



HiPIMS your system



hiP-V, a new HiPIMS power supply technology!

The industrial HiPIMS-PS innovation!

...a new approach...

**Seventh International Conference on Fundamentals
and Industrial Applications of HIPIMS 2016**





HiPIMS your system



Outline

Part I (general)

- What is HiPIMS?
 - Characteristics of Plasma Generation for HiPIMS
 - compared to other industrial available applications
- Brief look into History, Push/Pull Market view
- History-Conclusion

Part II



- Motivation
- Partners / the Manufacturer
- Features...
- Volt Reversal / Regulation / ARC-Handling / Applications
- HiPIMS Power Pack
- Product Overview
- Control Interface types
- Quality / Safety
- Summary

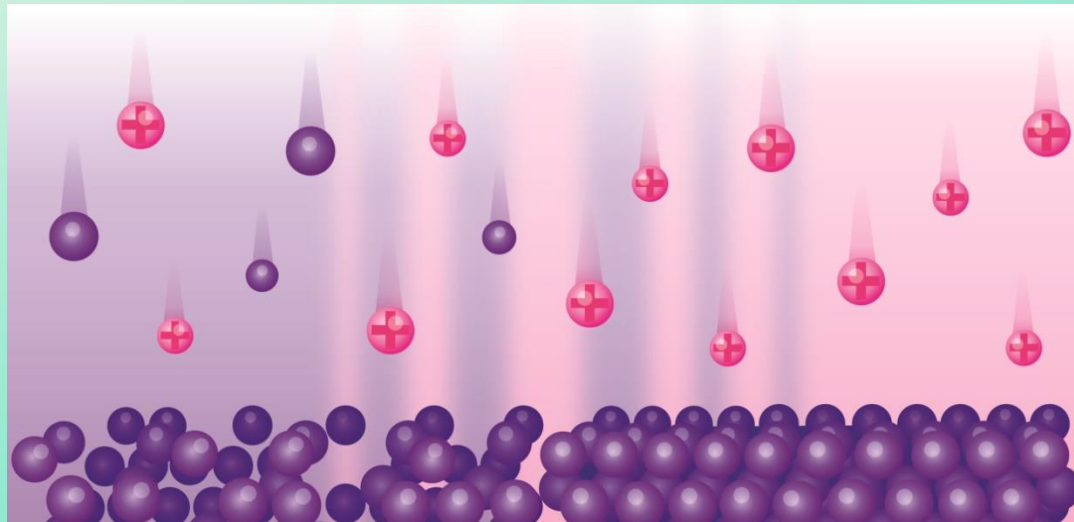


HiPIMS your system



What is HIPIMS ?

Hi – Power – Impuls – Magnetron - Sputtering



DC

VS

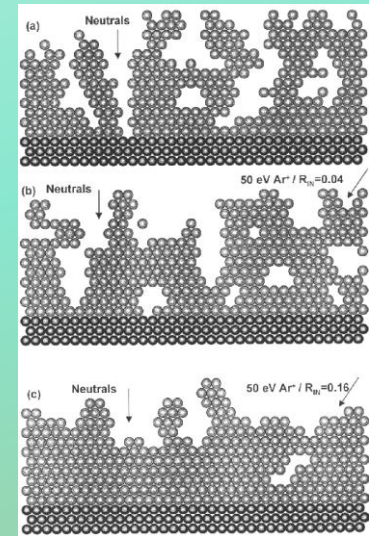
HiPIMS

ADVANTAGE:

- HiPIMS results in denser and smoother films (with smaller grains) compared to dcMS.

DISADVANTAGE:

- slow deposition rate, higher price, (a bit..) more complicated.



Increasing film density with increasing content of ionized sputtered material is known since 1987:

Effect of ion / neutral ratio

- (a) ions / neutrals: 0
- (b) ions / neutrals: 0.04
- (c) ions / neutrals: 0.16

Source: K.-H. Müller; Phys. Rev. B 35, (1987) 7906



HiPIMS your system



What is HIPIMS ?

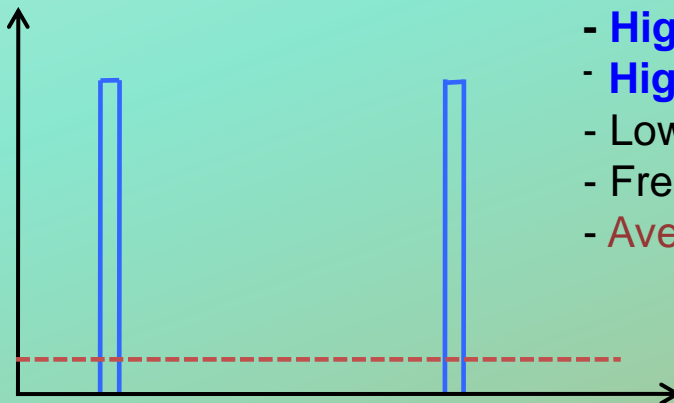
Innovative physical vapor deposition technique

High degree of ionization of the layer-forming material
from 4.5 up to > 90 % (C to Ti)

“Coatings with completely new or significantly improved properties regarding e.g. density, hardness, roughness, refractive index, not yet realized with any other technology available.” *

Characteristics of plasma generation:

instead of **DC** the **“Power is applied in pulses”** (average power stays equal)



- **High peak power density** ($> 0.5 \text{ kW/cm}^2$)*
- **High peak current density** ($> 0.2 \text{ A/cm}^2$)*
- Low duty cycle (< 0.1) *
- Frequency $< 1,5 \text{ KHz}$
- **Average power** is comparable to DCMS*

* Source Fraunhofer Inst. IST Braunschweig



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What is a HIPIMS-PS ?

In power electronics **“Power applied in pulses”** means:

„Delivering (applying) **controlled high power pulses** with a certain **voltage/ current / pulse length / frequency** to a system.“



this is “in principle” the standard technology for supplying power to trains, trams, subways

.... and many other industrial electrical machinery where high peak power pulses (voltage or current regulated) with a certain pulse length and a certain frequency.

Power-Pulses can be created different ways.....

.... e.g. via a controlled repeatable discharging of capacitors, charged by a switch mode direct current power source.





HiPIMS your system



What is a HIPIMS-PS ?

In power electronics **“Power applied in pulses”** means:

„Delivering (applying) **controlled high power pulses** with a certain **voltage/ current / pulse length / frequency** into a system.“

Comparison of Pulses

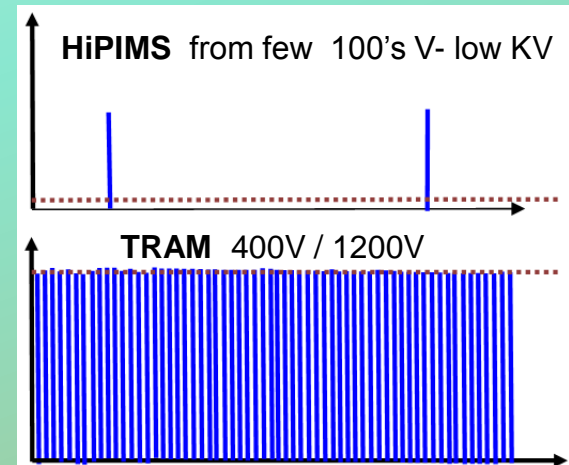
-> very similar Pulses

HiPIMS << average power →

TRAM >> average power →



ARC-Handling



downscaling a Tram PS → HiPIMS-Characteristics for plasma generation
→ Does it work ????????

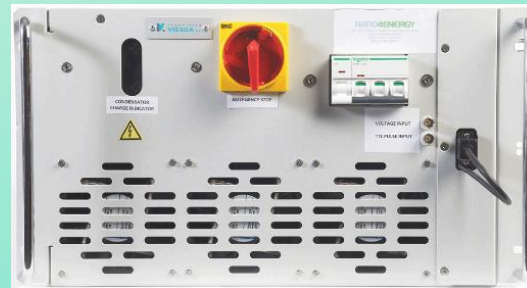


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What is a HIPIMS-PS ?

➔ YES !!!

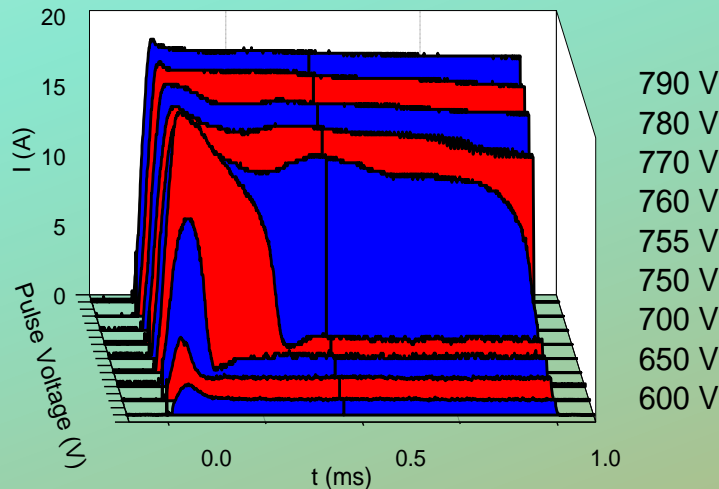


With this units!
Manufactured in 2008.
The first prototype
called
"GrandPa"

for scientific work

and for industrial use

Cu-Zn-Sn 2" target
Precise V control
allows current run-away
I.Fernandez-Martinez,
nano4Energy
HIPIMS 2011



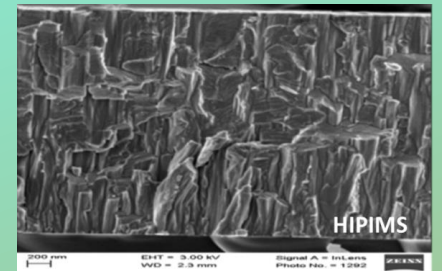
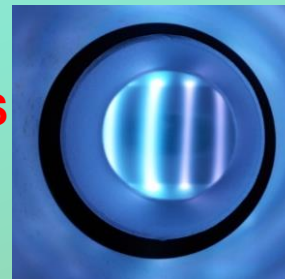
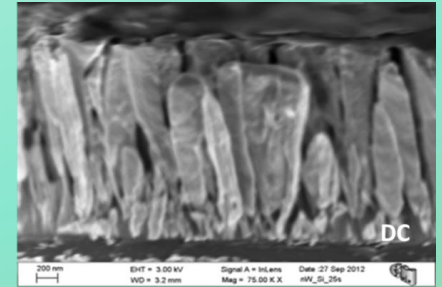
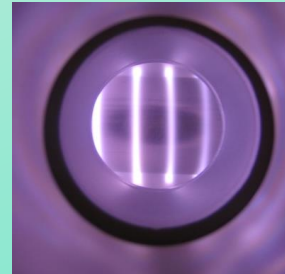
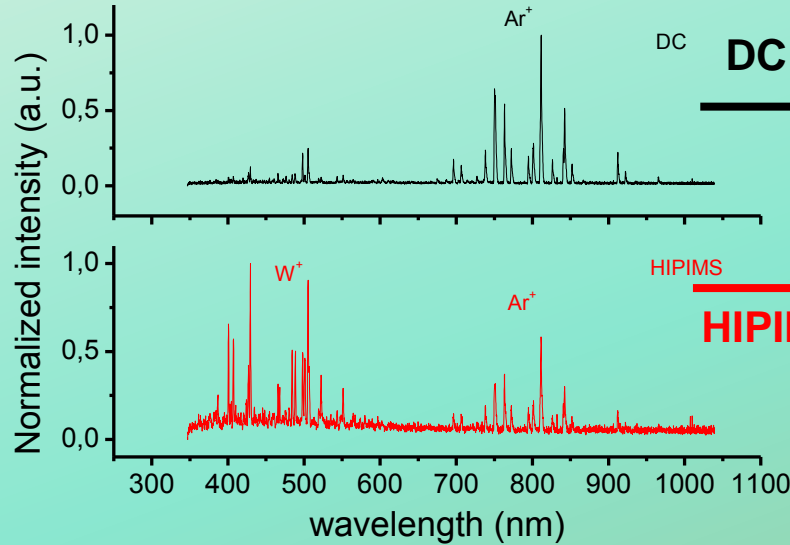


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What is a HIPIMS-PS ?

W coatings for Nuclear Fusion (2012)



nano4ENERGY

In collaboration with:





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HiPIMS History

- Some Hi-Power plasma discharge (HiPIMS-like) have been reported already in the 1950's; and before ...
- The HiPIMS technology is said to be used by Russian scientists since the early 80's.
- In 1999, the academia and industrial research became aware of the use of HiPIMS-technology by a paper “called the seminal HiPIMS paper” from V. Kouznetsov et al
(V.Koustnetsov, et al., Surf. Coat. Technol, 122, 290-293 (1999) for the application of filling 1 μm vias with aspect ratio of 1:1.2)
 - ➔ KICK-OFF for the HiPIMS-Technology
- Most promising perspective and positive outlook forecasts given by scientists and technologists for the HiPIMS –technology!!
- HiPIMS Technology was said to be the most promising (industrial) thin film deposition technique for the future..... !!
- Since then, several HiPIMS events HiPIMS-WS, HiPIMS-Days, HiPIMS-Sessions, HiPIMS-Conferences have taken place.





HiPIMS your system



HIPIMS History

Early HiPIMS publications „The Historical Development of HIPIMS Power Supplies: From Laboratory to Production”
by Dirk Ochs, Presented at the 51st SVC TechCon in Chicago, IL, in the HIPIMS; Session on April 21, 2008

Year	Author	Feature
1968 – 72, published 1974	O.A. Malkin	13 MW pulses, 120 μ s duration multiple ionization seen N2 plasma, 1 Torr 20 – 60mm diameter parallel plate no magnetic field (hence high pressure) not for coating deposition
1981	Tyuryukanov	magnetic field introduced circular magnetron type plasma Ar Plasma, 0.7 Pa pressure 48 kW (120A) into 50mm diameter magnetron not for coating deposition
1993	Mozgrin	Planar magnetrons used for HIPIMS sputter deposition Cu, Mo, Ti, Al, & Stainless Steel deposited 200 kW (200A) into 120mm target
1999	Fetisov	Continuation of Mozgrin work. Deposition of Oxides and Nitrides
1999	Kouznetsov	Removed pre-ignition plasma Popularization in the west
2001	Kouznetsov	first patent
2002	Ehiasarian	First upscaling to linear magnetrons
2004	Ehiasarian, Christie	First commercial industrial scale power supplies First Arc handling
2006	Gerhard Eichenhofer, hiP-V collaboration, 4A-PLASMA	first commercial HIPIMS deposition systems





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Summary take a look at the historical forecasts and perspectives

➔ KICK-OFF for the HiPIMS-Technology in 1999

HiPIMS Technology was said to be the most promising (industrial) thin film deposition technique for the future..... 😊 !!

„HiPIMS processing tools will grow by a factor of FIVE/a for at least the next 5 - 10 years!“ Quote of a well known scientist and entrepreneur in this industry in 2008.

But the scientific results for the HiPIMS-Technology are hard to transfer direct into industrial scale processing ...(not because they were wrong ... non industrial) ... and same is true for the proposed markets or applications!

According to the predictions, the future should be now? But...

- Real Industrial Break through, where is it?
- Why has the real industrial breakthrough not yet started?
- Where are the many expected processing tools ?

Industrial Applications so far:

Niche products in hard coatings
some medical coatings,
some coating on plastics and polymer
anti corrosive, anti bacterial.....etc....

HiPIMS has not gone main stream yet 😞 !

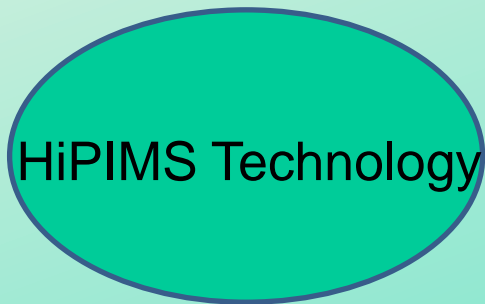


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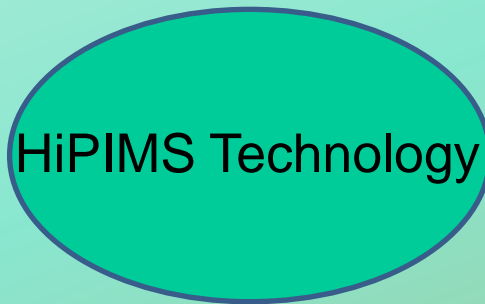


HiPIMS Market View

Push / Pull Principle - Technology push vs. Market pull



We are still here 😞



Lets move

We should be here 😊

Where are we?





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HiPIMS History-Market

Perspective and the positive outlook forecasts given by scientists and technologists in the past decade for the HiPIMS technology, the real industrial breakthrough has not yet started.

HiPIMS is still a niche technology

I dare to ask this the question:

Why does this world need another
HiPIMS Power supply
manufacturer ????



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HiPIMS History

Part of the answer could be because of this:



..... this has hapened in the past to many HiPIMS PS !!!

by now HiPIMS-PS technology
should have left the

„ALCHEMY STAGE“



In igne succus omnium, arte, corporum. Urens fit vnda, limpida et potissima.



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HiPIMS History Conclusion

“The HiPIMS power supply technology up to now was not industrially ready! HiPIMS PS were very expensive, not very flexible, unreliable and unsafe to use, built with non-conform components.”

Citation by the creators of the hiP-V, and the motivation!

The HiPIMS processing technology must be understood!

It is not only the power supply which contributes to this great deposition technology, it is also process regulation (monitoring), the magnetron system (magnetic configurations), the gas flow, the pumping speed, etc...

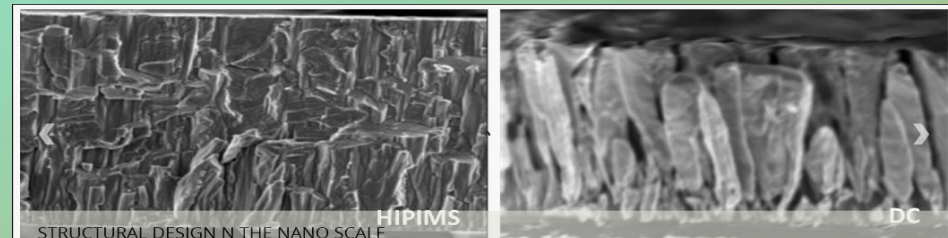
But the **!!! HiPIMS-PS is heart of the HiPIMS-Technology !!!**

.... the most versatile and the most sensitive processing instrument

The HiPIMS technology vs DCMS has great advantages !!

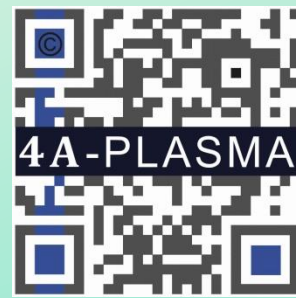
such as:

- Higher mechanical stability of layer systems
- Improved adhesion of layers
- Higher electric conductivity of layers
- Improved refraction index
- Improved barrier properties
- and and and





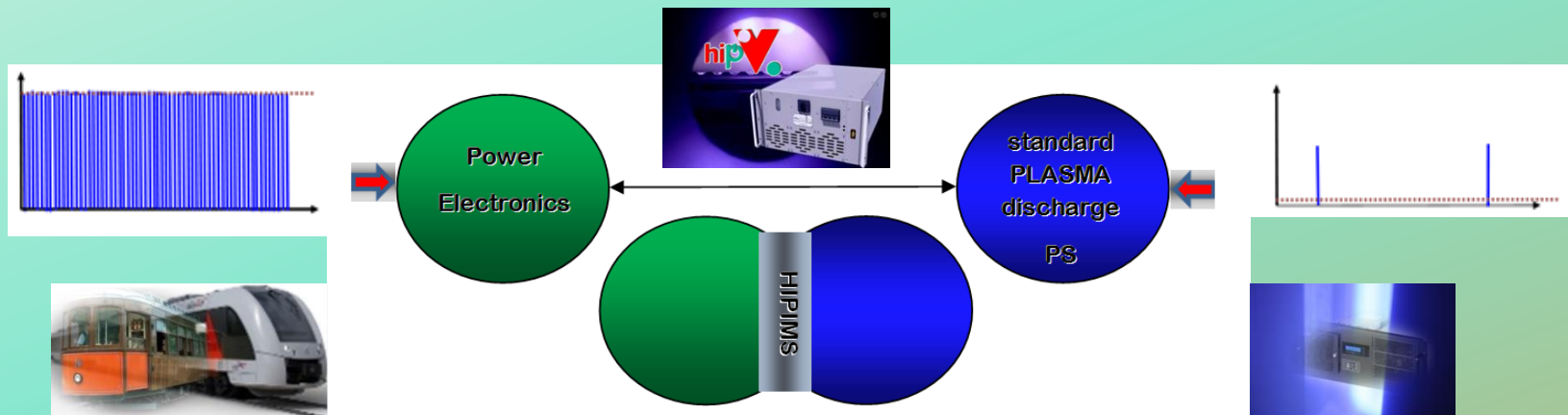
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HIPIMS Motivation

„To contribute and do our share to industrialize the HiPIMS-Technology with a sophisticated HiPIMS-PS“

Why not use a PS technology which is already available, qualified and proven, and adjust it to the “characteristics of plasma generation for HiPIMS”?



The new HiPIMS-PS Technology, was created as a co-production by an experienced team of scientists, researchers, technologists, metallurgists, process engineers and last but not least, a highly skilled, highly experienced power supply manufacturer.

To be joined in a new collaboration: www.hiPV.eu ➔ KICK-OFF 2014



HiPIMS your system



hiP-V the Partners

Ingenieria Viesca - the manufacturer

...(DESIGN AND MANUFACTURE OF POWER ELECTRONIC EQUIPMENT) is a company with an international reputation of designing and manufacturing high voltage switch mode power systems with the highest reliability “**products that never fail**”. This has been proven in great No of units installed in public-transportation systems around the globe.

Nano4Energy - the scientific part & the HiPIMS-application lab

...provide cutting edge process development for the thin film and sputtering industry. The company focus is to build bridges between the science communities and production industry by adapting state of the art laboratory processes to industrial use.

4A-PLASMA(formerly abeg-engineering) - product marketing

...looks back on many years of experience in application, marketing / product-marketing / product-creation and sales in the plasma power supply industry for industrial thin film processing. The competent contact for plasma power supply consultations.

...and many thanks to all the unnamed experts in this field from the academia and industry which helped us with their contributions and input.



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HIPIMS hiP-V Features

The highly flexible HiPIMS PS (post **GranPa** era):

- 1, 6, 10, 20, 30 KW Base units
- Voltage, Current, Power regulation,
- Ultra fast ARC-Handling (V or I detect, absolute values or delta values (%))
Voltage reversal after ARC, immediatly quenches the ARC
I / V reg. is adjustable -> Voltage regulation is faster, can be disabled for certain applications
- Pulsing frequencies up to 25 / 40KHz (1KHz / 2 KHz is standart),
- Pulse durations from μs up to ms range
standart pulse is from $5\mu\text{s}$ to 1ms but can be extended to 5ms, 10ms ...
- PS units can be put in series or parallel -> increase Voltage / Power / Current



HiPIMS your system



HIPIMS hiP-V Features

The highly flexible HiPIMS PS cont. :

true ALL in ONE HiPIMS-PS for many applications

- HiPIMS-PS, Uni-Polar / Bi-Polar / Single-Dual Magnetron (or any other plasma source, ion / beam)
- DC-PS; magnetron sputtering, PECVD, Etch
- DC-pulse-PS; magnetron sputtering, PECVD, Etch
- DC-Bias-PS;
- DC-pulse Bias-PS;
- HiPIMS-Bias-PS – DC;
- HiPIMS Bias DC-pulse Uni-Polar / Bi-Polar
- Superimposed and Sequential operation
-> HiPIMS + DC (DC-Pulse possible)





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HiPIMS hiP-V Features

The highly flexible HiPIMS PS:

- Can be operated optionally with the capacitors (enabled HiPIMS functionality) or without capacitors (disabled HiPIMS functionality) -> (HiPIMS ON/OFF)
- Optionally: adjustable capacitance (increase or decrease)
- Voltage, Current, Power regulation,
 - Average Power Regulation
 - Peak Power Regulation
 - Average Current Regulation
 - Peak Current Regulation
- Coarse / Fine regulation adjustment in (<100A or > 100A)





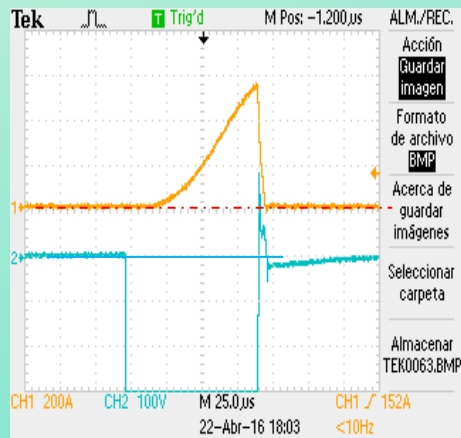
HiPIMS your system



HiPIMS hiP-V Volt.Reversal

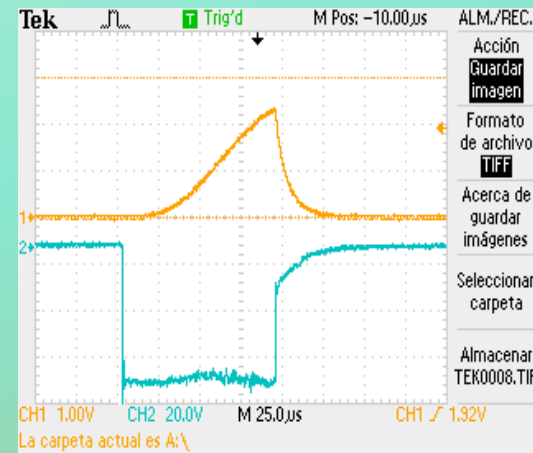
The highly flexible HiPIMS PS:

Voltage reversal after each pulse
(short peak)



Patent application number GB1605162.5 (March 2016)

Regular, no Voltage reversal



- This adds many advantages:
- discharging the substarte ✓
 - reduces ARcing ✓
 - improves film properties ??
 - and many more



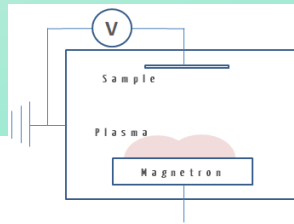
HiPIMS your system



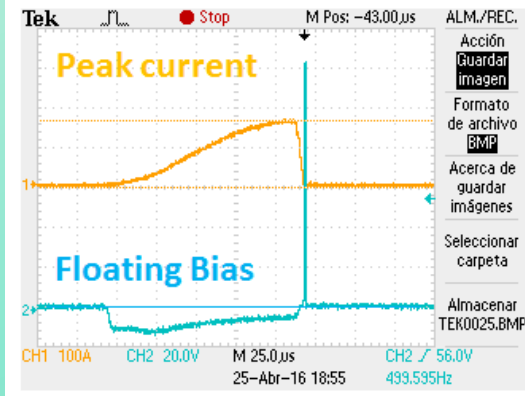
HIPIMS hiP-V Volt.Reversal

Voltage reversal after each pulse (optional is voltage peak adjustment)

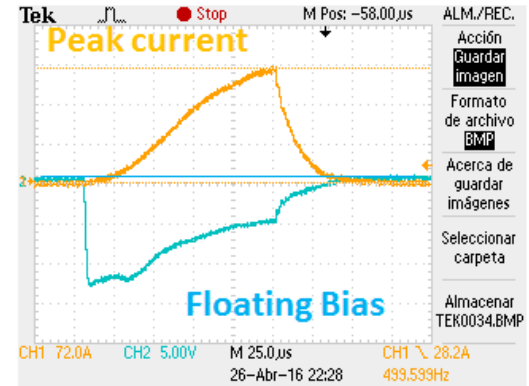
Floating Bias Potential



With positive voltage reversal



Without positive voltage reversal



Hardness [GPa]	22.0	13
POSITIVE V revers	YES	NO

- improves film properties ✓ ✓ ✓



HiPIMS your system



HIPIMS hiP-V Regulation

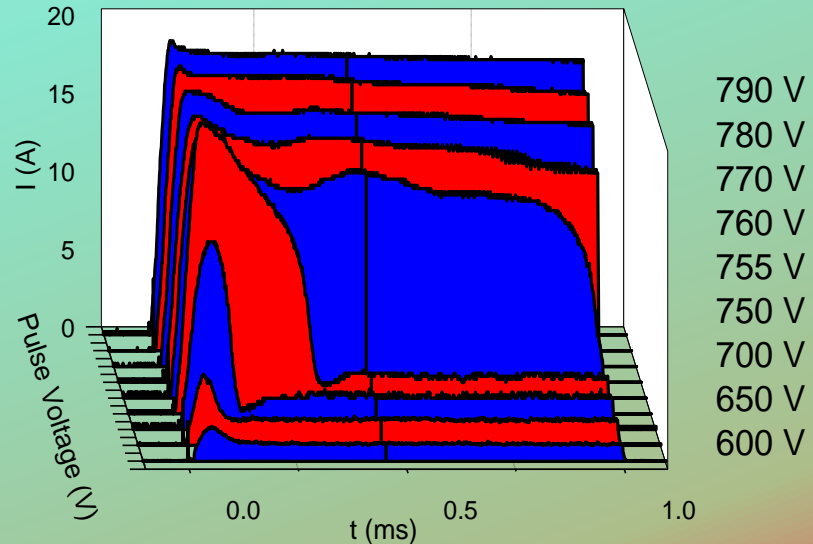
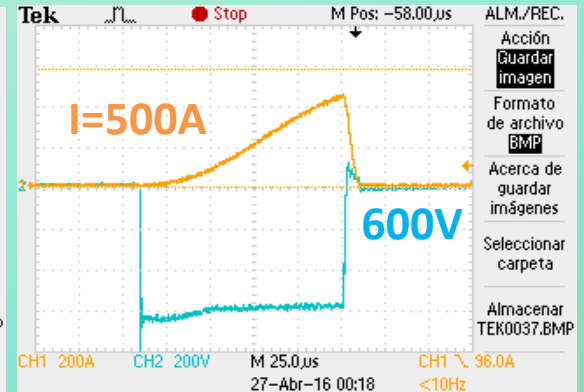
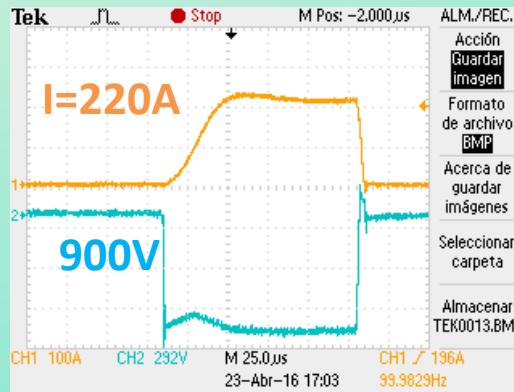
!Highly Accurate!
Regulation

Power Regulation:
(Peak / Average)

Voltage Regulation :

Cu-Zn-Sn 2" target
Precise V control
allows current run-away
I.Fernandez-Martinez,
HIPIMS 2011

Metallic mode (Ti+N , 3kW) Poisoned mode (Ti+N, 3kW)



790 V
780 V
770 V
760 V
755 V
750 V
700 V
650 V
600 V

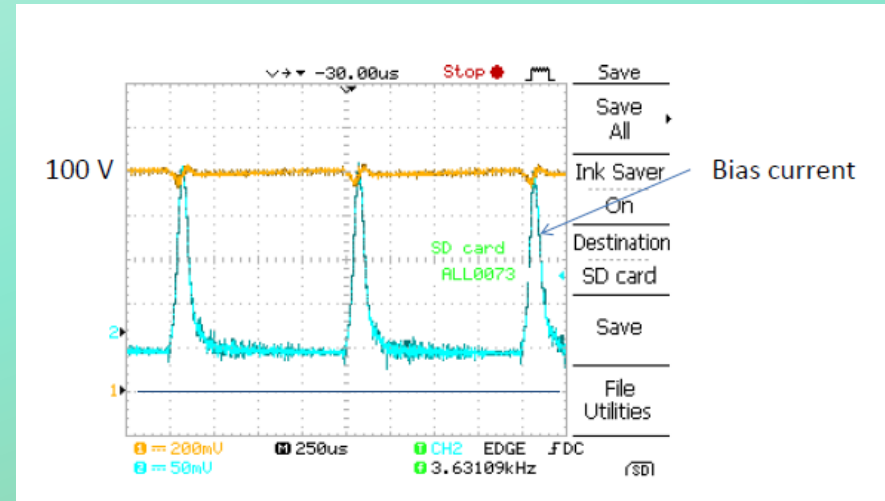
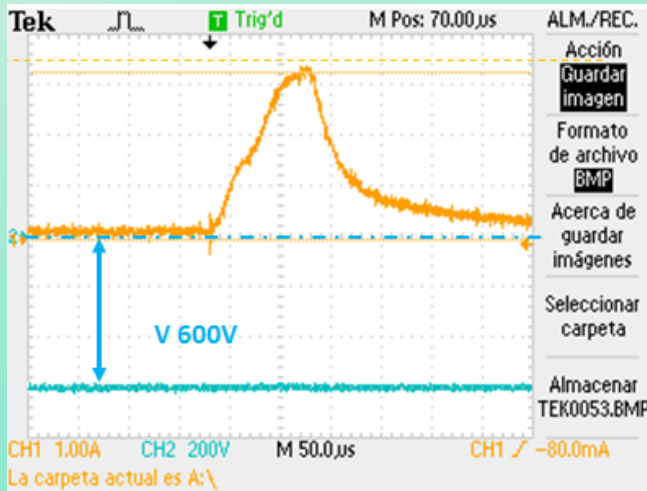


HiPIMS your system



HIPIIMS hiP-V Regulation

Bias operation (Voltage Regulation):



Capacitor can be software connected to work as Bias (maintain V) or disconnected to work as Straight DC

Bias current

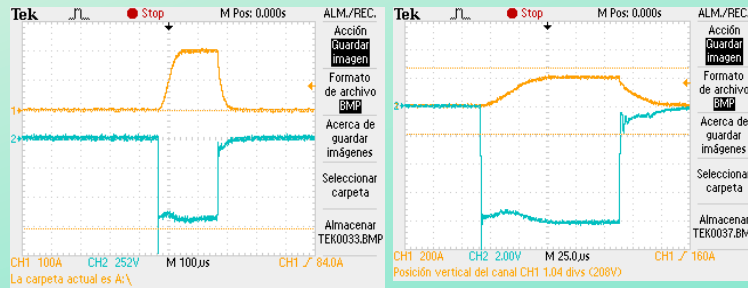


HiPIMS your system

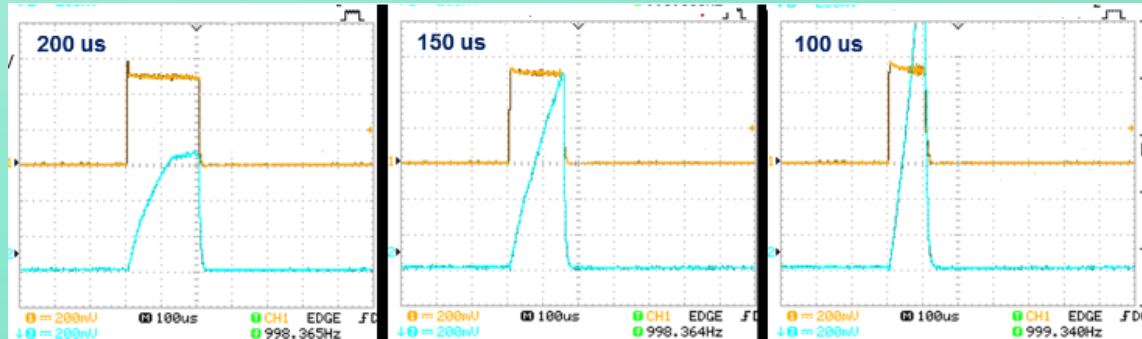


HIPIIMS hiP-V Regulation

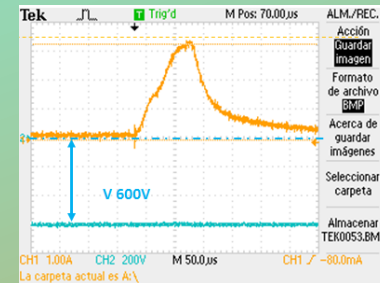
**Current Regulation:
(Peak, Average)**



Voltage Regulation:



Voltage Regulation (Bias):





HiPIMS your system



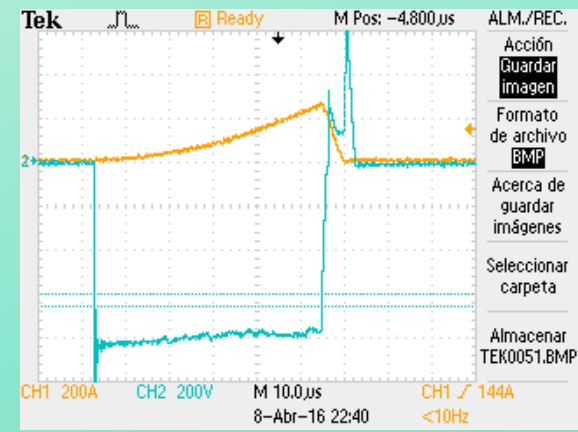
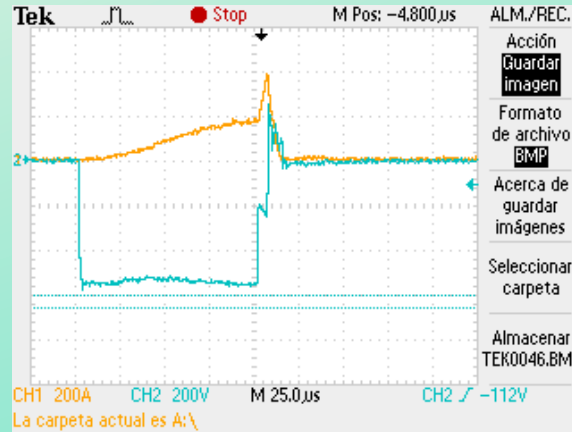
HIPIMS hiP-V ARC-detection

ARC detection:
(sensitivity adjustment)

immediate
ARC-detection

very fast...

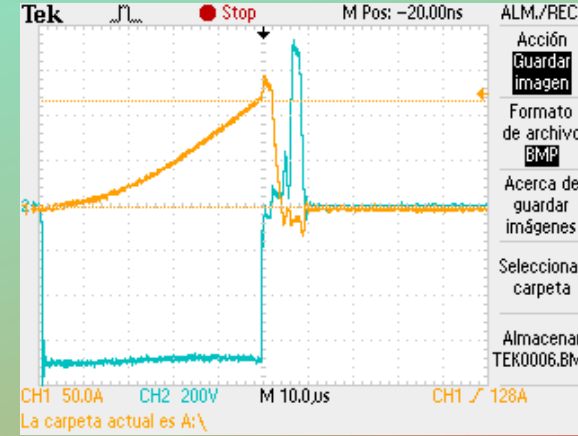
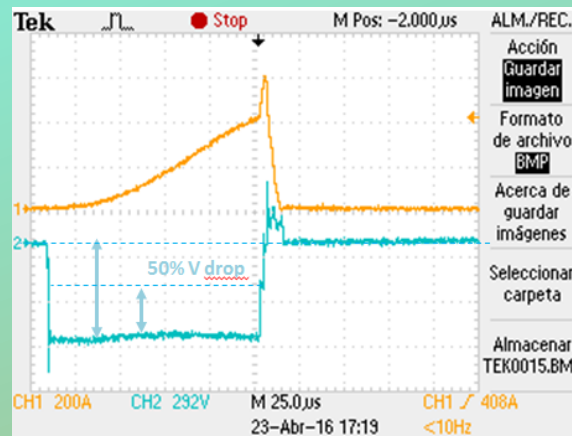
- ARC-handling
- ARC-quenching



I current threshold mode

dI/dU voltage mode

absolute value or delta values

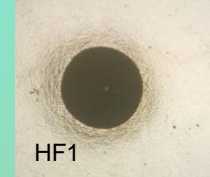
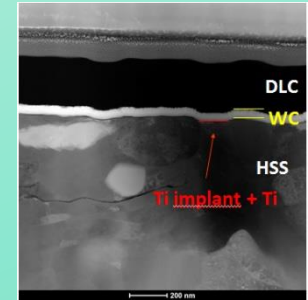
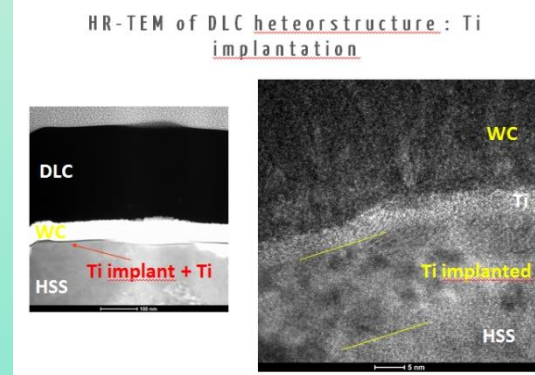
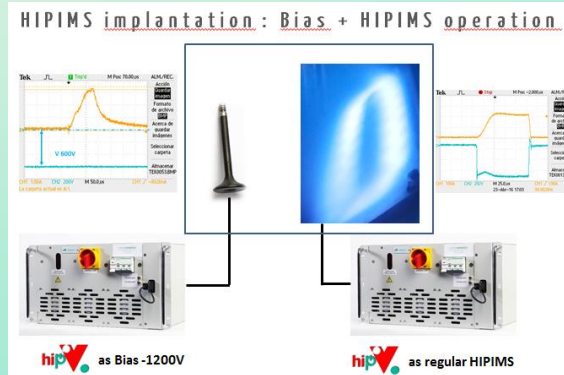




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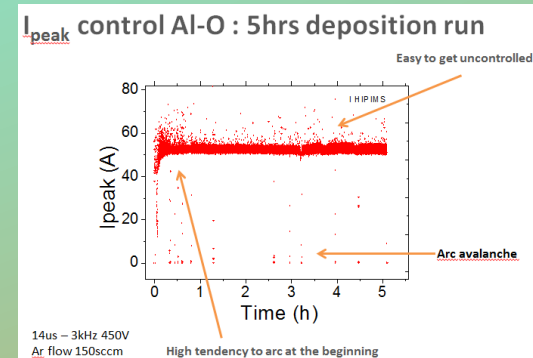
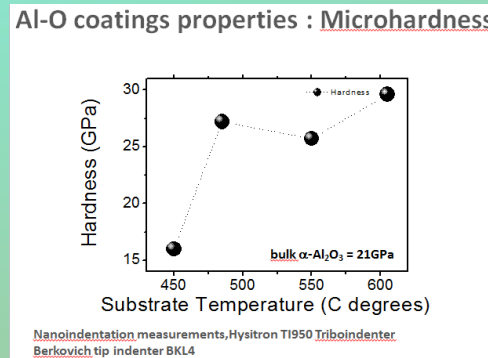
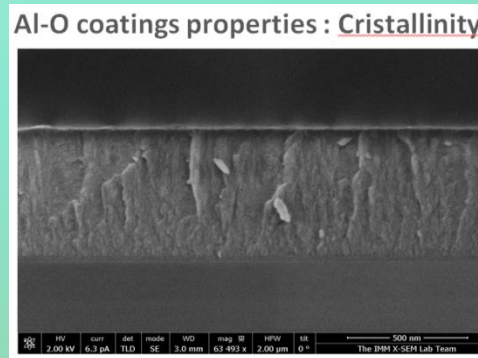
HIPIMS hiP-V Applications



DLC Applications

Hardness = 32 Gpa
Young modulus = 220 Gpa
500nm thick DLC

Al-Oxide Applications





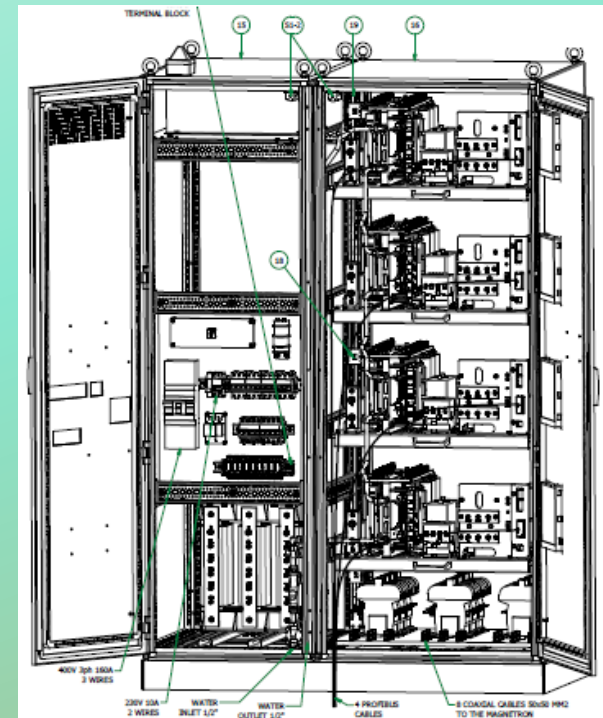
HiPIMS your system



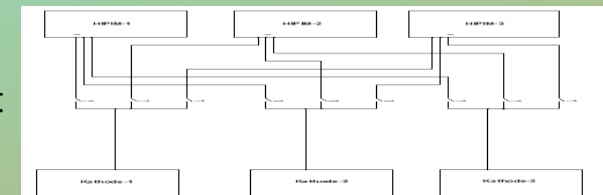
HiPIMS Power -Pack

The HiPIMS Power-Pack

- most flexible, adds flexibility
- combines 2, 3, 4, 5... different units
- can be used as single units cabinet
- multi Power levels, switchable 1 x 2 x ...
- or as combination of parallel / seriell PS in any combination
- > multi processing tool
- HiPIMS / HiPIMS-Bias / DC DC-P



power switching unit





HiPIMS your system



Product Range hiP-V

	hiP-V 1KW	hiP-V 6KW	hiP-V 10KW Opt.A	hiP-V 10KW Opt.B	hiP-V 20KW Opt.A	hiP-V 20KW Opt.B
Power	1KW	6KW	10KW	10KW	20KW	20KW
Peak Power	0,1MW	0,5MW	1,2MW	1,2MW	2,4MW	2,4MW
Voltage	1200V	1200V	1200V	1200V	1200V	1200V
Current max. HiPIMS	100A	500A	1000A	2000A	2000A	1000A
Current DC max.	3A	18A	25A	25A	50A	50A
Frequency max.	40KHz <small>P_{max} @1KHz</small>	2KHz <small>P_{max} @1KHz</small>	2KHz <small>P_{max} @1KHz</small>	1KHz	1KHz	2KHz <small>P_{max} @1KHz</small>
Time ON	5-1000µs	5-1000µs	5-1000µs	5-1000µs	5-1000µs	5-1000µs
ARC Control	< 3µs	< 3µs	< 3µs	< 3µs	< 3µs	< 3µs
Cooling	Air	Air	Water	Water	Water	Water

up to 80KW / 120KW possible



HiPIMS your system



Controls and Interface

hiP-V Control

User interface

controls via

- USB
- RS 232
- Analog
- Profibus
- Ethernet/Ethercat
- more upon request

Viesca Supervisor Pulsed Power Supply 110054 (Connected)

File Real Time Diagnostic Tools Help

STATUS > WORKING
MODE > HI-PIMS (PROGRAM)

Last Stop : Vin overvoltage (10 : 51 : 58 4 / 23 / 2016)
Failure N° : 0

Software version : 1.0.2
Memory Record : 0

Sw compile date : 18 / Apr / 2016
Last Failure : output overcurrent

DC/DC Conv
Pi 460 W
Vi 554 V
Ii 0.8 A

V middle 694 V

Pulse Gen

Ioutput range 5A-500A

PTC ON
Capacitor ON

Total n° arcs 9
Arcs/sec 0

I out peak 378 A
P out 927 W
P Limitation

NOMINAL VALUES	Actual	Requested
Voltage (V middle)	699 V	700
Power (P out)	2000 W	2000
Current (I middle)	6 A	6

I middle 1.3 A
I Limitation

ARC MANAGEMENT	Actual	Requested
Current threshold (A)	449 A	450
I-Max.Number arcs/sec	5	5
Voltage arc level (%)	50 %	50
V-Max.Number arcs/sec	101	101
Pulse Time ON	120 uS	120
Pulsing frequency	100 hz	100

PC time : 10 : 53 : 33 23 / 4 / 2016
Control Temp 22.7 °C

Start Send Changes Stop



HiPIMS your system



hiP-V Quality/Safety

The hiP-V product lines are exclusively manufactured with components already qualified and used for the **aeronautics** industry and **railway** systems such as trains, trams and subways. These components comply with the highest quality and safety standards for the use in public transportation systems.

This gears up the hiP-V products to a maximum on quality, reliability and durability.

The pulsed power supply described in this document is fully compliant, but not only, with the following railway standards:

- EN 61000-3-12-2006 Electromagnetic compatibility (EMC) part 3-12: limits for harmonic currents produced by equipment connected to public low-voltage systems with input current greater than 16 a and equal to or less than 75 a per phase
- EN 61010-1:2002 Safety requirements for electrical equipment for measurement, control, and laboratory use -- Part 1: General requirements
- EN 61204-3-2002 Low voltage power supplies, d.c. output -- Part 3: Electromagnetic compatibility (EMC).
- EN 61000-6-3-2006 Electromagnetic compatibility (EMC). Generic standards. Emission standard for residential, commercial and light- industrial environments
- EN 61000-6-2-2006 Electromagnetic compatibility (EMC) -- Part 6-2: Generic standards - Immunity for industrial environments
- MIL STD 217 Reliability Prediction of Electronic Equipment

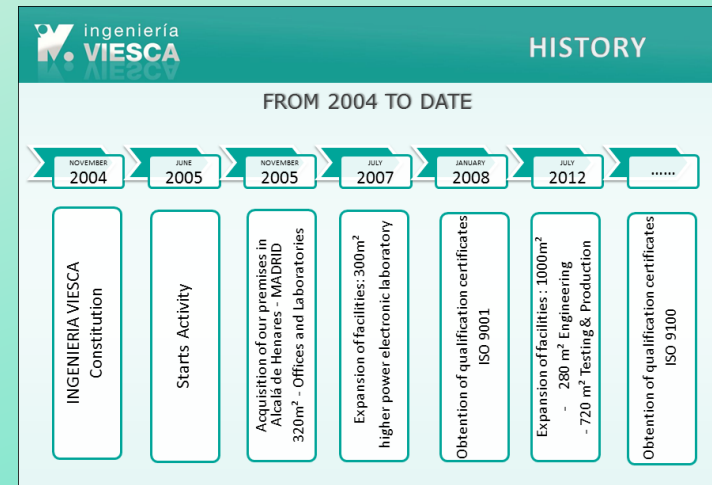




HiPIMS your system



HiPIMS The Manufacturer



Markets, Electronic Equipment for:

- Automotive
- Aviation
- EOLIC
- Industrial
- Railways (light and heavy)

Annual Revenue:

- 2015 approx. 3 Million €
- 2016 expected 7 Million €





HiPIMS your system



hiP-V The Manufacturer

Statement of the manufacturer:

WE CONTROL ALL STAGES OF THE PRODUCT FROM THE STUDY OF
CUSTOMER NEEDS
UNTIL AFTER SALES AND COMMISSIONING OF EQUIPMENT

IMPLEMENTED STANDARDS COMPLY WITH THE RULES IN
DIFFERENT SECTORS WE WORK

RAILWAY - AERONAUTICS



..... and they for sure are at least equal (most likely substantially exceed) the standards for most of the commercially available plasma power supplies on the market.



HiPIMS your system



HiPIMS hiP-V Summary

Advantages:

- created in the field, driven by technology, manufactured with experience,
- most flexible / highly reliable
- multiple use -> a true "ALL in ONE"
- ultra fast ARC-handling
- UniPolar / BiPolar operation
- voltage reversal after the pulse
- easy installation and handling
- HiPIMS-Power-Pack
- fast response upon customer requests
- very competitive pricing



It is not only the HiPIMS-PS, we deliver TECHNOLOGY



HiPIMS your system



HiPIMS hiP-V Summary

hiP-V, is the new industrial HiPIMS-PS Technology!
...but well known and used many, many times for public transportation...

Let's

The logo for HiPIMS, where the letter 'H' is red, followed by a thumbs-up icon, and the letters 'PIMS' are red.



HiPIMS your system



About us or Leitmotiv

we do not :

- have to focus on shareholder value
- drive to highest volume at lowest manufacturing cost
- desperately want to achieve the highest margin

we do:

- focus on our customer
- focus on quality products
- drive to highest quality at reasonable pricing
- try to achieve the highest customer satisfaction

we want -> a fair WIN / WIN relationship with our customers



Thank you for your attention !!

There is more to come.



hiP-V Marketing & Sales

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