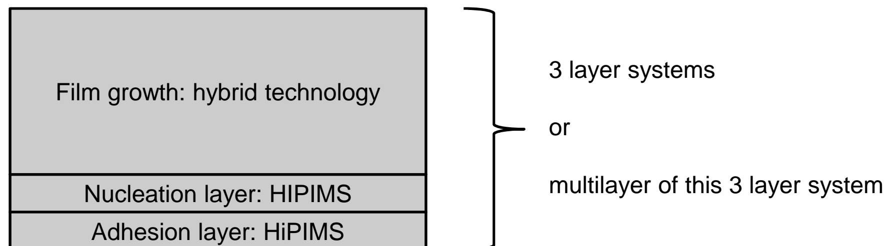
Outlook

Hybrid technology:

HiPIMS/DC magnetron sputtering + MW plasma source deposition

for carbon based coating systems

New coating concepts when HiPIMS is involved



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 melec company: M. Mark, G. Mark

… to our distribution partners

… and Roel Tietema & AEPSE organizing committee for the invitation

Thank you very much for your attention!

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