Nanocomposite Coatings Deposited by HiPIMS for Liquid Impingement Erosion (LIE) Resistance Application

Ganesh Kamath

Functional Coatings and Surface Engineering Laboratory
Department of Engineering Physics
Polytechnique Montréal

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Important properties of coating for protection against LIE

Good adhesion to substrate

High resilience and toughness

High fatigue strength

Lower residual stress

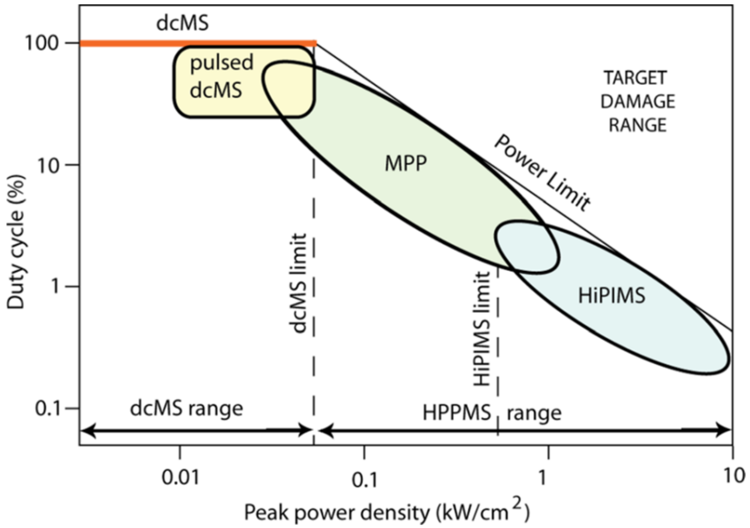
High thickness (5-25 μm) with dense microstructure

Functionally graded architectures with multifunctional properties

Is it possible to achieve above properties by using HIPIMS/MPPMS ???

Yet to be EXPLORED !!!!

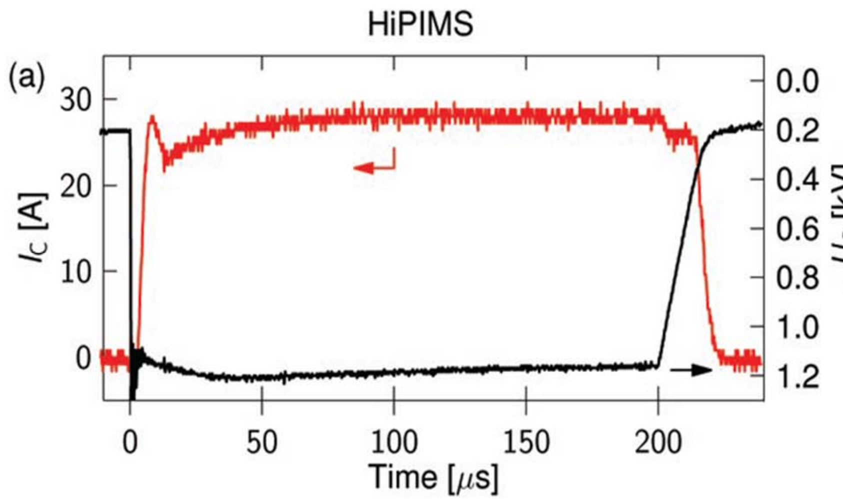
HIPIMS/MPPMS (Ionised PVD)



Plasma technique	Peak Power Density P_t (kW/cm^2)
DCMS and Pulsed DC	< 0.05
MPPMS	0.05< P_t < 0.5
HIPIMS	0.5 < P_t < 10

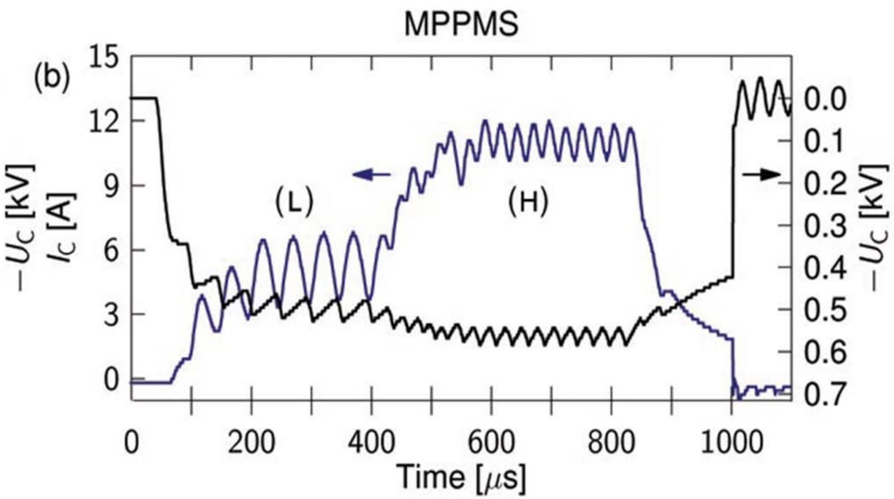
Ref: Gudmundsson et.al, JVSTA, 30, 031801

High Power Impulse Magnetron Sputtering



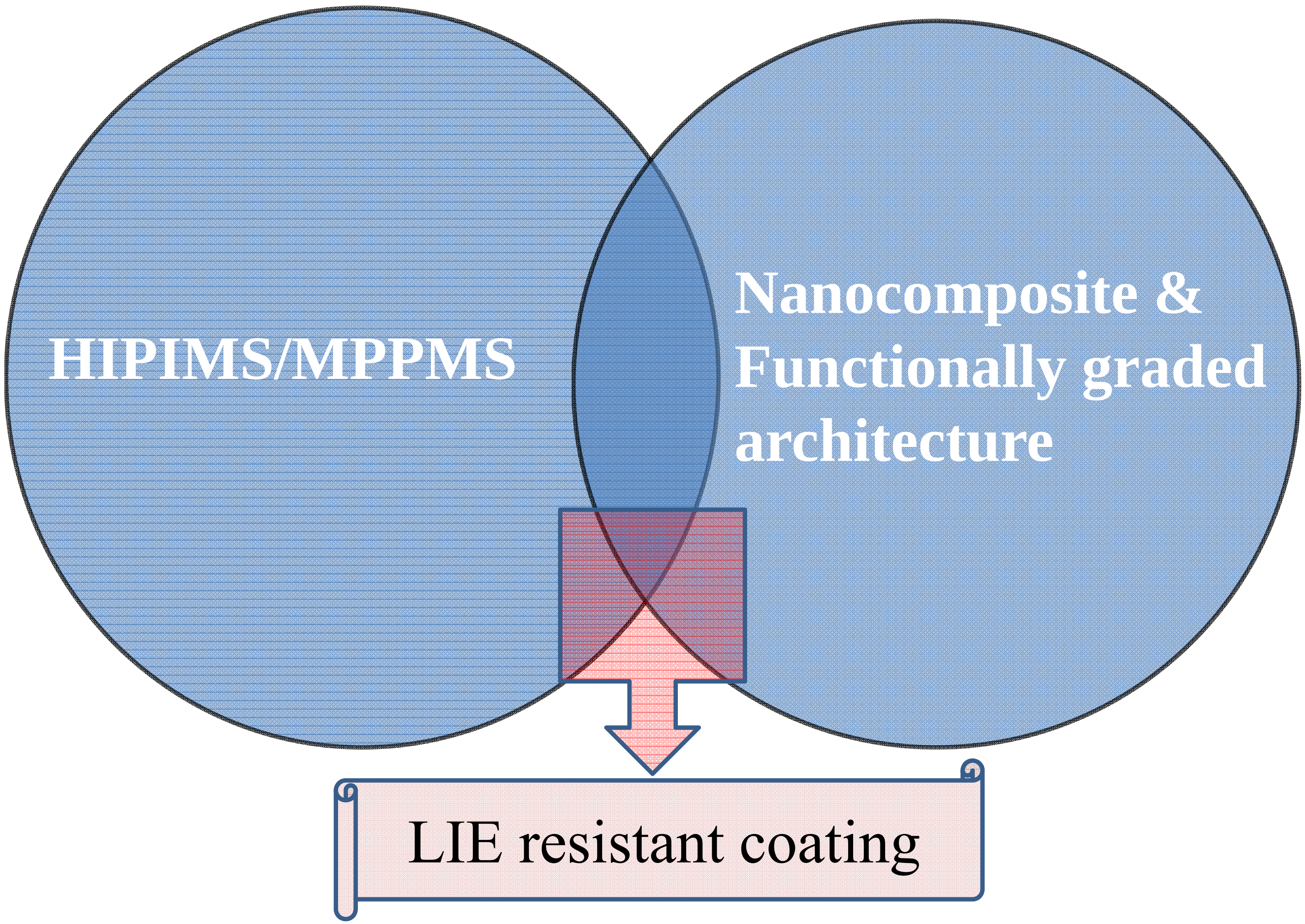
Rectangular voltage pulse
Pulse duration 50-200 μs
Duty cycle 1-10%

Modulated Pulse Power Magnetron Sputtering

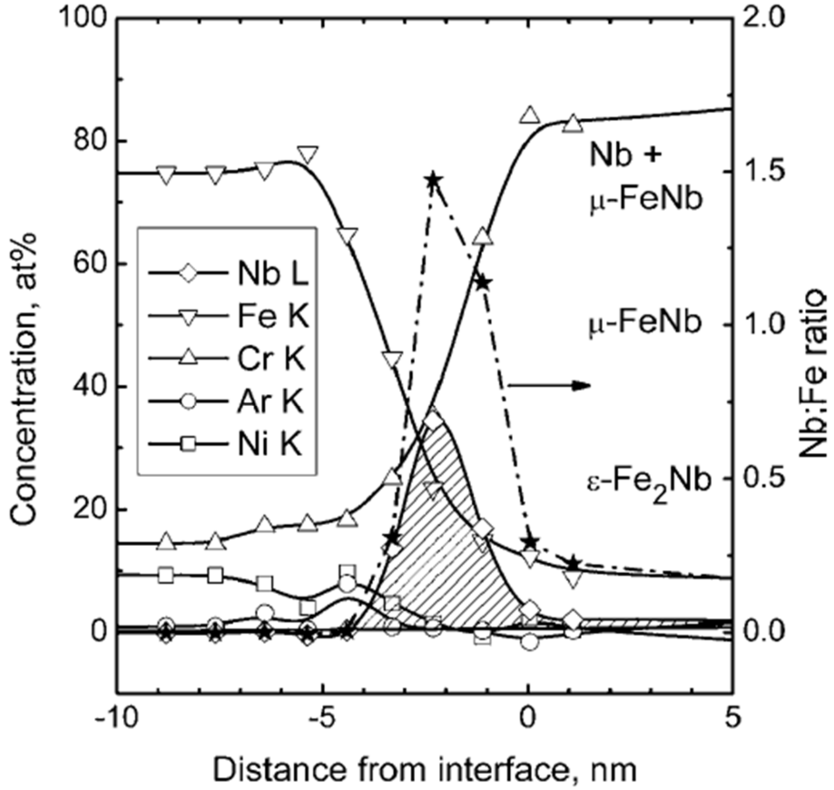


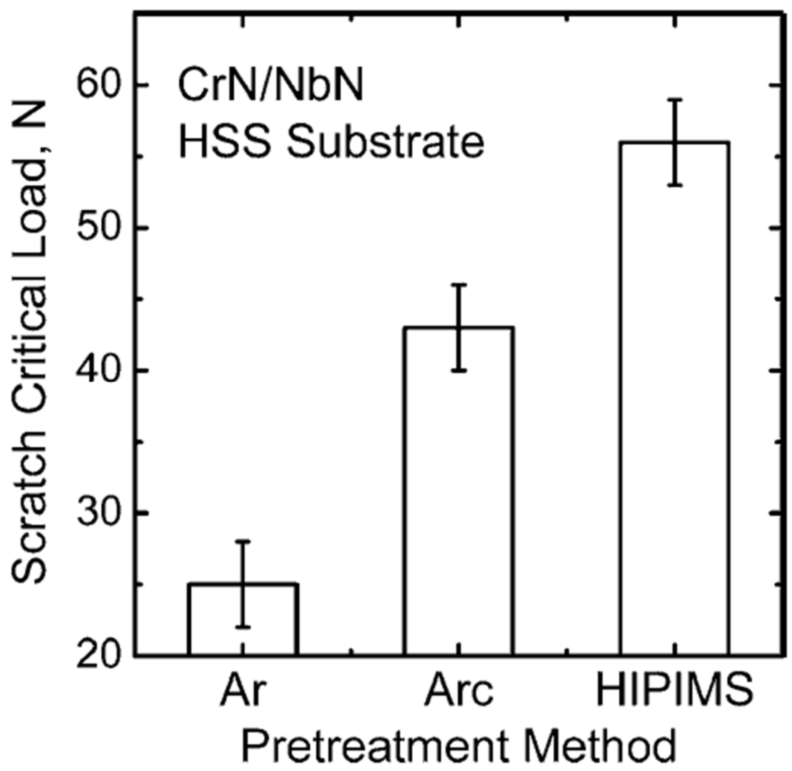
Sequence of micropulses (T_p ~10 μs)
Pulse duration 400-3000 μs
Duty cycle – 10-28%

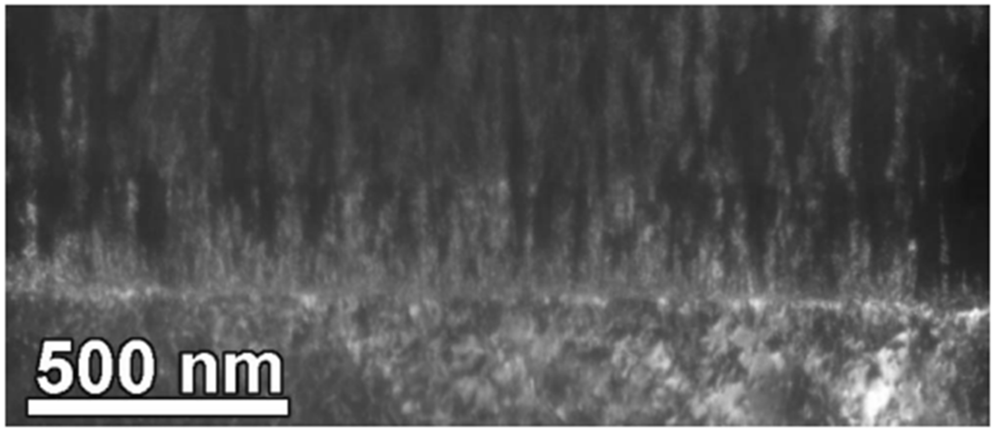
Strategy to reach the objective



Advantage of HIPIMS 1: Interface engineering by HIPIMS

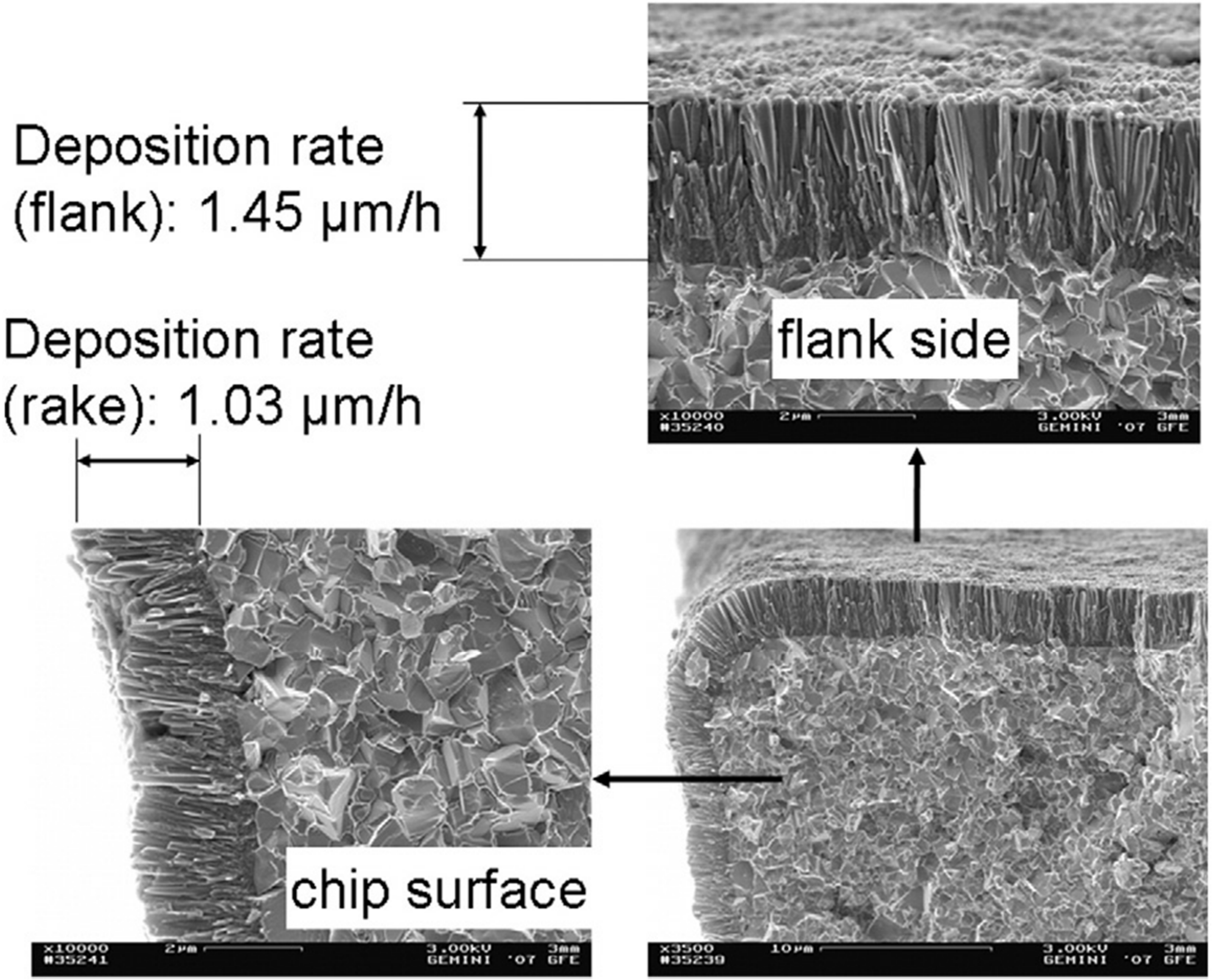






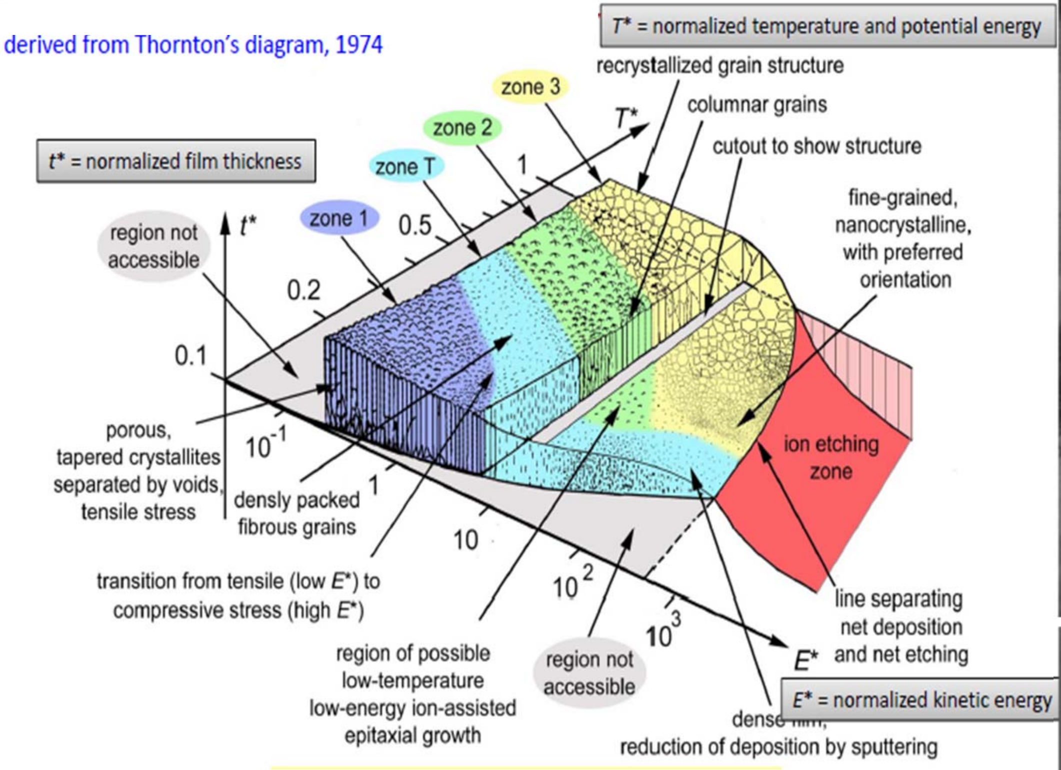
Ehiasarian et.al. J. Appl. Phys. 101, 054301 (2007)

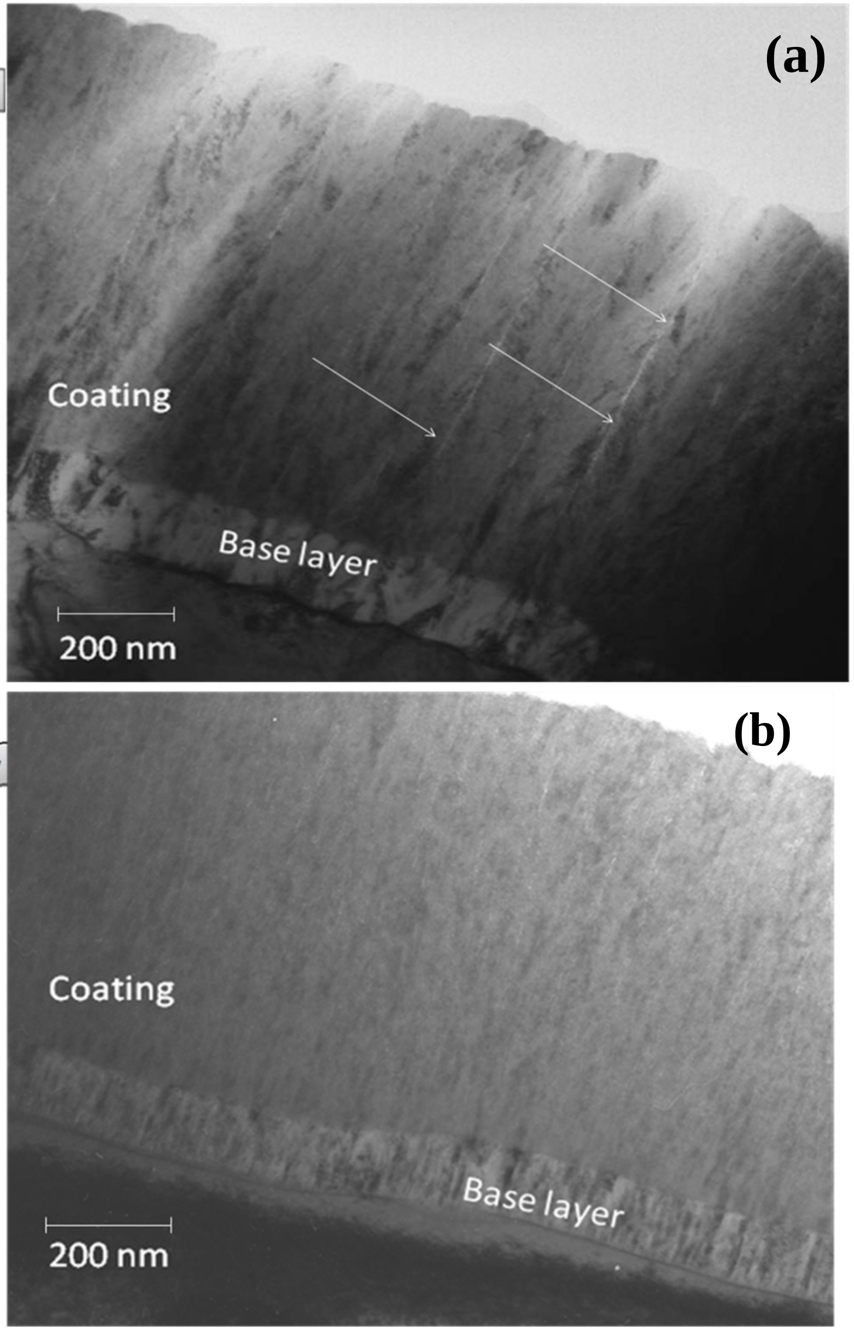
Advantage of HIPIMS 2. Deposition on complex shaped substrates



Ref: K. Bobzin et. al, J. Mater. Process. Technol. 209 (2008) 165.

Advantage of HIPIMS 3: thin Film Microstructure



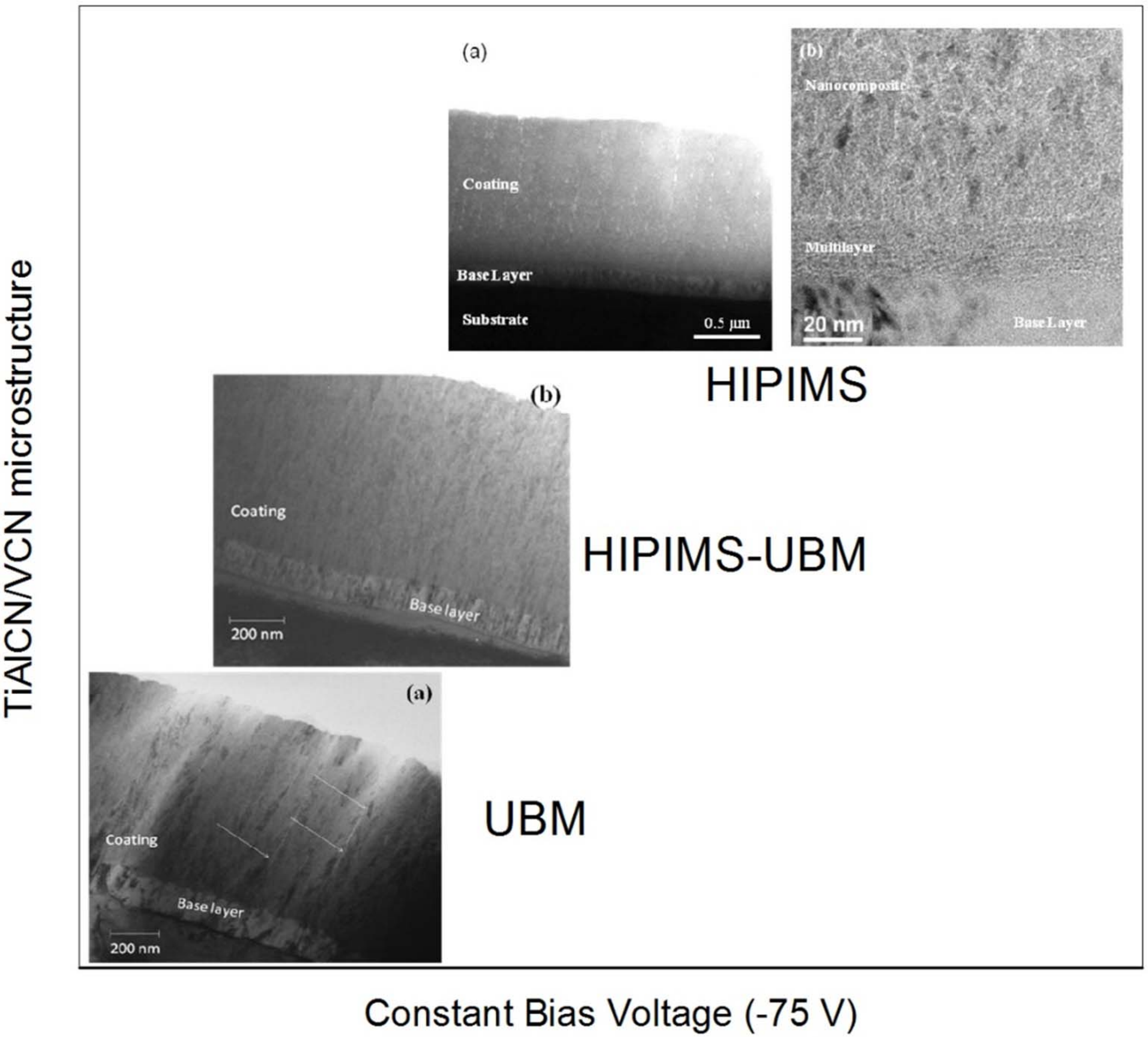


Biasing is to control the energy of incoming ions.

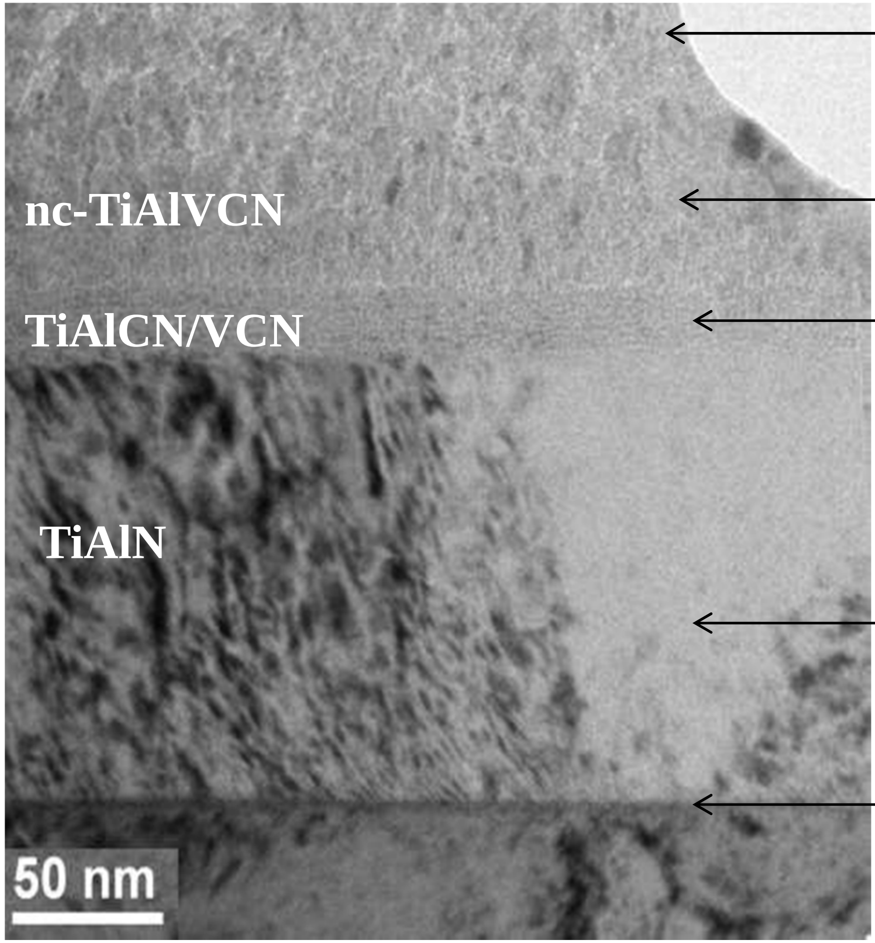
Low kinetic energy (10 eV – 100 eV) of arrival ions during ion assisted growth.

Ref: A. Anders, Thin Solid Films 518 (2010) 4087–4090

Advantage of HIPIMS 4. Tailoring Phase composition and graded architectures



Example of earlier work on HIPIMS



Dense amorphous top layer (no grain boundaries) therefore highly corrosion (oxidation) resistant

Nanocomposite zone providing high wear resistance

High toughness nanoscale multilayer at the bottom enhances the load bearing capacity

TiAlN base layer for smooth hardness transition and stress management

V implanted by HIPIMS coating/substrate interface delivering strong adhesion

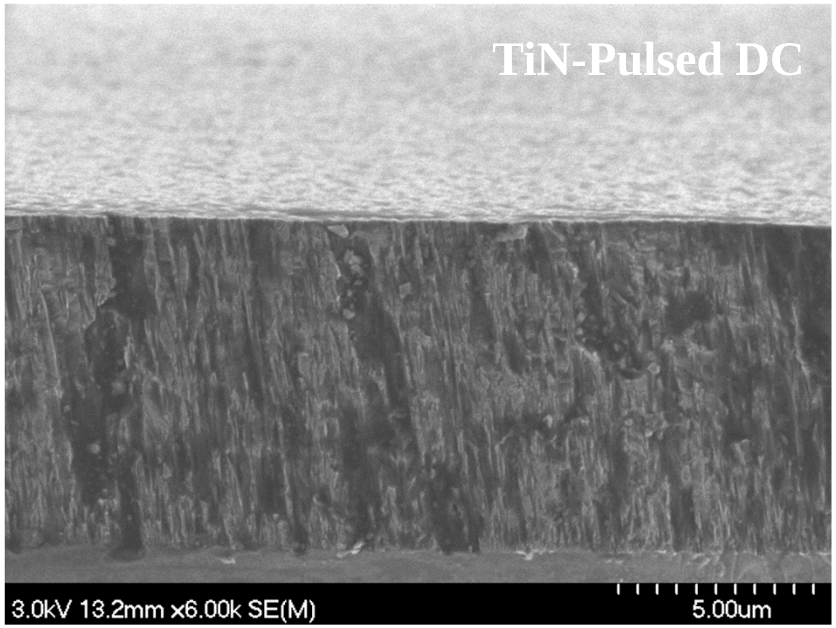
TEM cross section of nanostructured TiAlCN/VCN coating

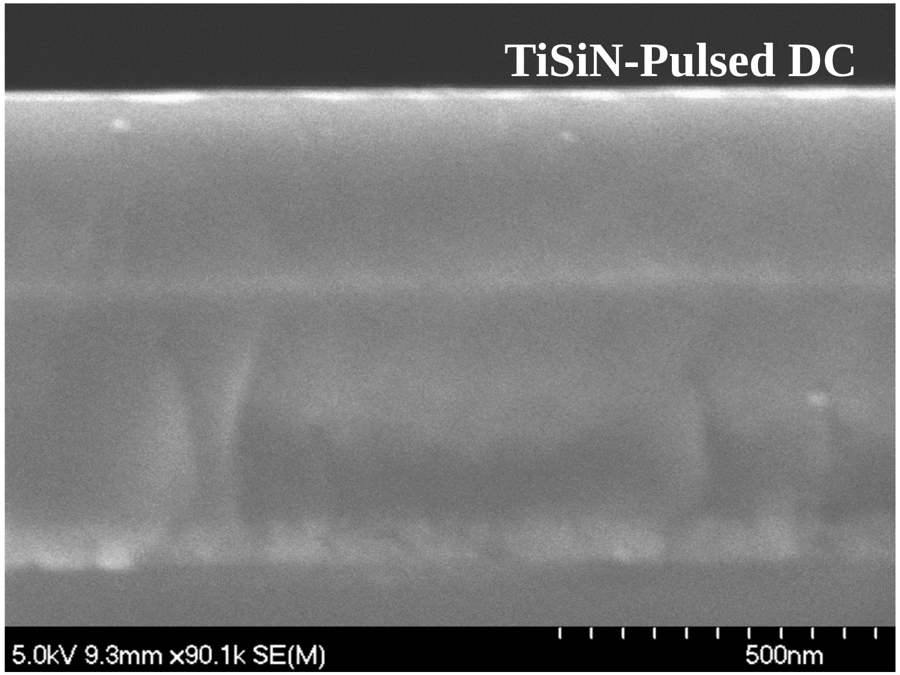
Ref: ***G. Kamath, P. Hovsepian and A. Ehiasarian, SVC 2011***

What has been done earlier ?

Optimization of TiN and TiSiN by Pulsed DC

Coating	Technique	Thickness (μm)	Hardness (GPa)	Young's modulus (Gpa)	$Ar:N_2$	Power	
						Ti	Si
TiN	PDC	8	25	~ 301	3:1	0	0
TiSiN	PDC	1	32	~ 300	3:1	400	50
TiSiN	PDC	1	37	~ 300	3:1	400	100



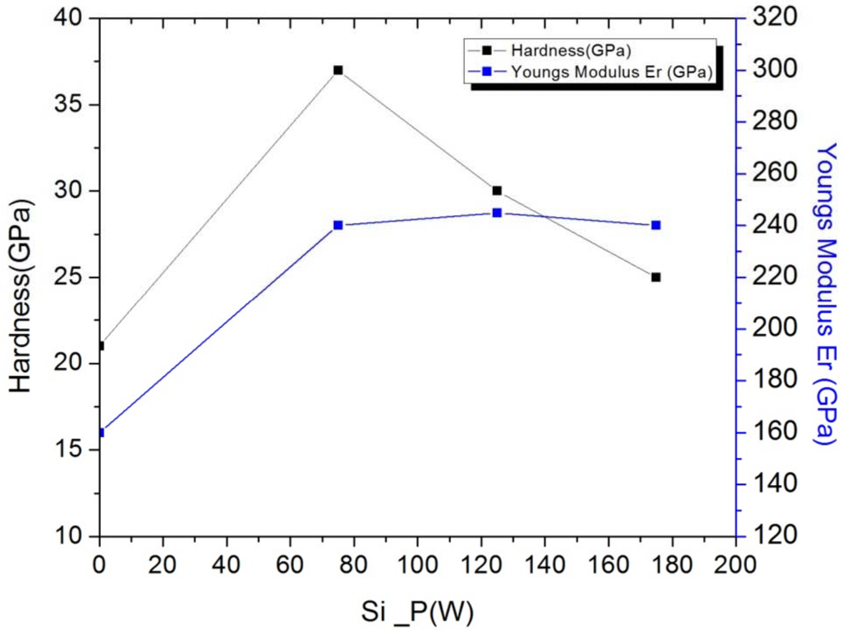


Deposition parameters for TiSiN and TiN by MPPMS and Pulsed DC

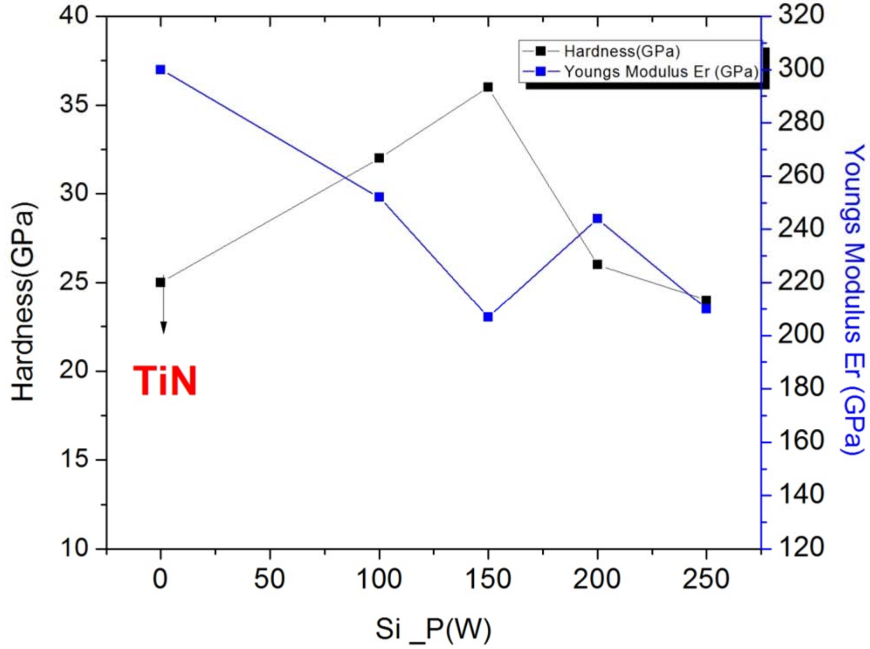
		TiN		TiSiN	
Power supply		**Pinnacle**	**MPPMS**	**PULSED DC**	**MPPMS**
Pressure		**5.2** mTorr	**4.5** mTorr	**5.2** mTorr	**4.6** mTorr
Ar : N_2 flow ratio		**3: 1 sccm**	**16:1 sccm**	**3: 1 sccm**	**16 : 1 sccm**
Applied power	Ti	**400** W	**300** W	**400** W	**300** W
	Si	0	0	150	75
Cathode voltage		**-350** V average	**-600** V average	**-350** V average	**-600** V average
Bias voltage		**- 100 V**	**-75 V**	**-100 V**	**-70 V**
Pulse length		**3 μs**	**1300 μs**	**3 μs**	**1300 μs**
Frequency		**300 k**Hz	**75** Hz	**300** kHz	**75** Hz
Dep. rate		**0.13** nm/s	**0.15** nm/s	**0.18** nm/s	**0.20** nm/s

Mechanical properties of TiSiN by MPPMS and Pulsed DC

TiSiN by MPPMS



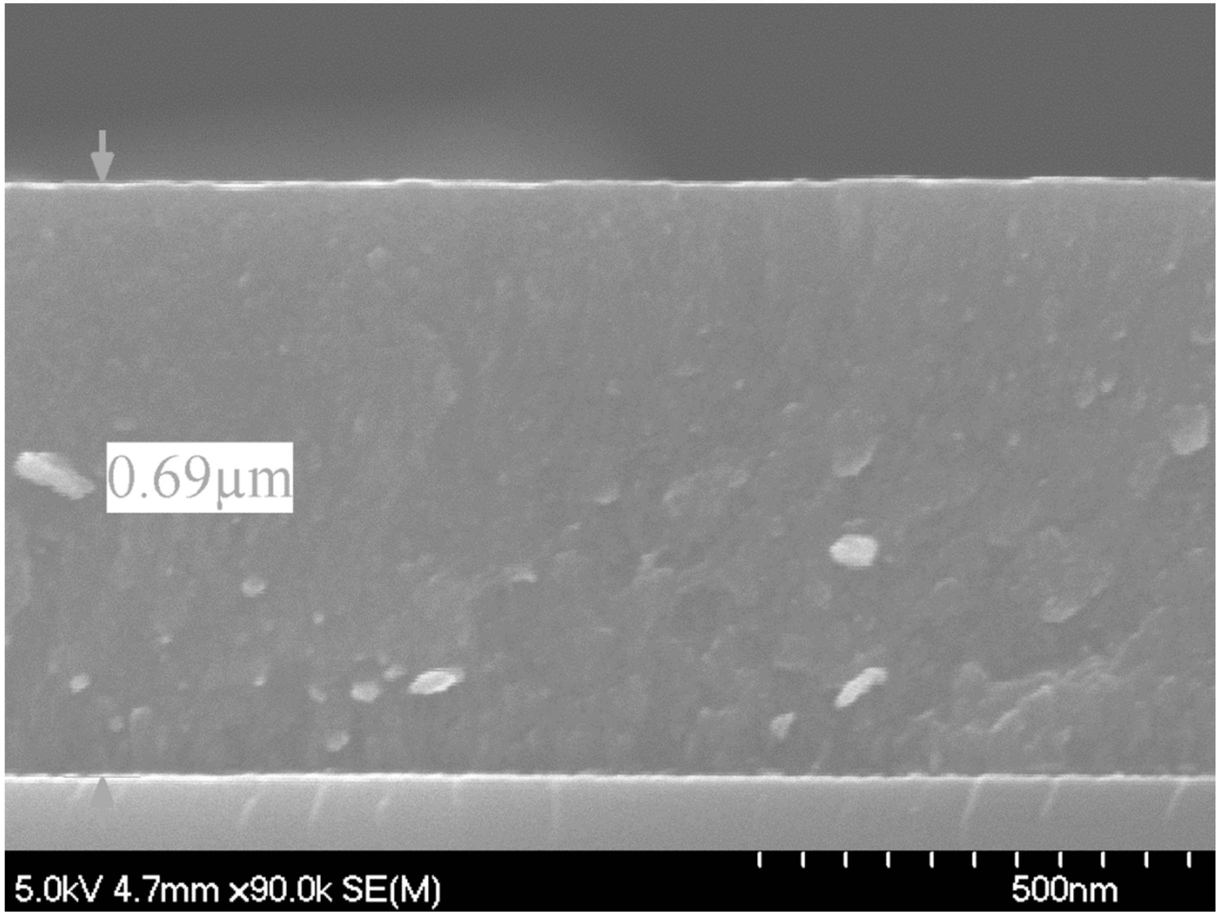
TiSiN by Pulsed DC



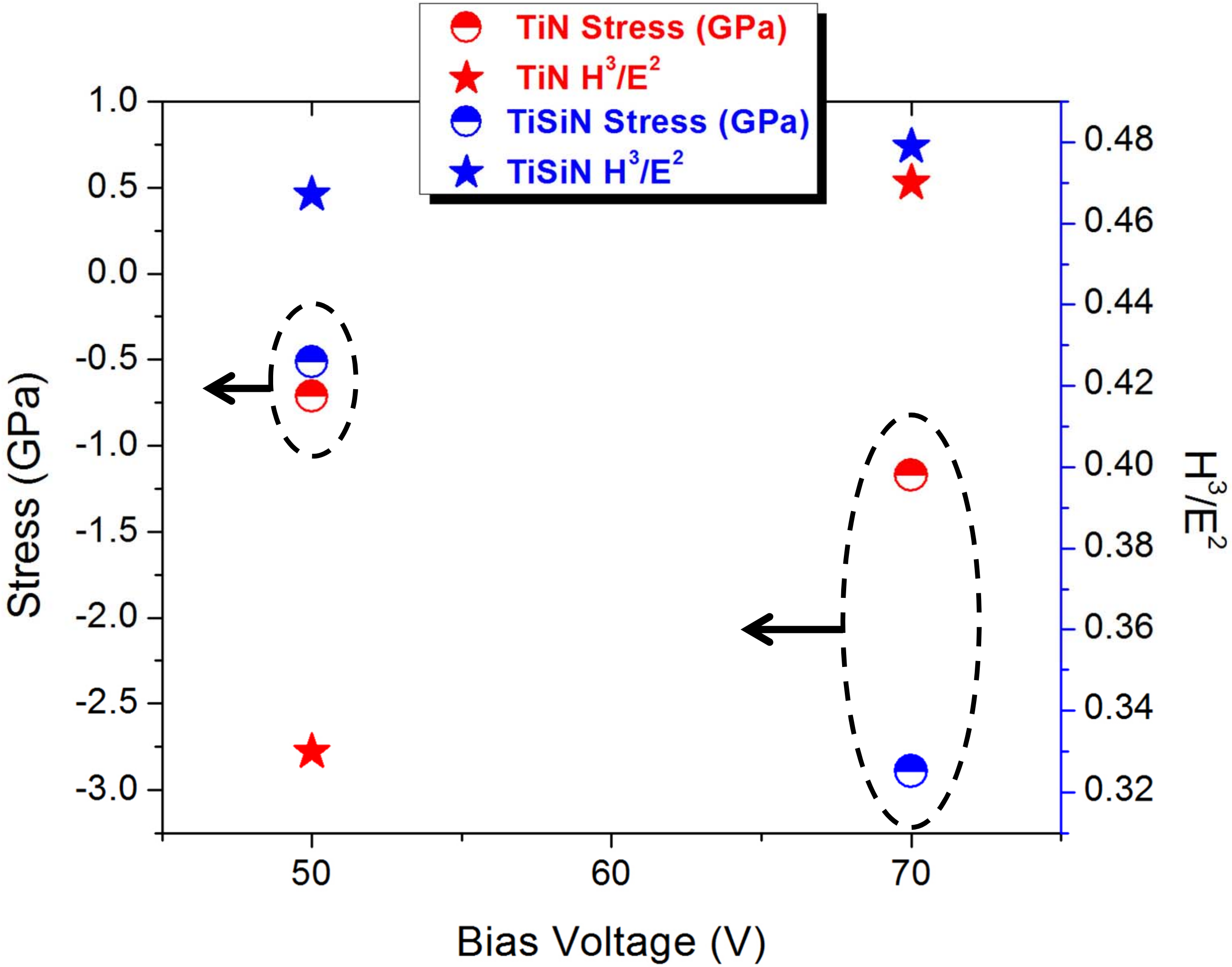
SEM microstructure of TiSiN deposited by HIPIMS

TiSiN by HIPIMS

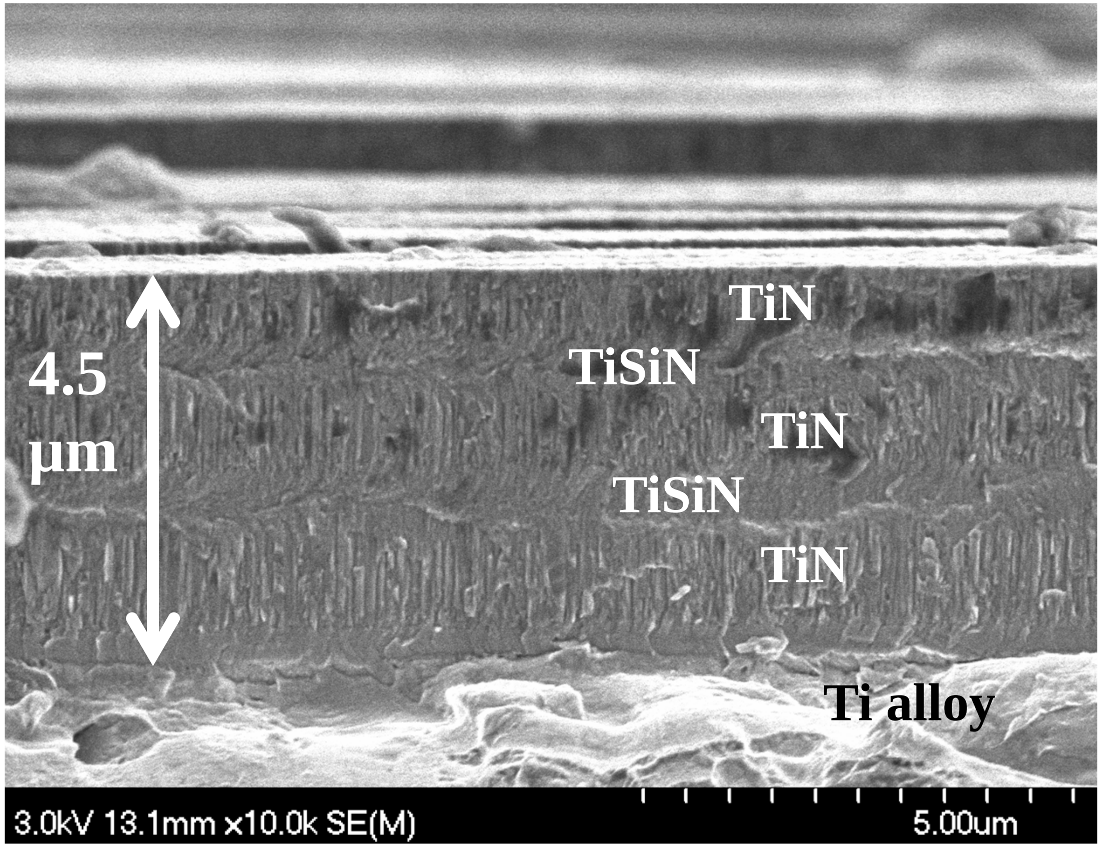
T (μm)	H (GP)	E_r (GPa)	Power (W) Ti	Si
0.7	**37**	**240**	500	**75**

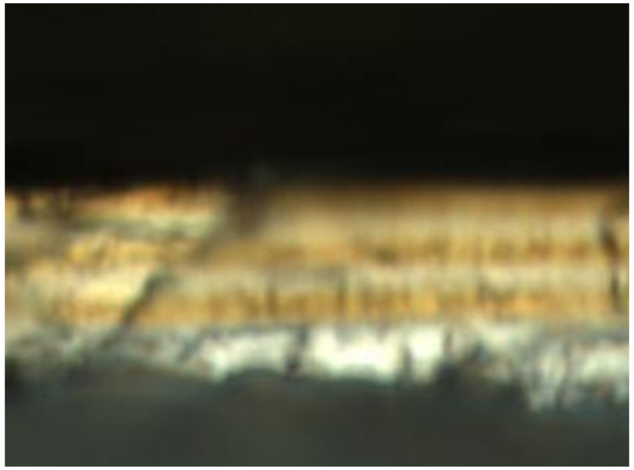


Mechanical Properties and Stress of TiN and TiSiN deposited by HIPIMS



TiN/TiSiN multilayer deposited by HIPIMS





TiN/TiSiN by HIPIMS

T (µm)	H (GP)	E_r (GPa)	Power (W) Ti	Si
4.5	**22**	**200**	500	**75**

Conclusion :

- TiN and TiSiN is successfully optimized by HIPIMS for optimal mechanical properties.

- About 5 µm thick TiN/TiSiN multilayer coatings were deposited by HIPIMS on Ti-alloys substrates.

Near future work include :

- Deposition of thick (> 10 µm) TiN/TiSiN multilayer on various substrates and characterization of microstructure, mechanical and tribological properties .

- Incorporate ***carbon*** during the growth of TiN/TiSiN multilayer in order to improve the coating's elasticity (and LIE resistance?).