



New concept of HIPIMS biasing - power supply and process parameters selection

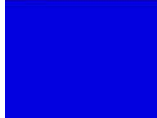
Pawel Ozimek, Mariusz Cichowlas, Andrzej Klimczak, Piotr Róžański,

Huettinger Electronic

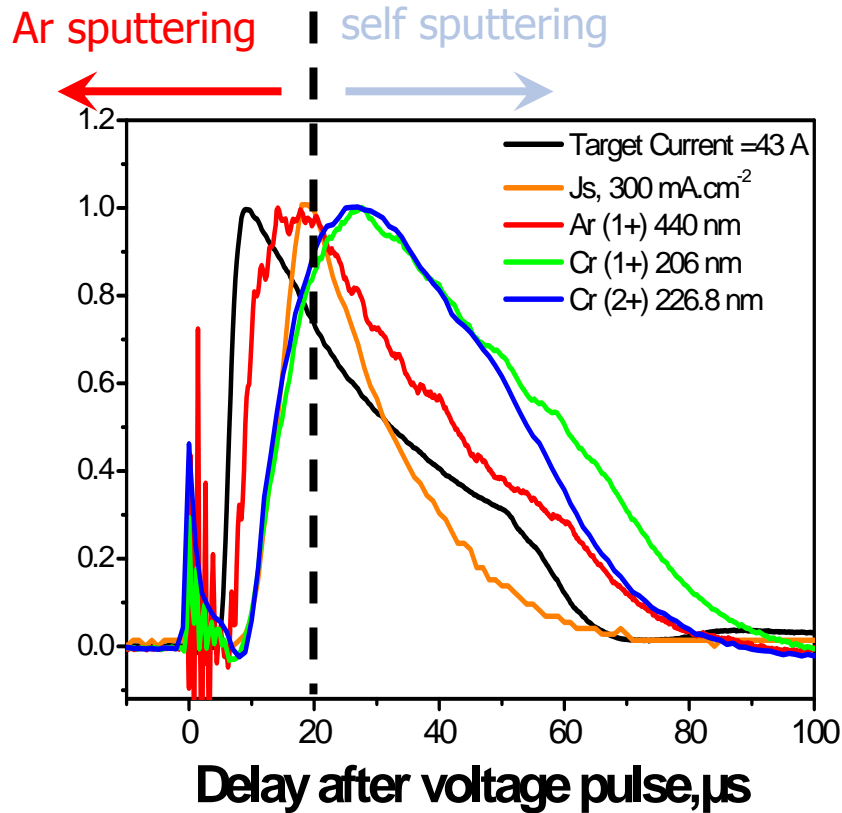


Advantages of the HIPIMS process

- The most recent development of PVD-Pulsed-Sputtering-Technology utilizing extreme high power densities
- Dense plasma with high ionization degree and high ion flux comparable to the arc discharge but without droplet phase
- Effective ion bombardment (lower substrate temperature possible)
- Improved protection of substrate surface against corrosion
- Improved cutting performance of tools pre-treated by HIPIMS
- Low substrate temperature level enables foil coating applications
- Wide range of application
 - Substrate Pretreatment
 - Hard & Decorative droplet-free coating,
 - Semiconductor applications e.g. trench filling



Time Evolution of the HIPIMS Plasma



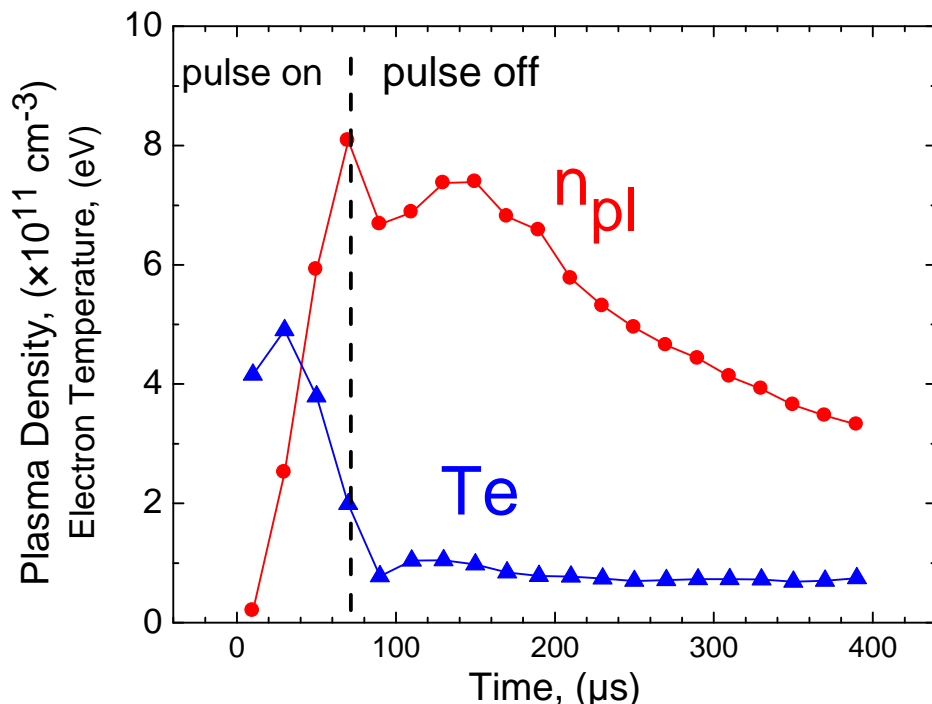
HIPIMS plasma evolves within each pulse - from Ar sputtering to metal ion sputtering

Too short pulses generate gas plasma and cut the production of metal vapour

Ehiasarian, New, Munz, Hultman, Helmersson, Kouznetsov, Vacuum (2002)

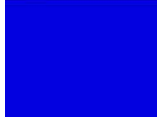


Plasma Density and Electron Temperature Near Substrate as a Function of Time



Current density 1.7 A/cm^2
Power density 680 W/cm^2

- Typically, ions bombard the substrate for much longer than the target power pulse.
- During the power pulse, plasma density increases and electron temperature reduces due to collisions
- At peak power, electron temperatures are $< 2 \text{ eV}$ - similar to arc discharges at Local Thermal Equilibrium



To bias or not to bias in the HIPIMS process?

- Biasing voltage increases mobility of depositing species which ensures:
 - high density of coating microstructure.

- High ion energy ensures improved adhesion by :
 - shallow metal ion implantation,
 - modified surface lattice.

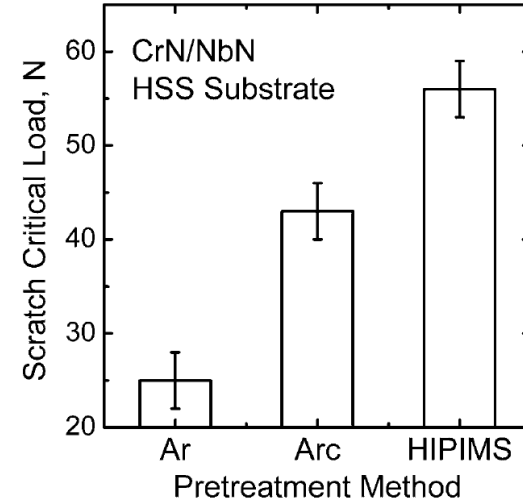
- Stable bias voltage ensures:
 - controllable surface stress,
 - clear coating-substrate interface,
 - homogenous density of coated film.



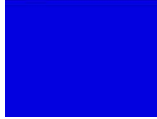
Adhesion – benefit of HIPIMS pretreatment

- Enhanced adhesion by Highpulse (reported by lit. ref.1)
 - Against standard DC sputtering adhesion is better because of:
 - Limiting Ar implantation into substrate/interface
 - Implanting metal atoms into substrate/interface
 - Against arc evaporation adhesion is better because of:
 - No droplets in the interface

- Experimental:
 - Substrate: 304 stainless steel and M2 high speed steel HSS
 - Interfaces treated with Highpulse Cr, Nb; standard sputtering, arc evaporation
 - $U_{bias} = -600\text{ V}$ and $U_{bias} = -1000\text{ V}$



Adhesion of CrN/NbN coatings on HSS substrate pretreated by Ar glow discharge, cathodic arc, and HIPIMS discharges.



Requirements for bias power supply for HIPIMS process

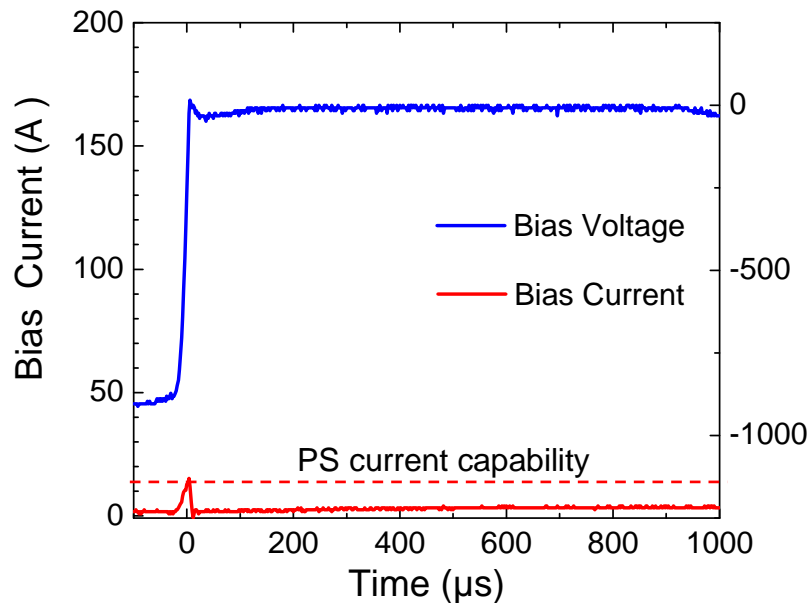
- Stable voltage during HIPIMS pulses as well as between the pulses (low impedance voltage source),
- ARC management fast enough to switch off rapidly rising bias current,
- Clear distinction of substrate arc and the regular substrate peak current,



HIPIMS biasing – hardware solutions

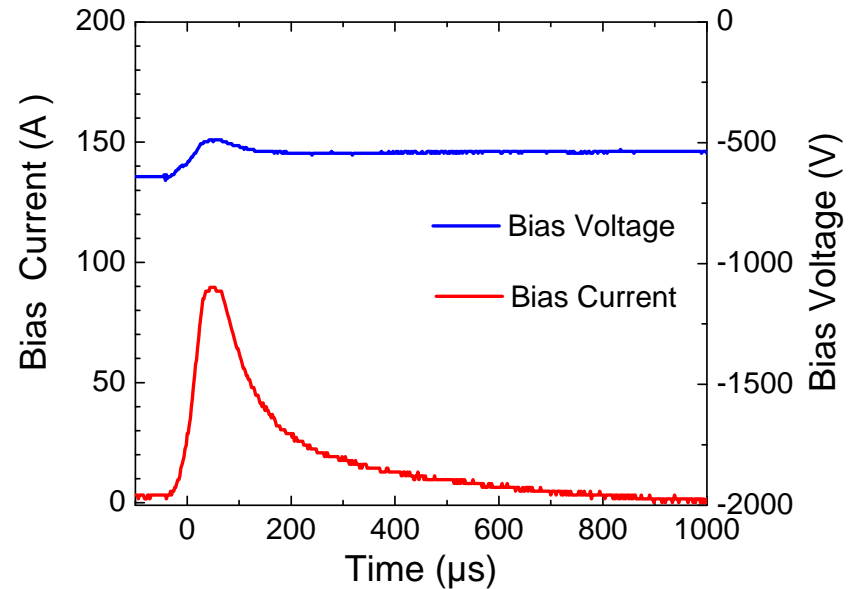
- Conventional biasing – not useful for HIPIMS applications
- Simplest solution – adoption of additional capacitor

Conventional Bias

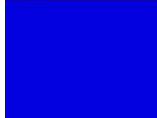


voltage drops to 0 V
as soon as current exceeds 15 A

Bias for HIPIMS

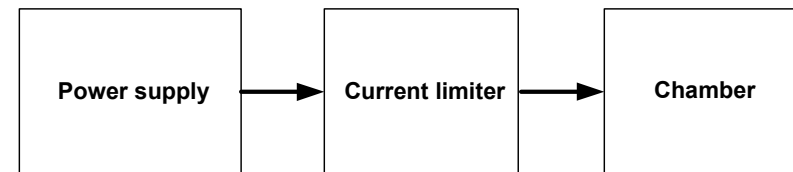
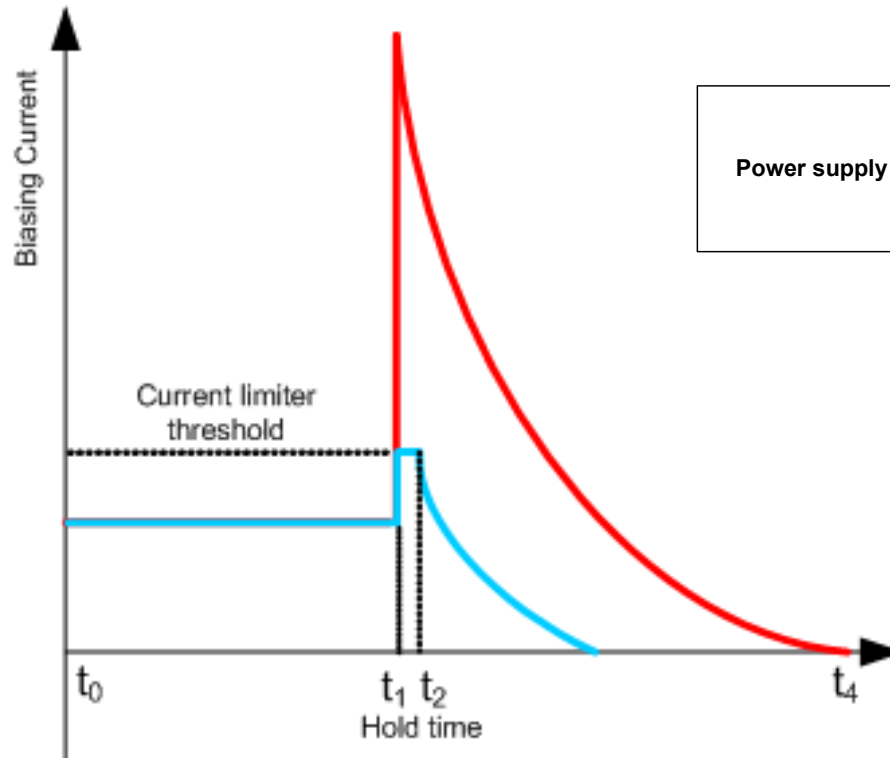


only small drop in voltage of observed
Bias current flows for several hundreds of µs



HIPIMS biasing – NEW solution

Current limiting device

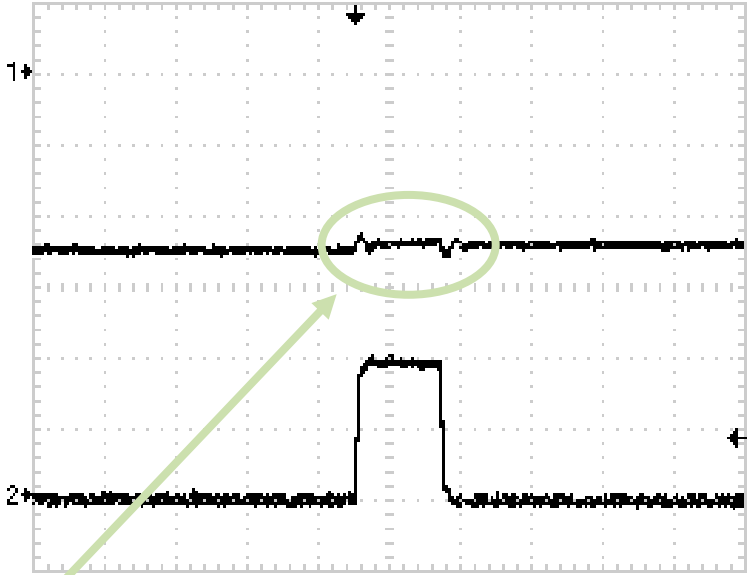
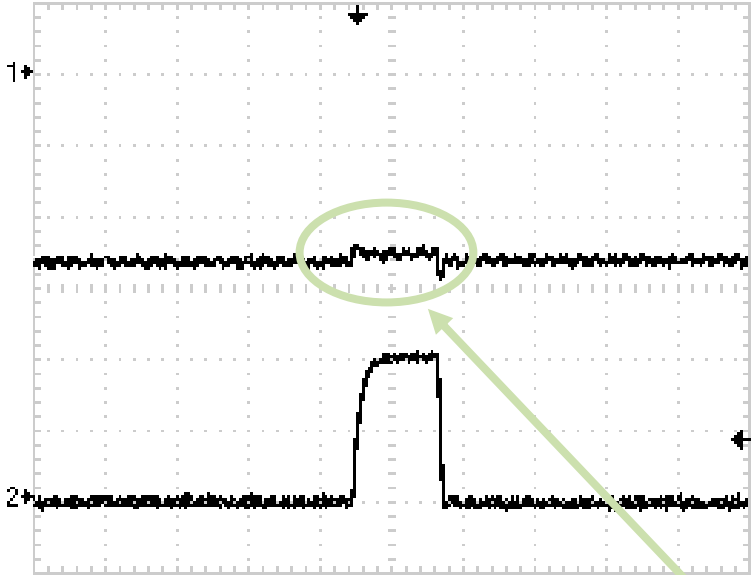




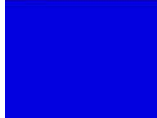
Bias Voltage stability during substrate current pulse

LV: 270V;
I_{peak}=100A

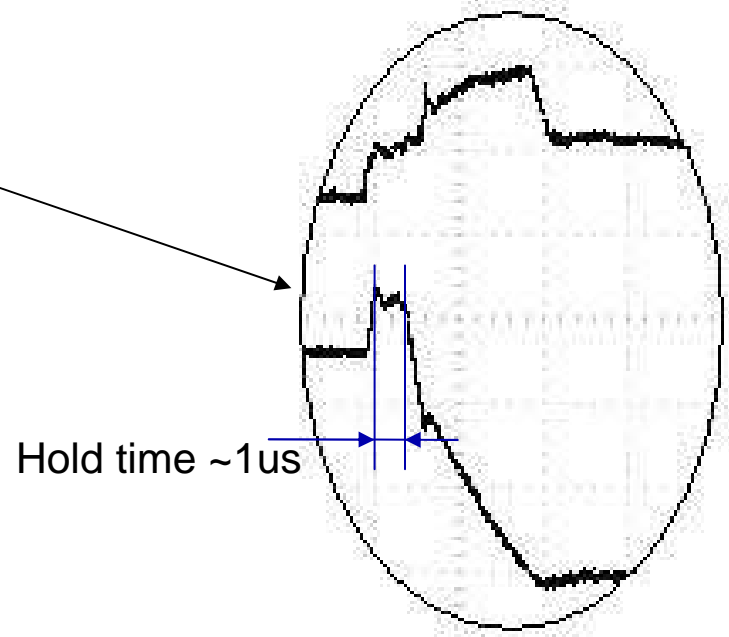
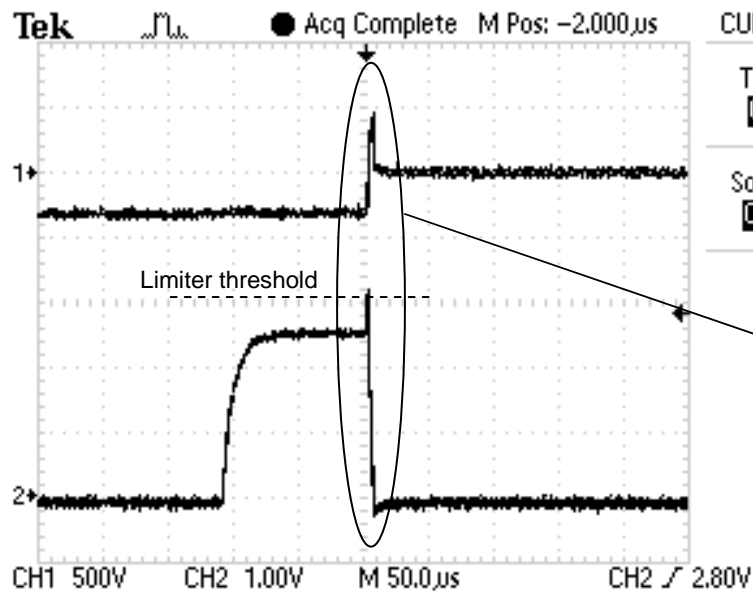
HV: 1200V;
I_{peak}=100A



Bias voltage drops < 10V



HIPIMS biasing – NEW solution

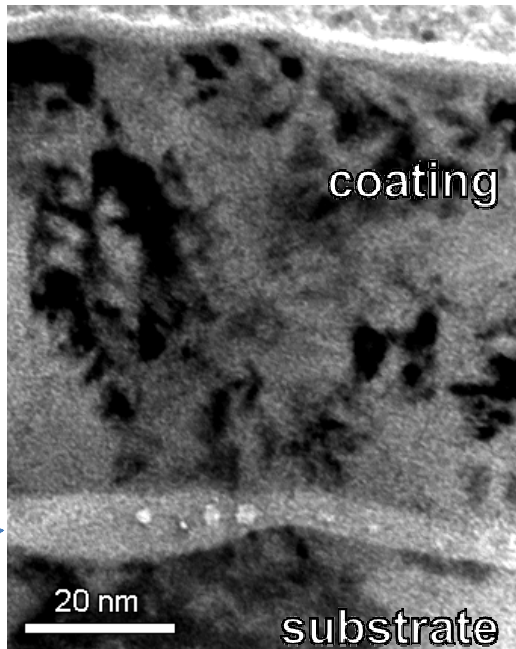


ARC during substrate current pulse
 Bias current is hold by the current limiter



Effect of Bias Method During Substrate Pretreatment by HIPIMS

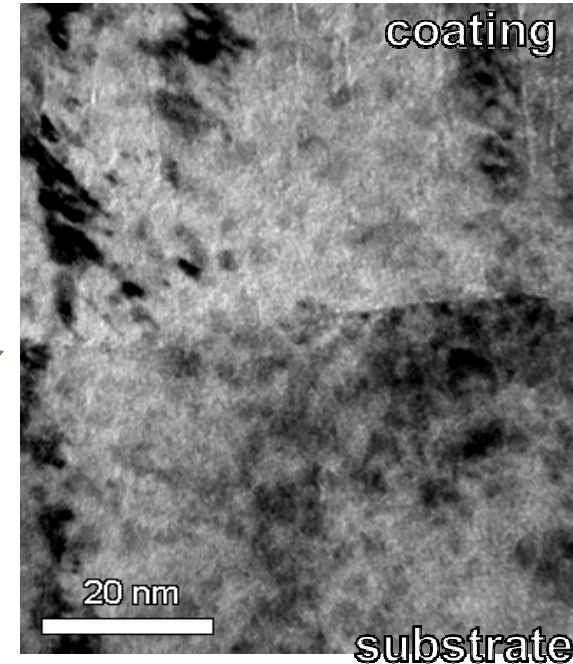
interface with **conventional Bias**



porous layer with holes



interface with **HMP Bias**



Fully dense interface



Poor adhesion of coating to substrate

Strong adhesion of coating to substrate

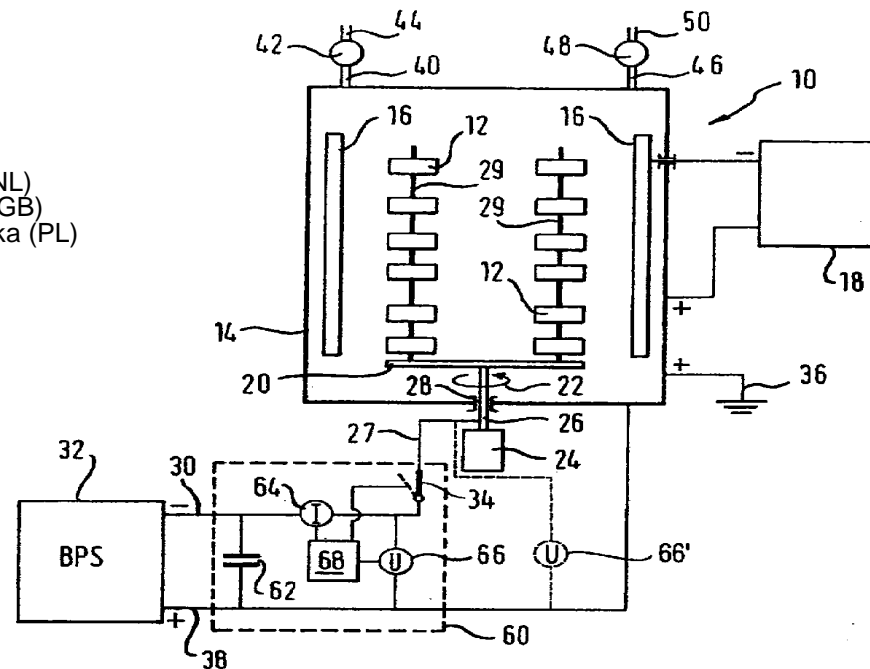


Ongoing patents

- **VACUUM TREATMENT APARATUS, A BIAS POWER SUPPLY AND A METHOD OF OPERATING A VACUUM TREATMENT APARATUS**

- US 2010/0025230 A1
- WO 2007/115819 A1
- GB 2 437 080 A
- CN 101461032 A
- KR 10-2009-0007750

- Inventors:
 - **Hauzer Techno Coating BV**, LL Venlo (NL)
 - **Sheffield Hallam University**, Sheffield (GB)
 - **Huettinger Electronic Sp. z o.o.** Zielonka (PL)

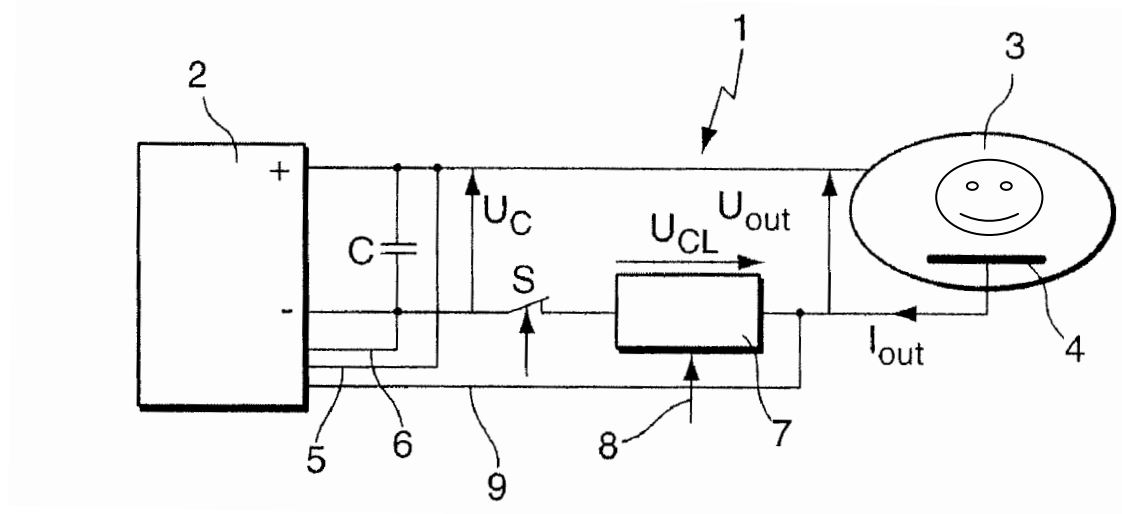




Ongoing patents

▪ CURRENT LIMITTING DEVICE FOR PLASMA POWER SUPPLY

- US 2009/0160417 A1
- EP 2 075 823 A1
- CA 2646522 A1
- Inventor:
 - **Huettinger Electronic Sp. z o.o.** Zielonka (PL)





Summary

- Hipims Bias Power Supply allows to:
 - Process with stable bias voltage,
 - Strong adhesion
 - High film density
 - Process with superior arc management,
 - Supports both pretreatment step (etching) (HV mode) and coating (LV mode)

- HBP with current limiter is a patented solution by Huettinger Electronic

TRUMPF



I look forward to your questions!