Applications of Surface Engineering in FFF 3D Printer Extrusion Systems

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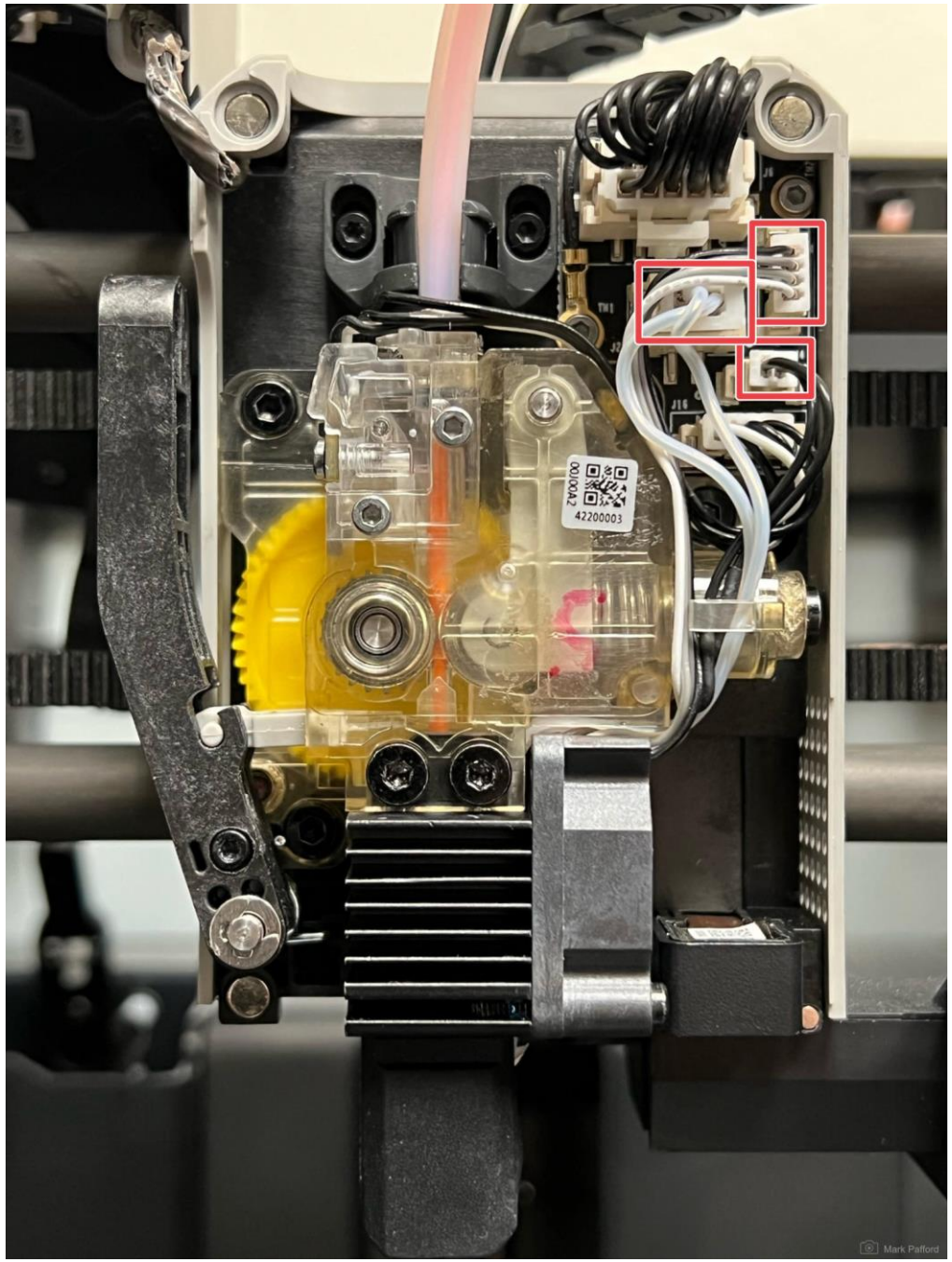
s232690

Advanced Surface Engineering Exam Presentation

Contents

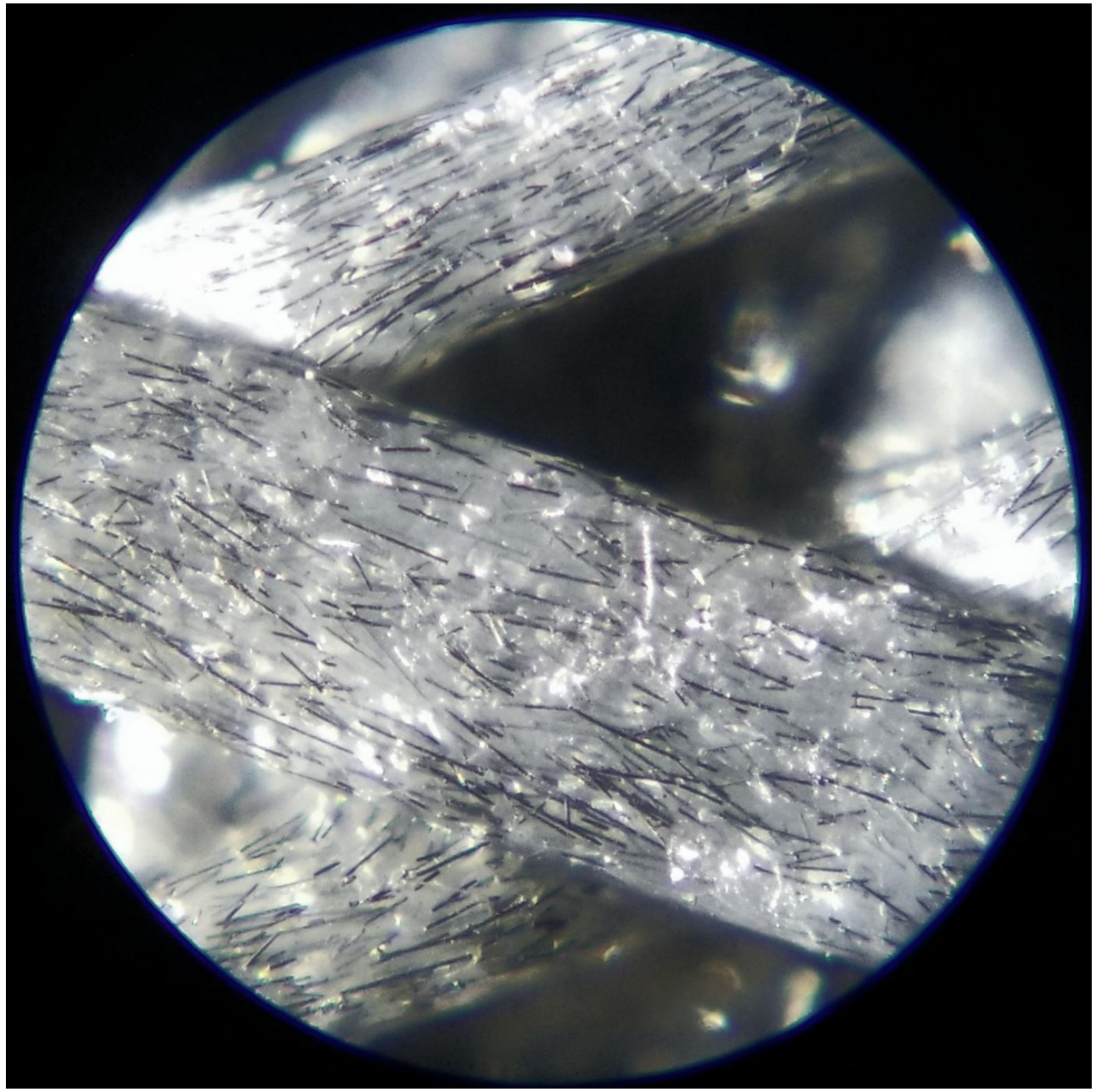
- Introduction to the problem – wear of components of the extrusion system from fiber reinforced filaments
- Existing solutions to wear issues
- Benefits of TiN coating for increased wear resistance
- Details about TiN coatings
- How are TiN coatings applied


AMS
X1-Carbon
Bambu Lab

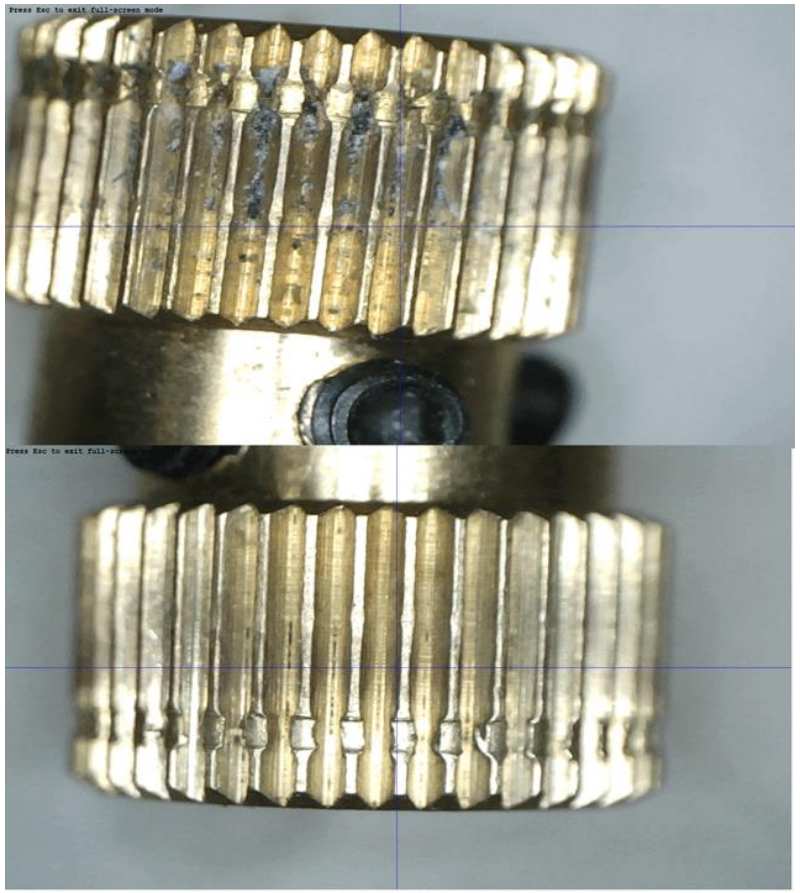

42200003
Mark Pafford

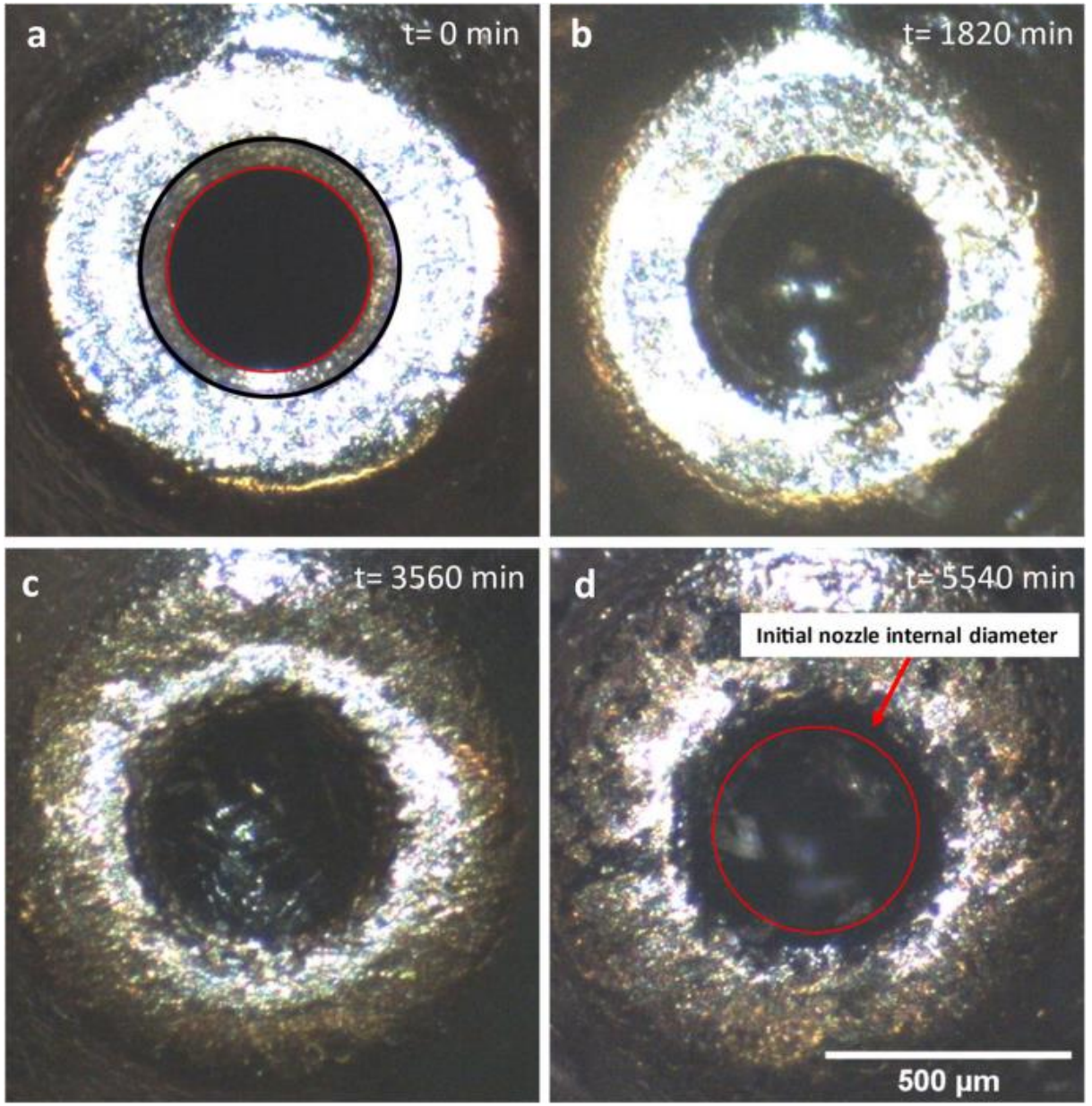
Typical setup

Fiber filled filament



Wear issues




a
t= 0 min
b
t= 1820 min
c
t= 3560 min
d
t= 5540 min
Initial nozzle internal diameter
500 µm

Existing solutions

Hardened Steel

TiN benefits

- Higher hardness
  (~2,200 HV vs steel ~700 HV)
- Lower friction
  (0.4–0.6 vs steel ~0.6–0.8.)
- Therefore less wear from
  fibers and additives

Comparison of nozzle / drive gear materials

Material	Vickers Hardness (HV)	Abrasive Wear Resistance	Toughness (Resistance to Fracture)
Brass (Cu alloy)	~130 HV	Poor: easily gouged & micro-cut by fibers	High ductility but soft
Hardened Steel (tool steel)	600–800 HV	Good: minimal wear at kg-scale	High metallic toughness
TiN-coated Nozzle (ceramic film)	1800–2100 HV	Excellent: fibers cannot scratch	Low (brittle coating)
Carbon Fiber (abrasive filler)	800–1100 HV	N/A (abrasive agent)	Low (brittle fibers)

How is TiN applied

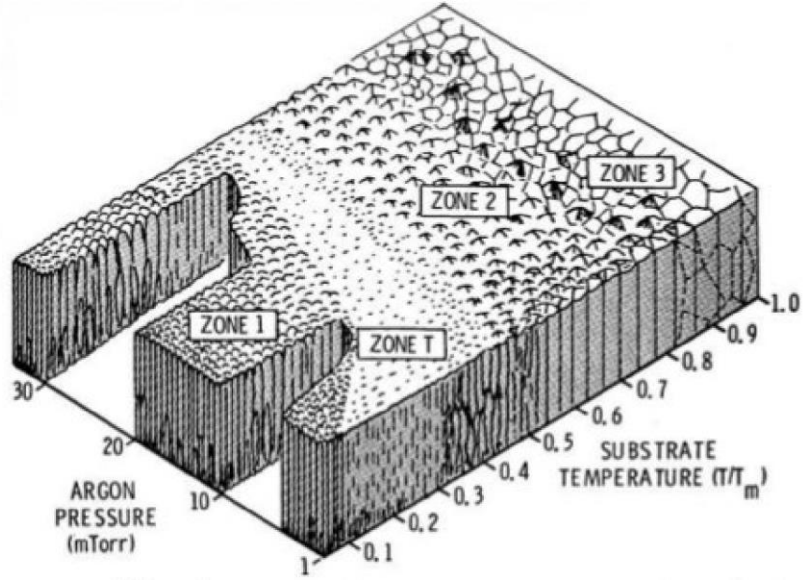
- PVD – (magnetron) sputtering of Titanium with Nitrogen gas
- CVD – titanium chloride + ammonia

- CVD results in a thicker coating than PVD
- CVD is more accommodating for difficult geometries
- A modern 3D printer nozzle has a hole with an aspect ratio of ~35

PVD TiN coating

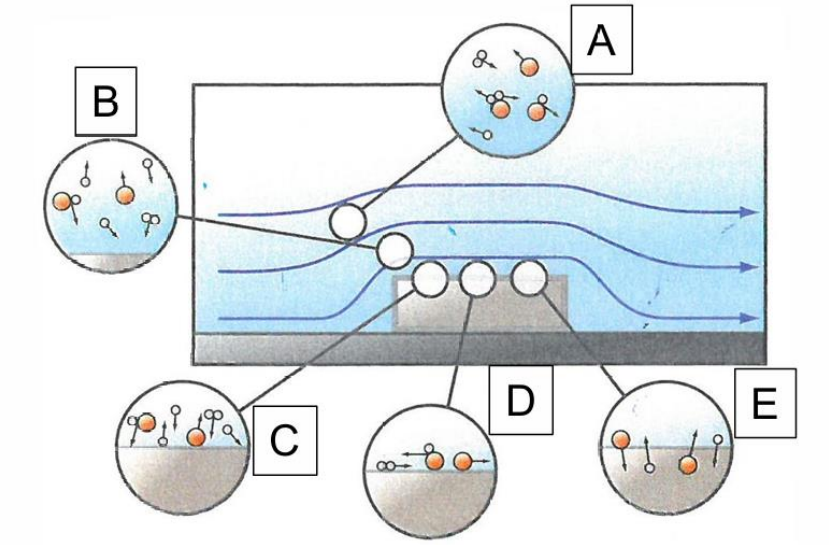
- Reactive PVD
  (nitrogen as the reactive gas)
- Slow deposition
  (but only thin layer needed)
- Tailoring of microstructure →
- BIQU specifically calls the extruder gear ‘nano coated’

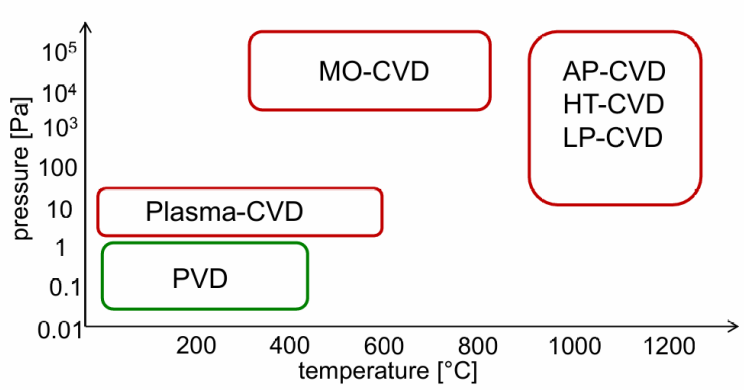
Coating	Sputter deposition rate [µm/h]	
	Conventional	Magnetron
TiN	0.9	12.6



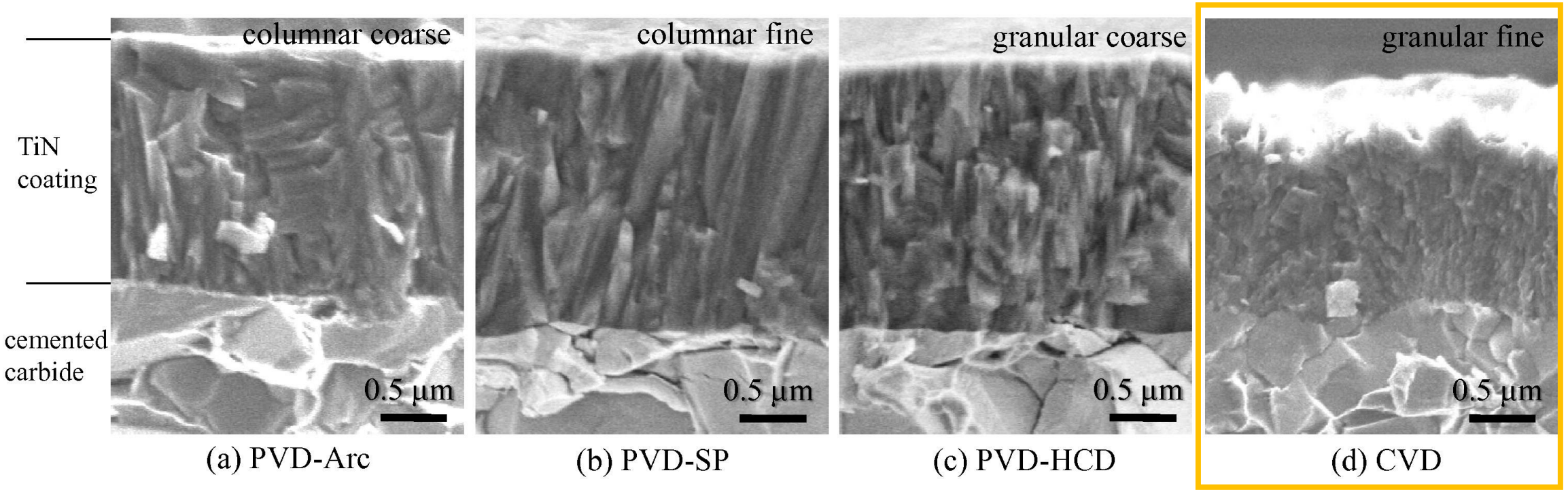
CVD TiN coating

- More homogenous application (although not completely)
- More mass production friendly
- Much higher temperature





Comparison of PVD vs CVD TiN coating



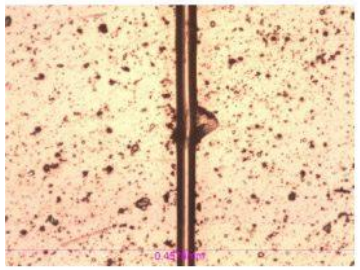
(a) PVD-Arc (b) PVD-SP (c) PVD-HCD (d) CVD

Weaknesses of TiN coating

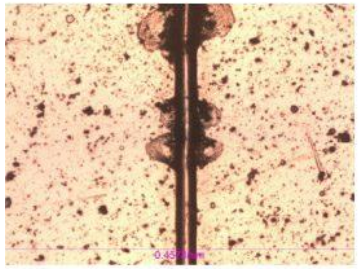
- Scratch test
- Unlikely to face such loads in this application

SAMPLE A

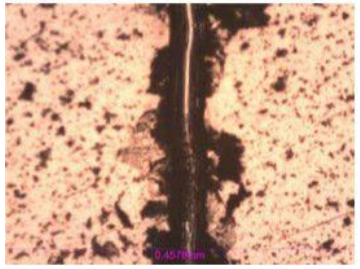
L_{c1} = 3.25 N



L_{c2} = 3.72 N

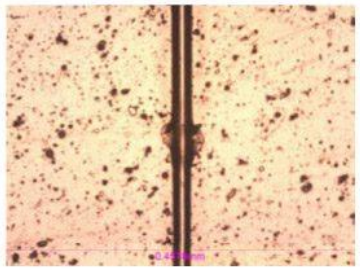


L_{c3} = 8.23 N

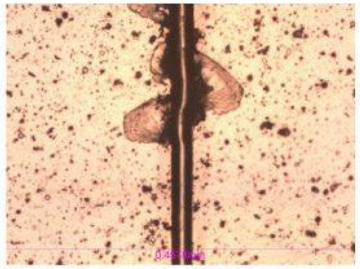


SAMPLE B

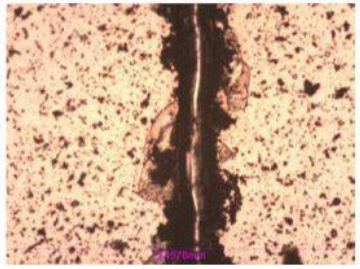
L_{c1} = 3.31 N



L_{c2} = 3.89 N

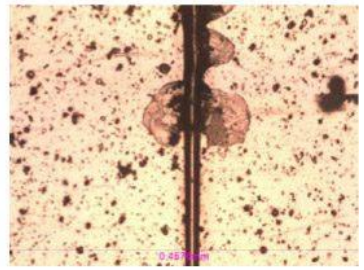


L_{c3} = 7.81 N

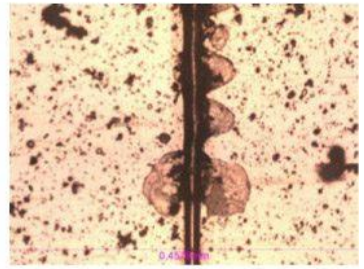


SAMPLE C

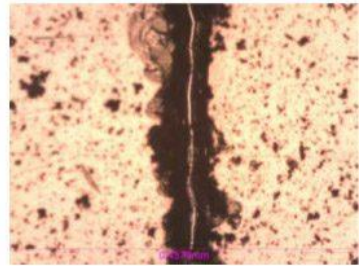
L_{c1} = 2.23 N



L_{c2} = 2.47 N



L_{c3} = 6.12 N



Sources of images

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- CNC kitchen
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