Hard nanostructured coatings on plasma nitrided Ti6Al4V

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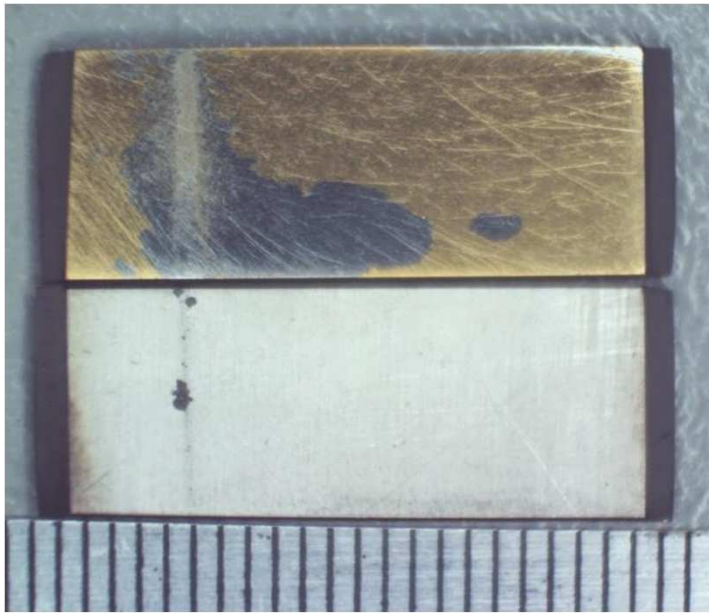
Overview

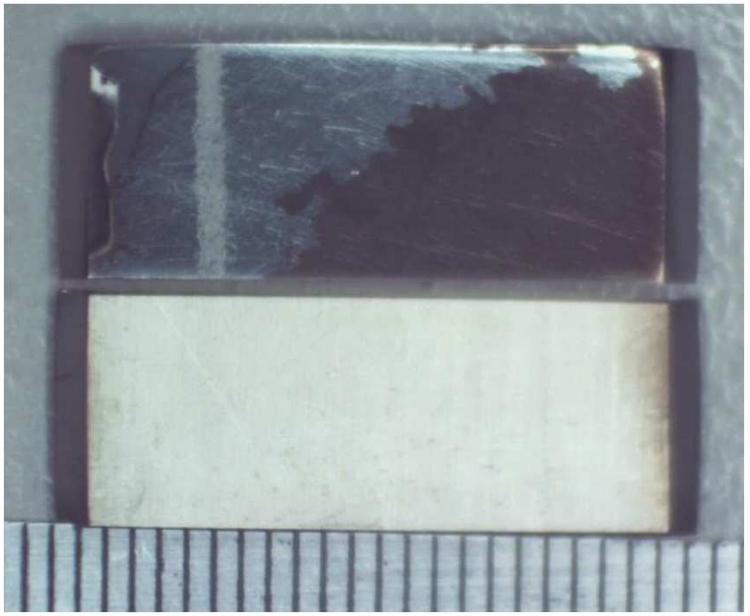
- Problem of coating spallation from substrate after first erosion tests
- Improving coating adhesion to Ti6Al4V by two types of plasma nitriding approaches:
  - RF nitriding
  - HiPIMS nitriding
- Nanocomposite TiSiN and multilayer TiN/Ti coating on HiPIMS nitrided surface
- Water erosion tests of nitrided samples and coated samples with HiPIMS nitrided surface
- Summary and outlook

Coating spallation under water erosion

TiN-TiSiN multilayer



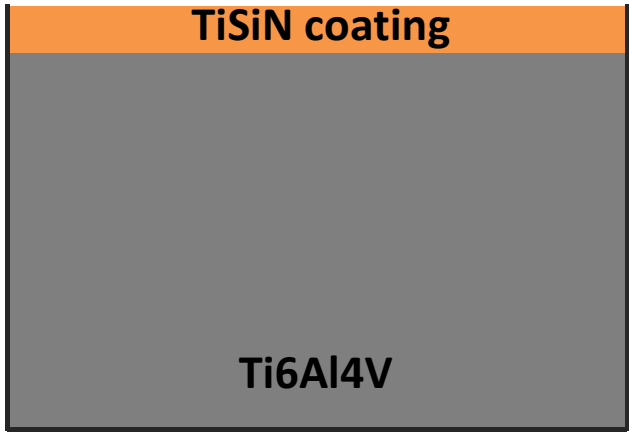
Ti-TiSiN multilayer



Severe spallation of coating after 30 seconds of erosion test!
Problem of coating adhesion to Ti6Al4V!

Erosion time: **30 s**
Nozzle: **400 µm**
Impinging speed: **350 m/s**
Estimated droplets size: **450 µm**
Water pressure: **30 psi**
Water flow: **0.05 l/min**

Problem of depositing hard coating on soft substrate

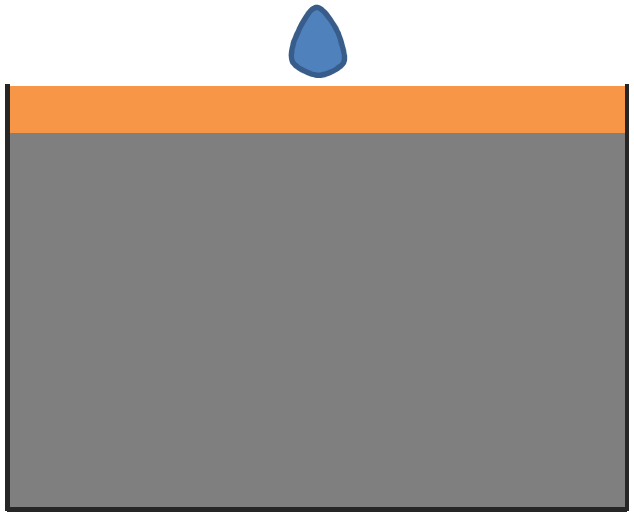


H ~ 37 GPa, E ~ 240 GPa

H ~ 3.5 GPa, E ~ 115 GPa

- soft substrate does not offer good support for brittle coating under high loads
- large difference in elastic modulus between coating and substrate causes high stress on the coating/substrate interface causing poor adhesion and failure during tribological operation
- difference in crystal structure of coating and Ti6Al4V is not favorable for adhesion

Deformation of hard and brittle coating during water impingement



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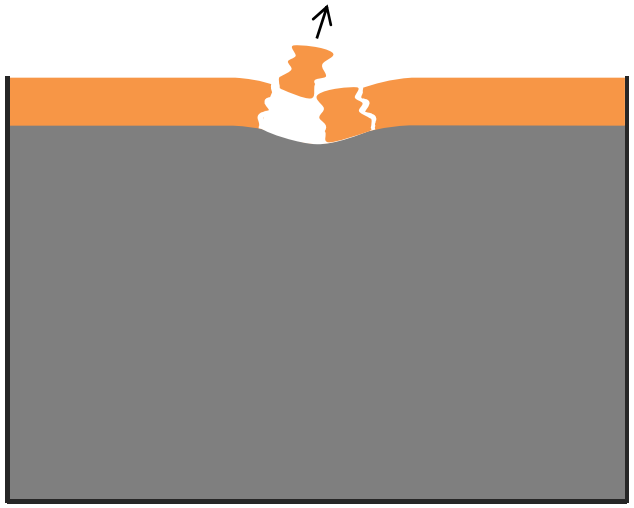

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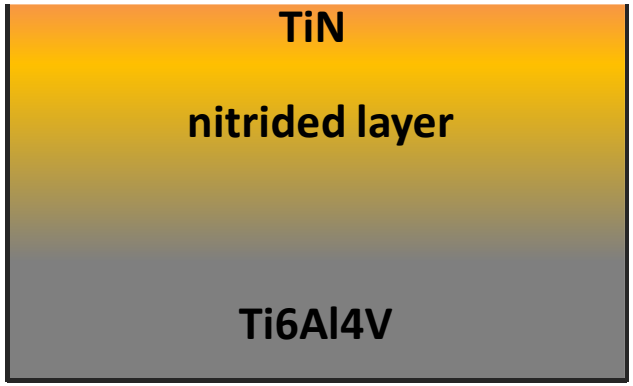
Improving adhesion of coating to Ti6Al4V

Duplex process: plasma nitriding + hard coating

compound layer (TiN and Ti_2N)

diffusion zone



H ~ 20 GPa, E ~ 160 GPa

H ~ 3.5 GPa, E ~ 115 GPa

- nitrided surface improves load-bearing capacity
- nitriding provides more gradual stress distribution from substrate to the coating due to smaller mismatch in shear modulus
- better lattice match and chemical affinity between nitrided surface and nitride coatings improves adhesion
- when coating is removed nitriding prevents fast erosion of substrate

plasma nitriding

Molinari, G. Straffelini, B. Tesi, T. Bacci, and G. Pradelli, *Wear* **203–204,** 447 (1997)
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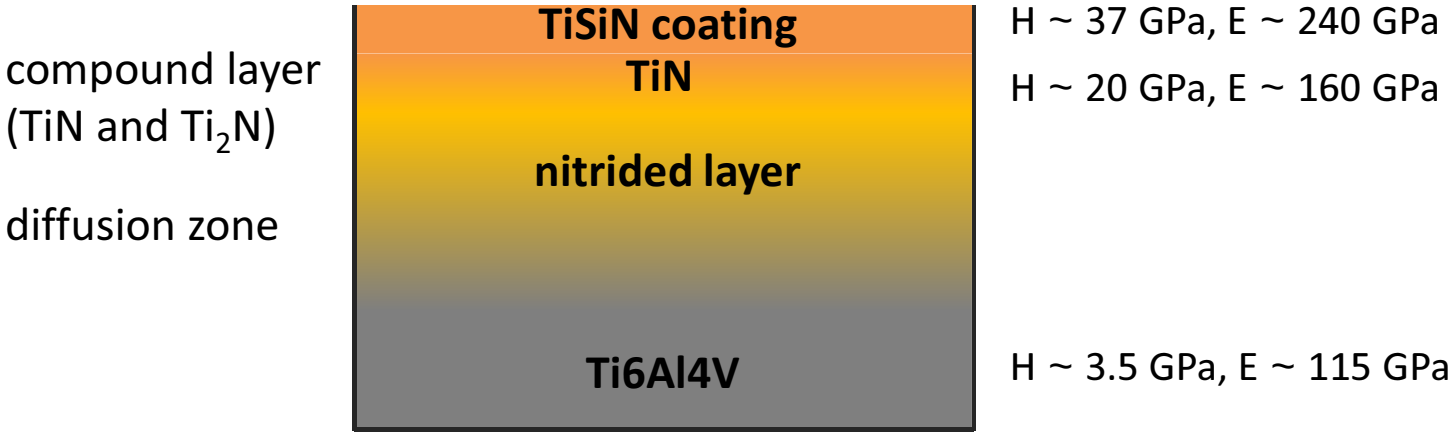

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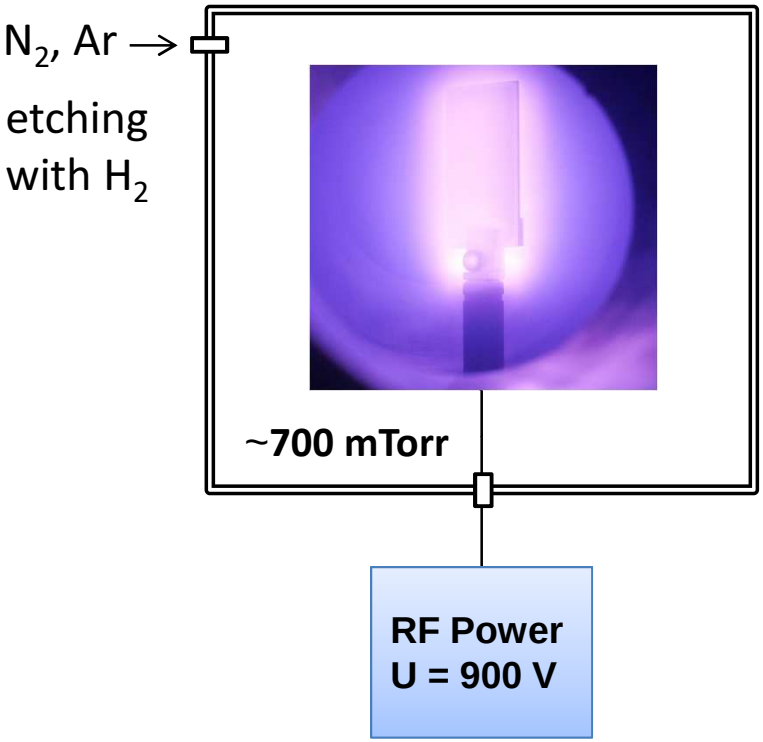
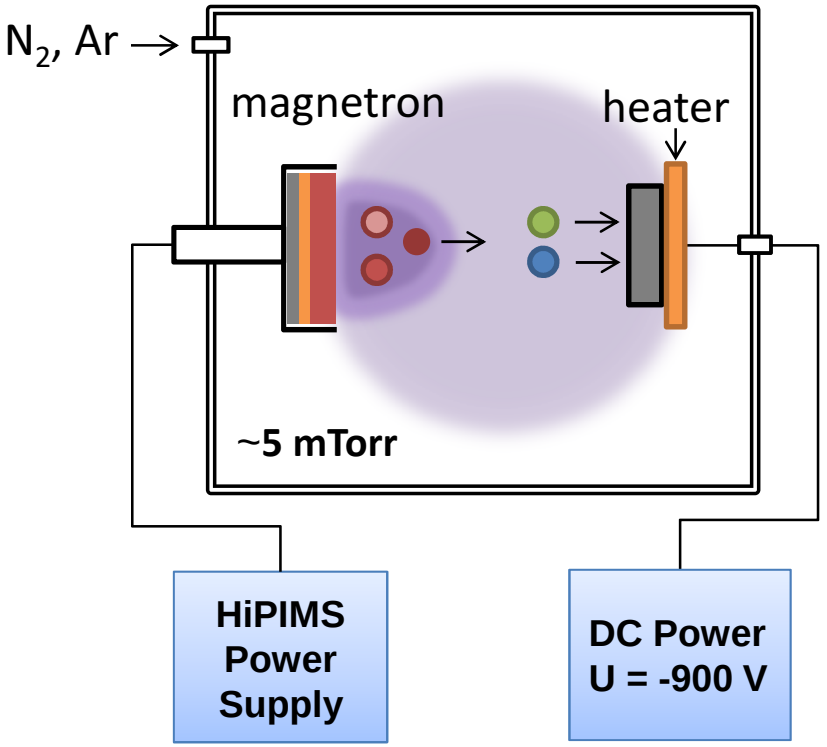
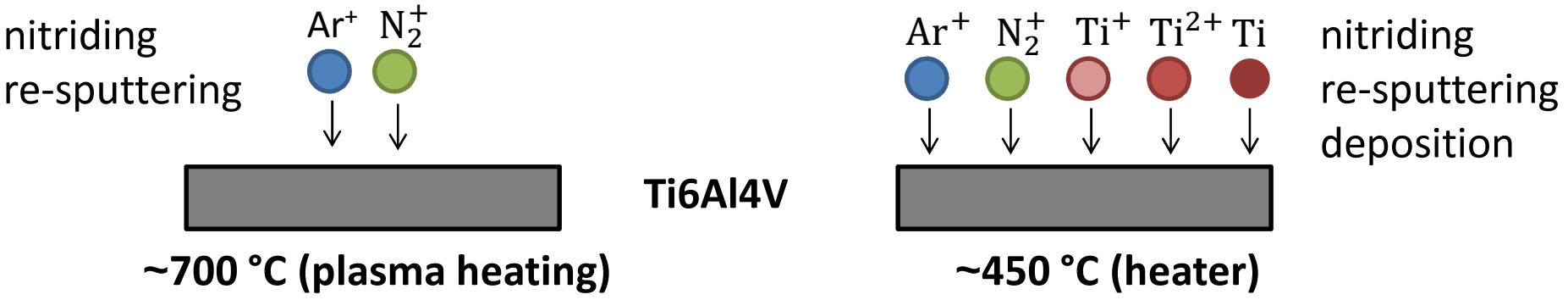
Approaches to plasma nitriding of Ti6Al4V

RF nitriding



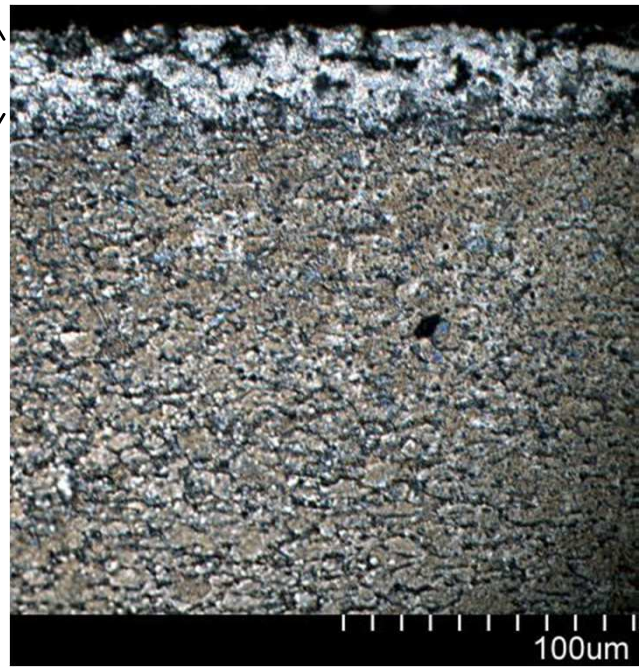
HiPIMS „nitriding“





Nitrided samples by RF and HiPIMS

RF nitriding



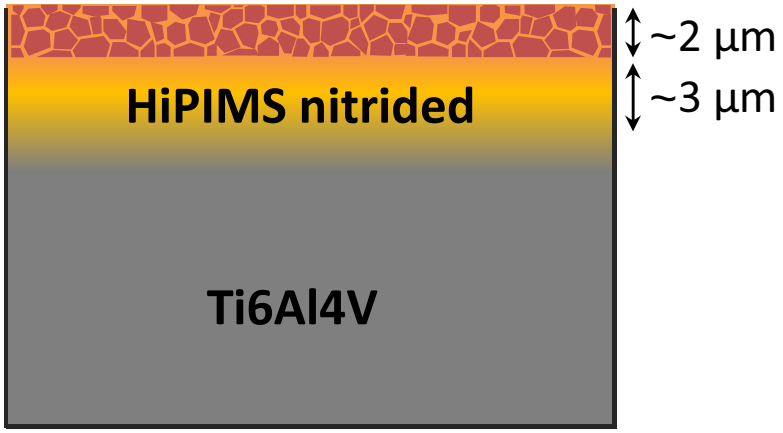
HiPIMS „nitriding“

type of nitriding	temp (°C)	p (mtorr)	ϕ_{Ar} (sccm)	ϕ_{N2} (sccm)	time (h)	voltage (V)	thickness (µm)	H (0.5 N) (GPa)
RF	**700**	**700**	10	90	4	-1000	~30	8-10
HiPIMS	**450**	**5**	35	2	3	-800	~2-3	6-8

Deposition of hard coatings on nitrided Ti6Al4V

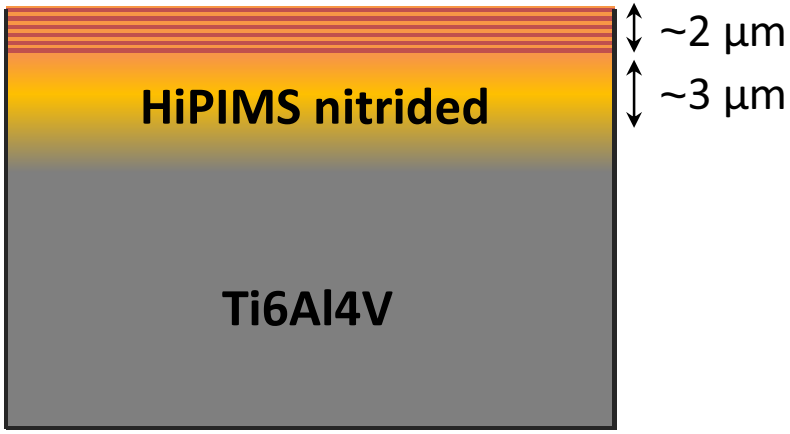
nanocomposite coating

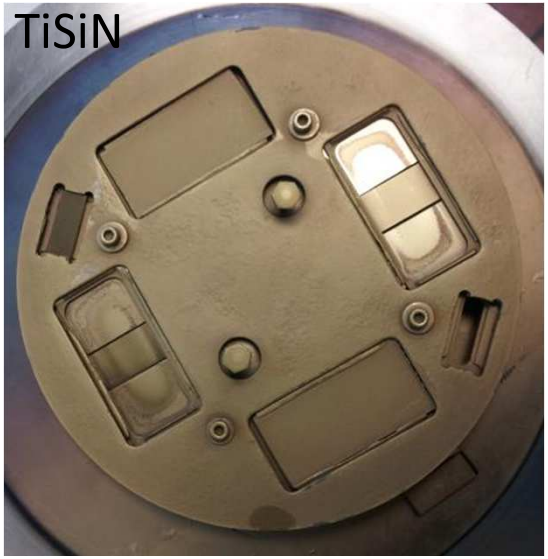
TiSiN



multilayer coating

3×(TiN/Ti)/TiN – 10 layers

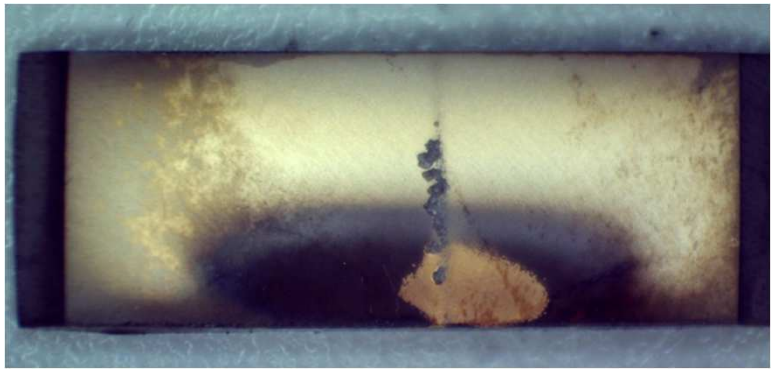




process	TiSiN	TiN/Ti
# of layers	1	10
nitriding time (h)	2	2
deposition time (h)	4	3.5
deposition temp (°C)	450	450
p (mtorr)	5	5
ϕ_{Ar}: ϕ_{N2}	17:1	17:1
substrate bias (V)	-45	-45
total thickness (µm)	~5	~5
hardness	35	22
elastic modulus	240	190

Water erosion test of nitrided samples

RF nitriding



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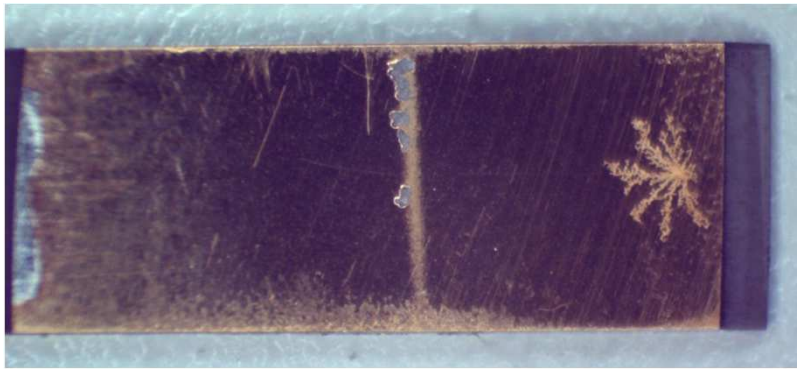
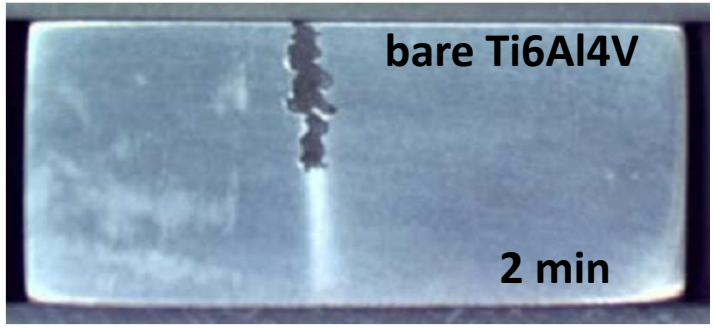
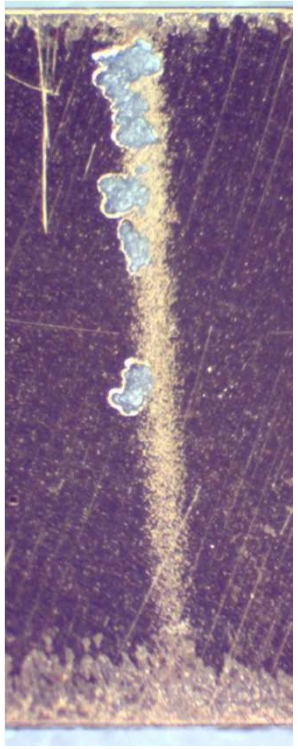
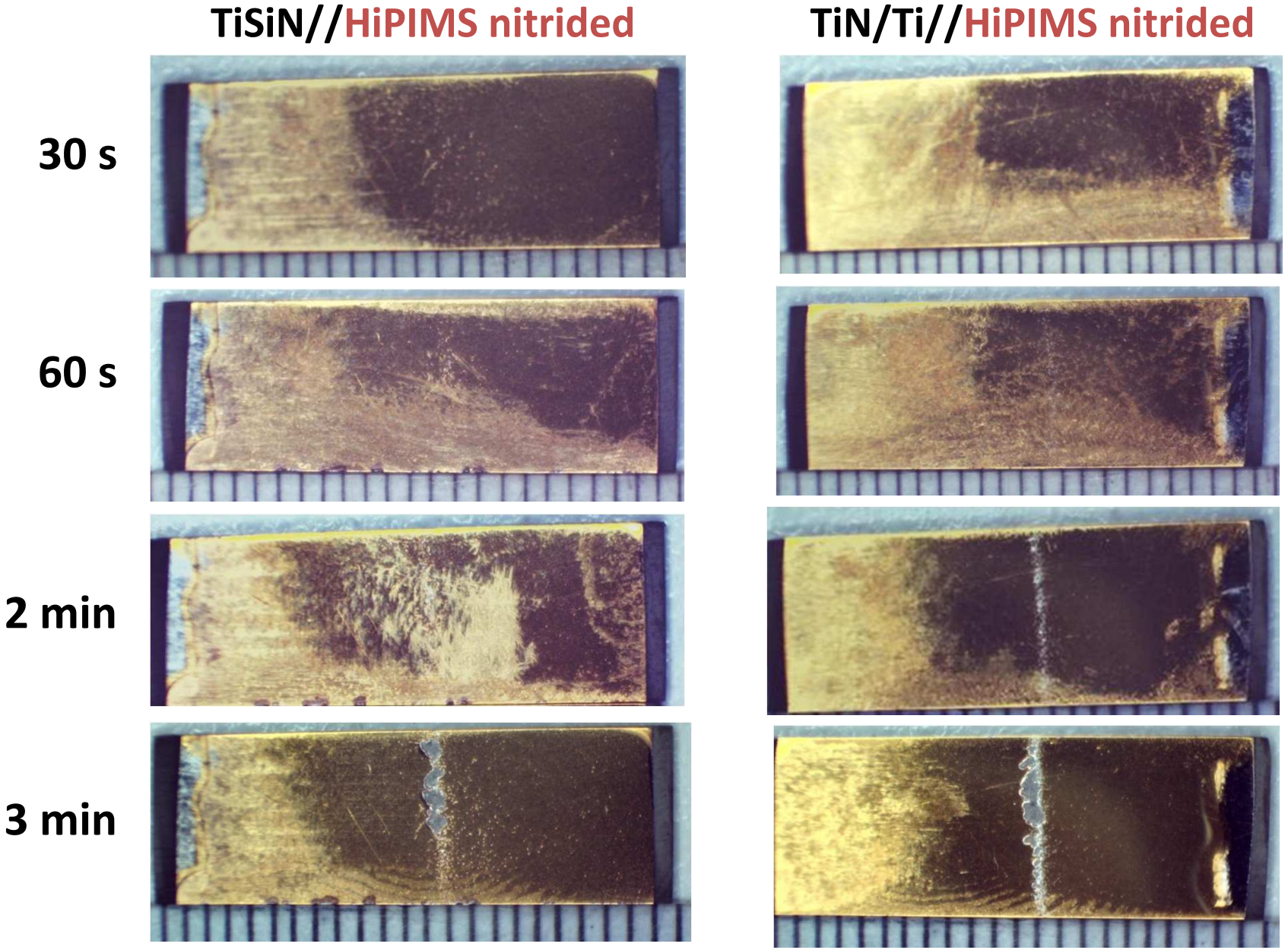




Erosion time: **2 min**
(30s + 30s + 60s)
Nozzle: **400 µm**
Impinging speed: **350 m/s**
Droplets size: ~**450 µm**
Water pressure: **30 psi**
Water flow: **0.05 l/min**



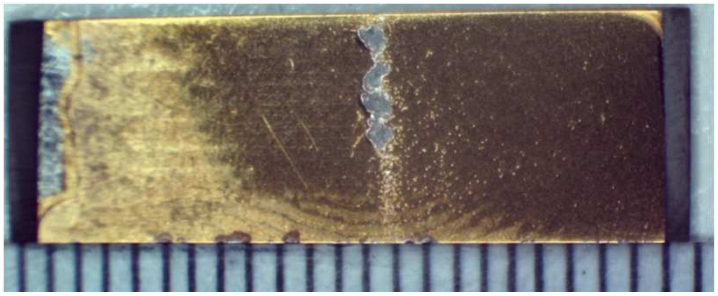
Water erosion test of coated samples

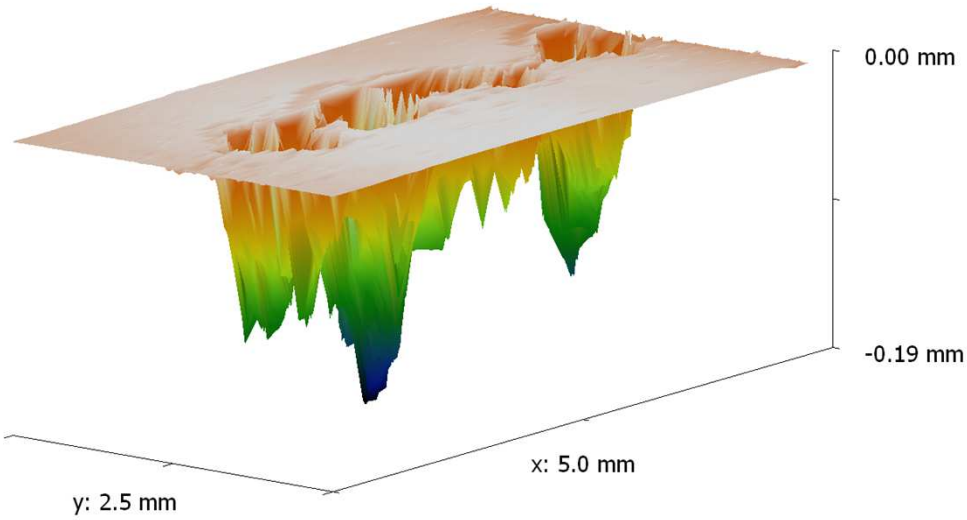


speed: **350 m/s**, nozzle: **400 µm**, droplets size: **450 µm**, water pressure: **30 psi**, water flow: **0.05 l/min**

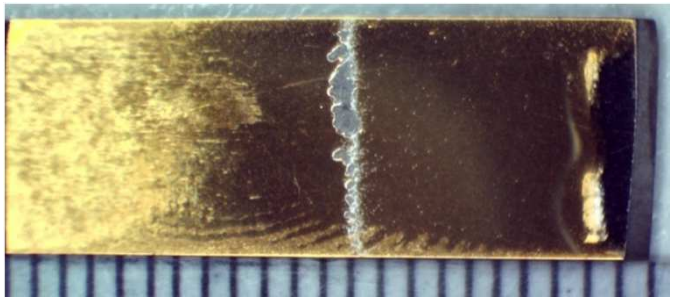
Erosion track of coated samples

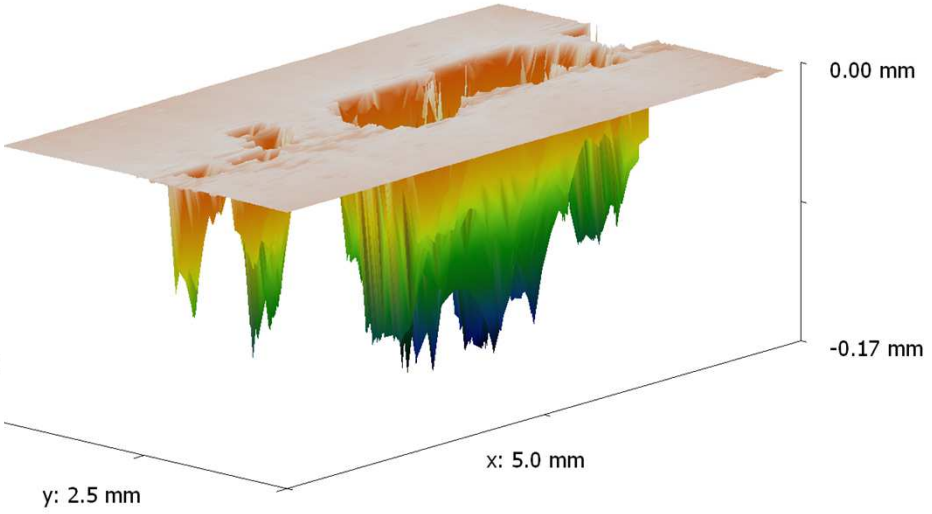
TiSiN//HiPIMS nitrided





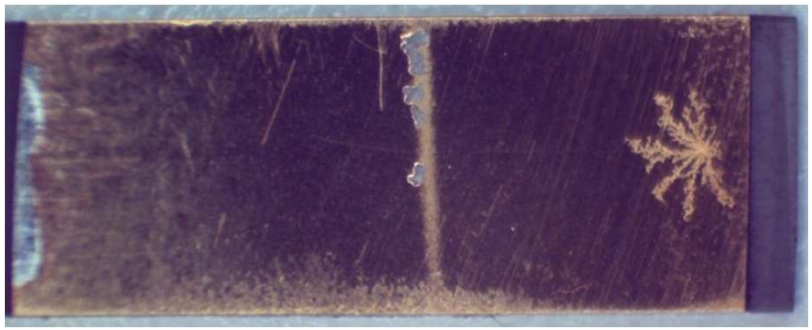
TiN/Ti//HiPIMS nitrided



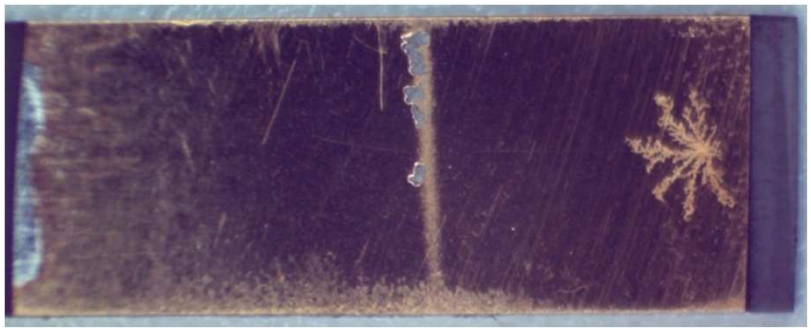


Comparison of erosion tracks on coated and nitrided samples after 2 minutes test

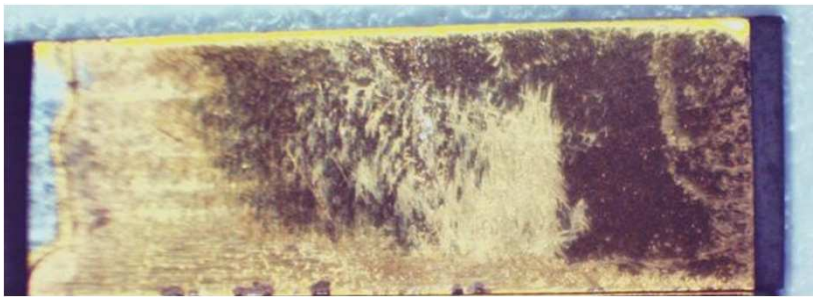
HiPIMS nitrided



HiPIMS nitrided



TiSiN//HiPIMS nitrided



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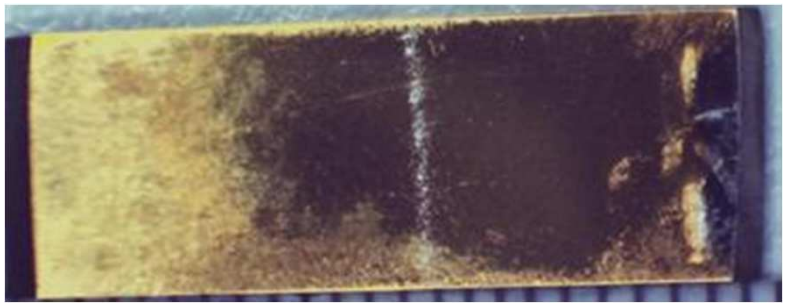

Summary

- **plasma nitriding** of Ti6Al4V was used to improve adhesion and load-bearing capacity for hard coatings
- two approaches for plasma nitriding were chosen:
  RF and HiPIMS nitriding
- **TiSiN nanocomposite** and **TiN/Ti multilayer** coatings were deposited over HiPIMS nitrided substrate
- nitriding alone improves water erosion resistance
- coated samples with HiPIMS nitrided layer show better water erosion resistance compered to HiPIMS nitrided samples

Plan of activities until the end of year

- **mechanical, structural and chemical analysis** of nitrided layer and coatings
- continuation of improving plasma nitriding: **DC nitriding**
- deposition of thick TiSiN nanocomposite and TiN/Ti multilayer coating (**~10 µm**) on RF or DC and HiPIMS nitrided surface
- incorporation of **carbon** into TiSiN coating for increasing H^3/E^2 ratio and deposition of thick coating (~10 µm) on nitrided surface

Research Activity	Progress	Risk of going beyond 2013
Literature Review	finished	no
Materials Selection	finished	no
Process Development	finished	no
Coating Characterization	in progress	no
Testing and optimization	in progress	no