SAND2019-3814C

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"To Coat" or "Not to Coat" for Friction and Wear Control

Keynote Panel Discussion

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U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

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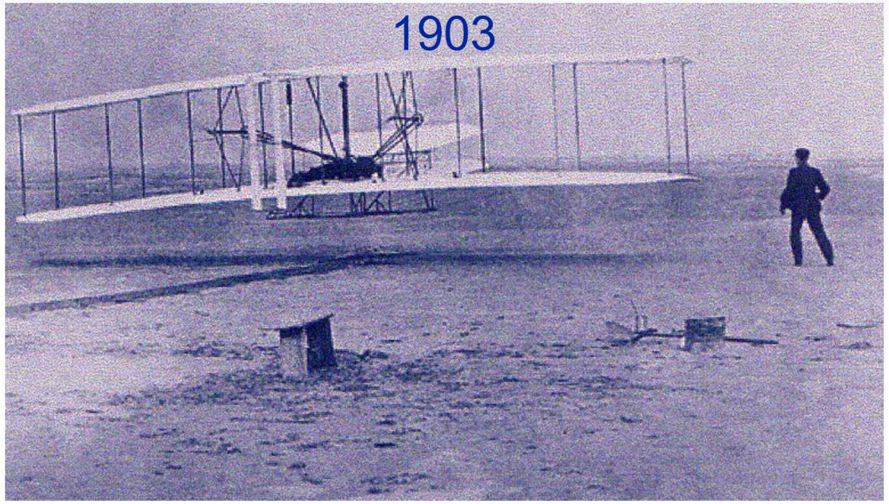
“To Coat” or “Not to Coat”

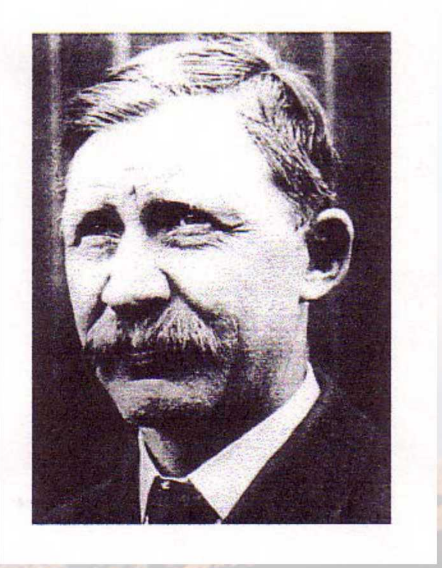
- In addition to suitable friction and wear characteristics, a material for a *tribocomponent* (whether it is bearing or a brake lining) must have a precise balance of physical and mechanical properties: thermal expansion, damping capacity, conformability, strength, stiffness, and fatigue life.

✓ It appears that this single most crucial materials design criterion was taken into account by Wright Brothers and their mechanic Mr. Charles Taylor, while building their engine that powered the historic flight at Kitty Hawk, little over a century ago.

- But it is somewhat ironic that in modern times, the approach for designing a moving mechanical assembly has been to identify the lubrication strategy after final decisions on materials selection and fabrication routes have already been put in place.

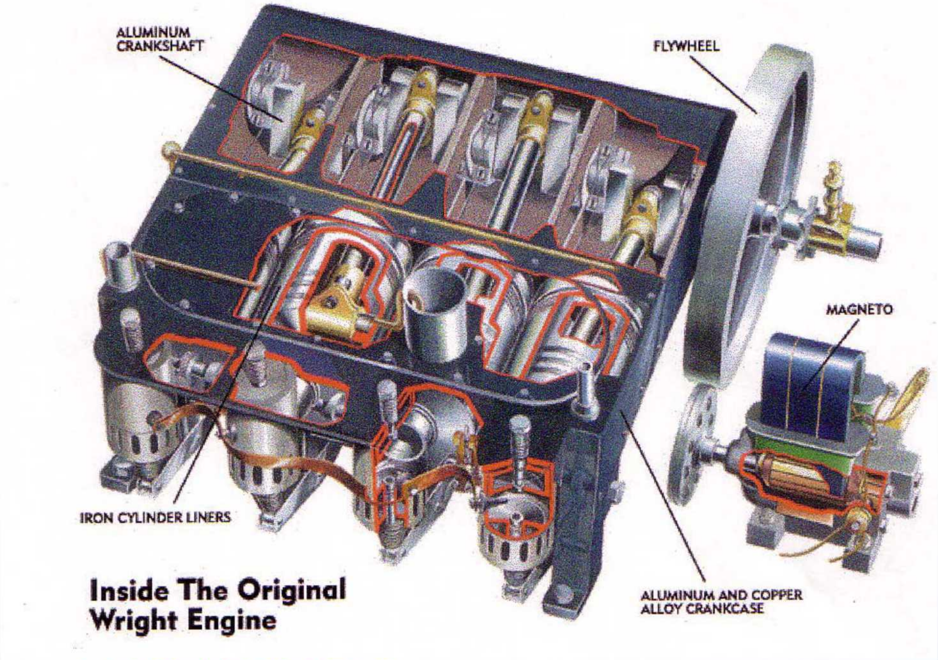
The Saga of Wright Brothers’ Engine and the birth of liners





Mr. Charles Taylor (Mechanic) Considered replacing Cast Iron with Al-Cu

- The Brothers needed an Engine with 8 HP weighing <180 lbs

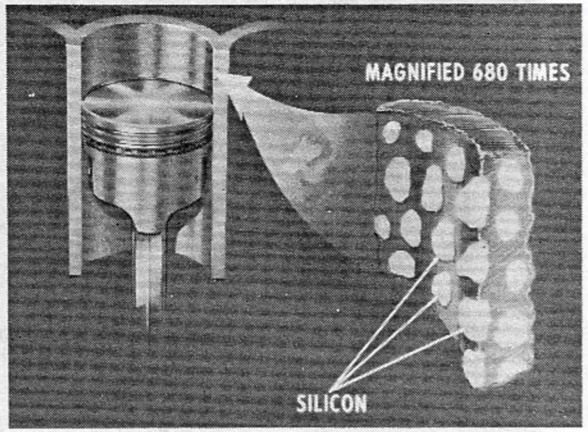


- 16 HP-12HP 178 lbs
- The Brothers used the extra weight allowance to strengthen the wings and frame
- But Al has a tendency for seizure and galling in the absence of complete fluid film lubrication

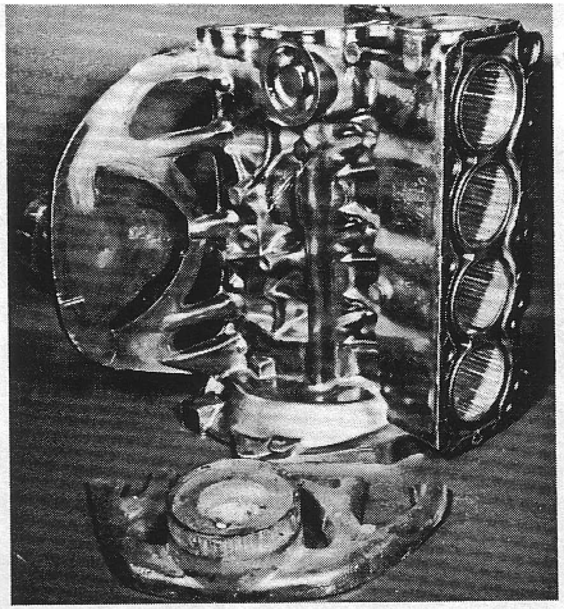
1970's

The (Short) Legacy of the Vega Engine: No Coating

Great Concept, but----?



Silicon surface cylinder bores



Vega engine block as removed from die

BASIC SPECIFICATIONS

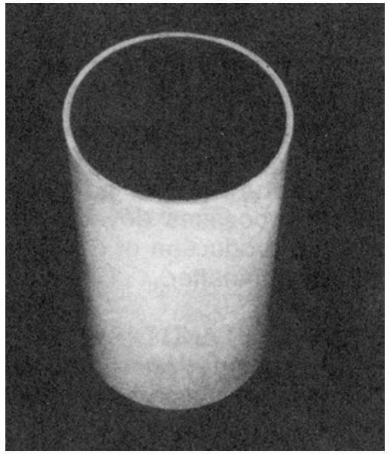
VEGA 2300–140 cu in. Overhead Cam 4-cyl Engine

GENERAL	
Type	In-Line OHC 4-cyl (L-4)
Gross horsepower	
Standard engine	90 at 4600-4800
Optional engine	110 at 4800
Gross torque	
Standard engine	136 at 2400
Optional engine	138 at 3200
Compression ratio	8.00:1
Bore and stroke	3.501 X 3.625
Firing order	1-3-4-2
Engine installation angle	3 deg 50 min
Fuel	Regular leaded and nonleaded 91 Octane
Carburetor	
Standard engine	One-barrel, Monojet
Optional engine	Two-barrel, downdraft
CYLINDER BLOCK	
Material	Die-cast high-silicon aluminum alloy
Bore spacing (C/L to C/L)	4.00
Number of bulkheads	Five

The Vega 2300 Engine, SAE 710147

Integrally Cast MMC Cylinder: Honda Corporation

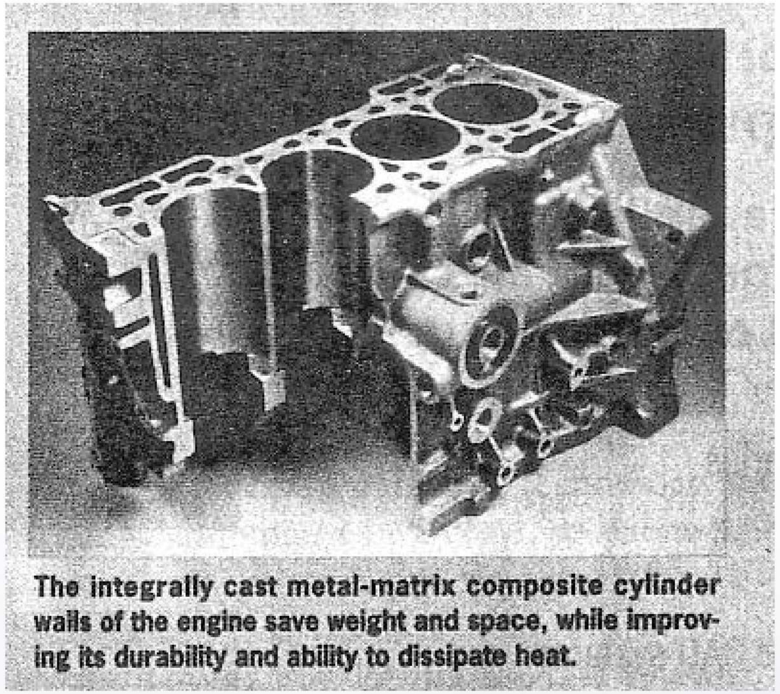
"No Coating" Success Story



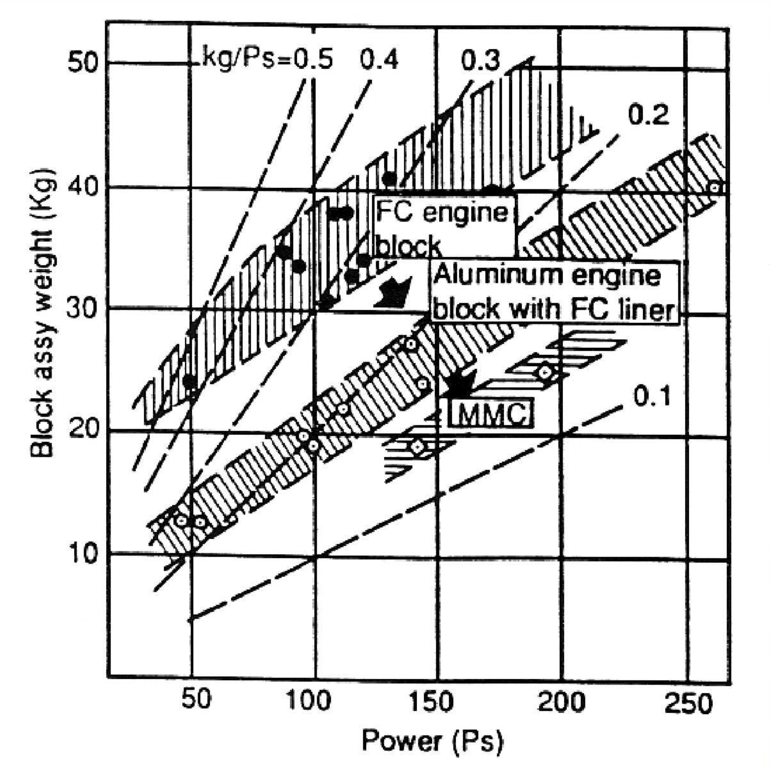
Preform

A porous hybrid material made out of Short alumina and Carbon fibers

- **Ceramic "preform" production**
- **Pressure casting process**
- **Honing**



- **Hybrid preforms: Carbon for thermal conduction, Aluminosilicate for strength**
- **Honing to minimize direct contact between Al and the piston ring**



The new engine block features higher performance, further compactness and weight reduction compared to cast-iron engine blocks and those made out of Al alloy with cast-iron liners

First introduced in Honda Prelude

M. Ebisawa et. al, "The Production Process for MMC Engine Block", SAE 910835

S. V. Prasad and R. Asthana, Tribology Letters, 17 (2004) 445-453

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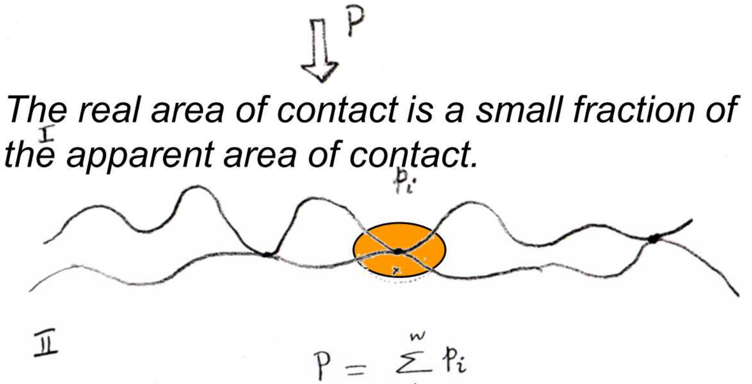
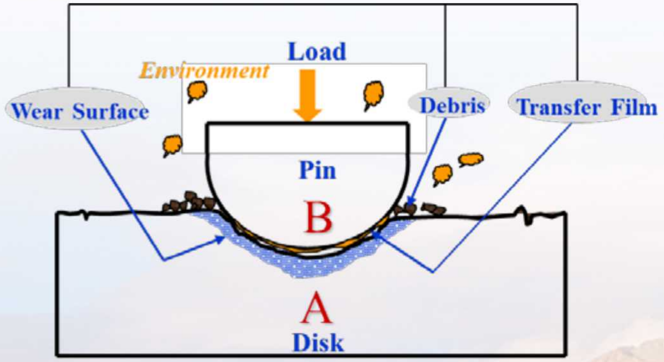
Fundamental Considerations

Engineering surfaces are never flat

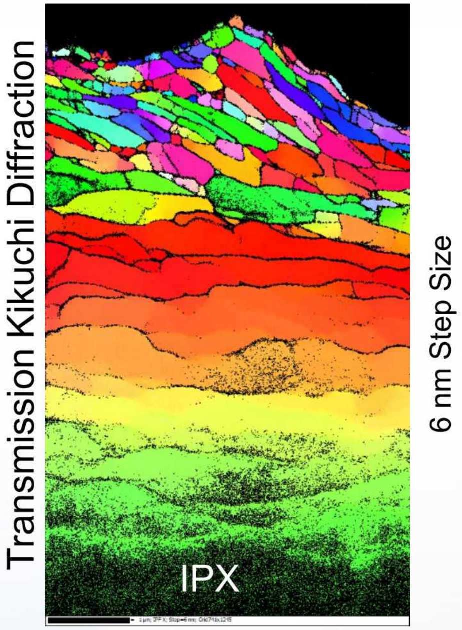
The real area of contact is a small fraction of the apparent area of contact.



Contact will be at asperity level

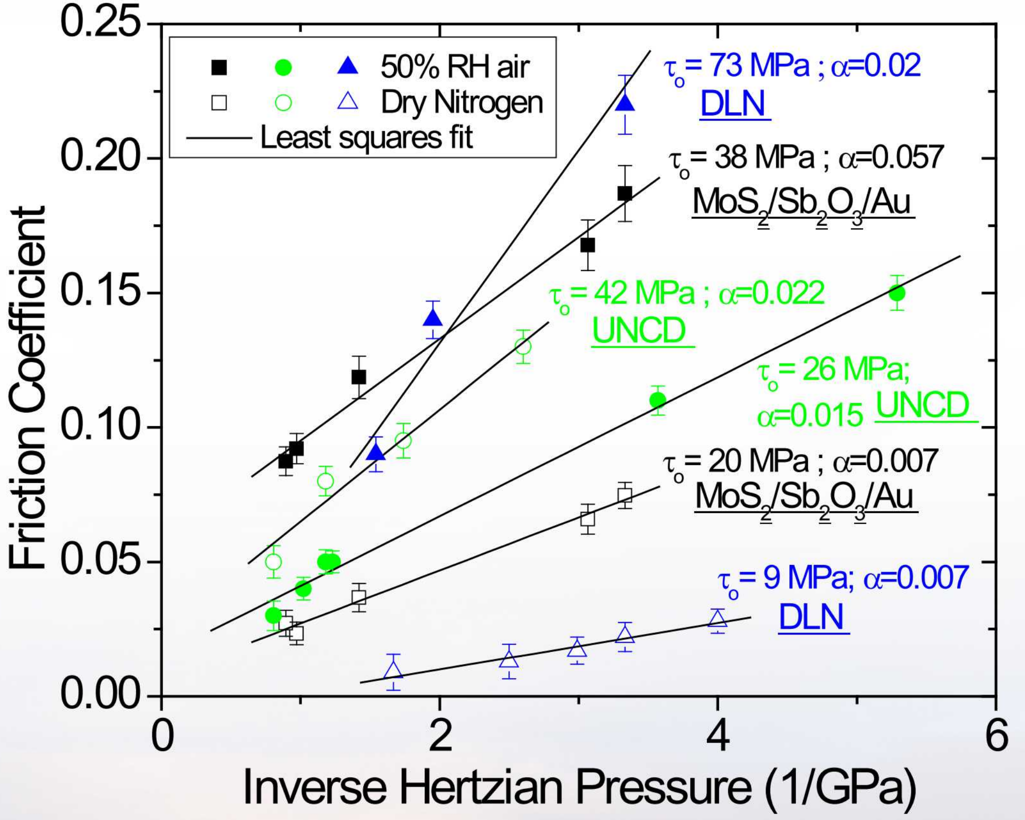


- Plastic deformation under contacting asperities
- Diffusion across the interface



Sliding-induced recrystallization in single crystal Nickel

Solid Lubricants



- Non-Amontons behavior
- Environmental dependence

T. W. Scharf and S. V. Prasad, Solid Lubricants: A Review, J. Maters. Science (2013) 48:511-531

S. V. Prasad, J. R. Michael and T. R. Christenson, Scritpta Mater 48 (2003) 255

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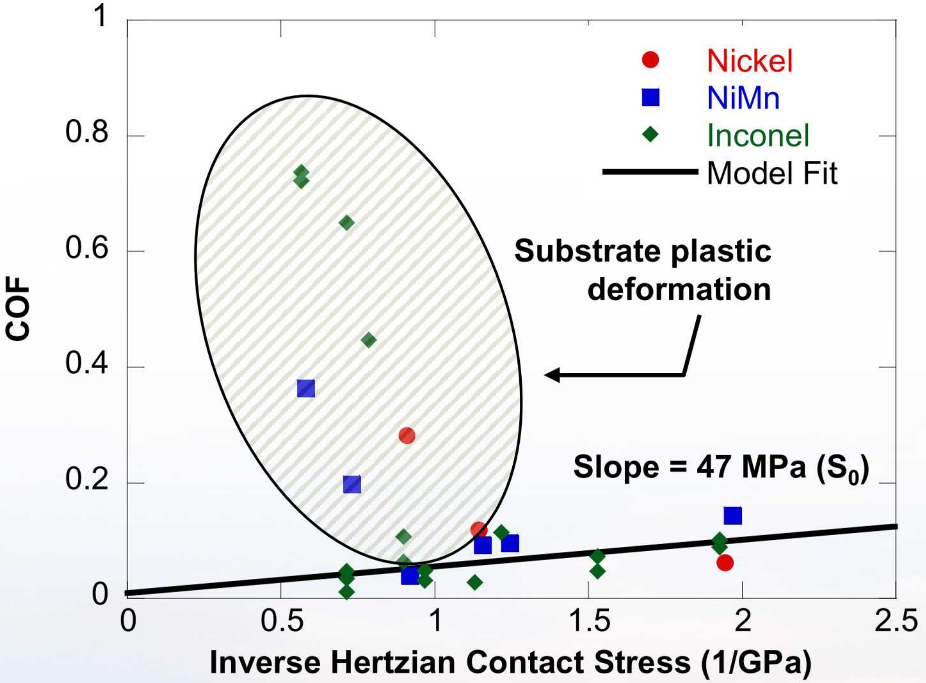
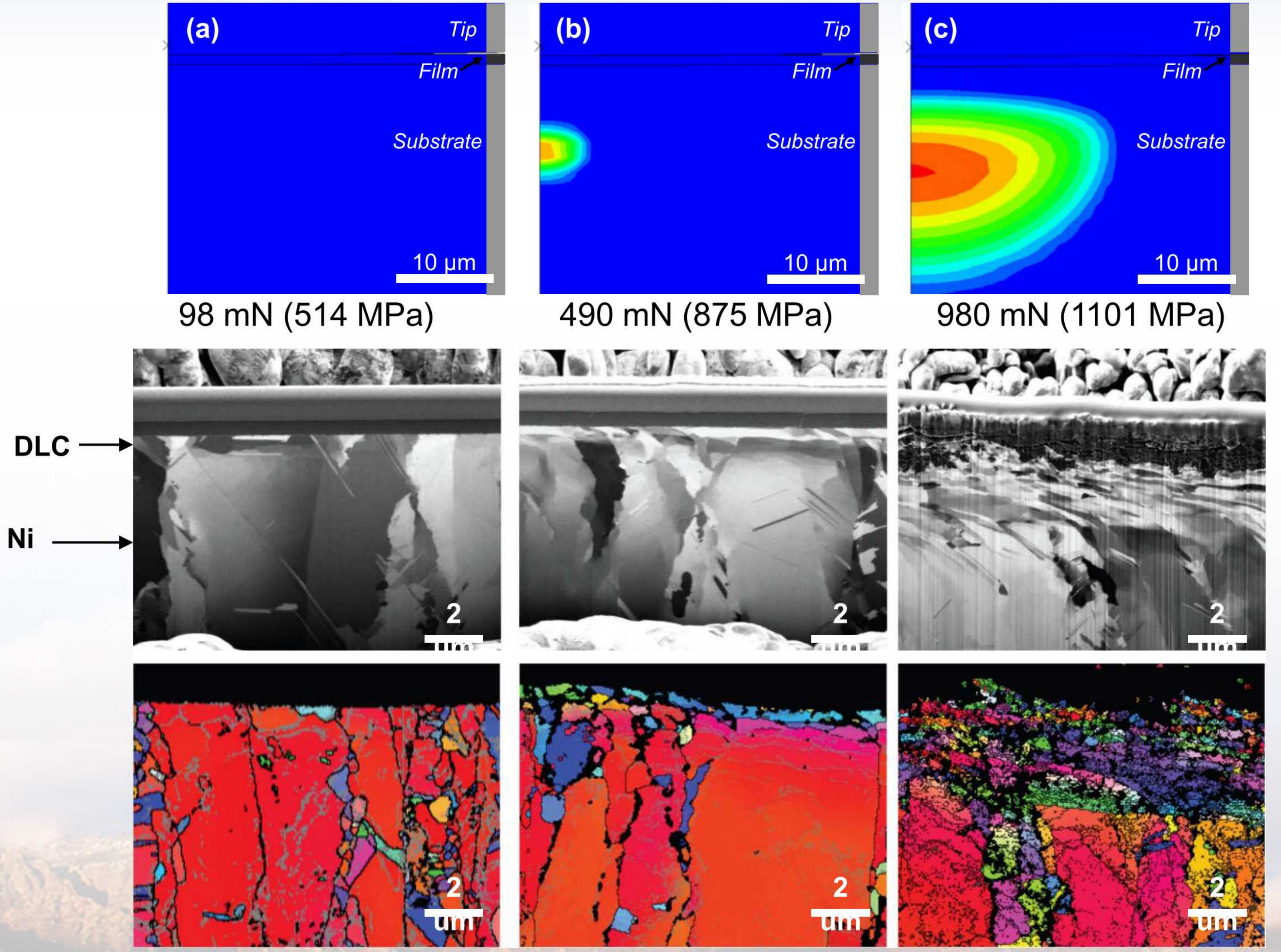
Substrate plastic deformation leads to coating failures





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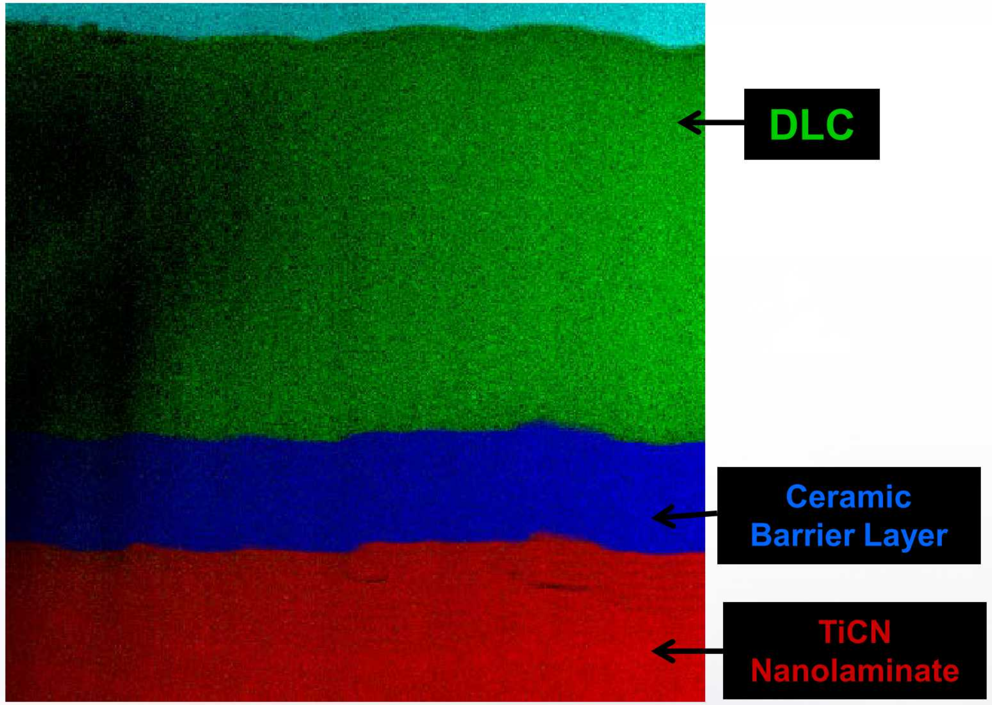
J.M. Jungk, J.R. Michael and S.V. Prasad, Acta Materialia, (2008) 56: 1956-1966.

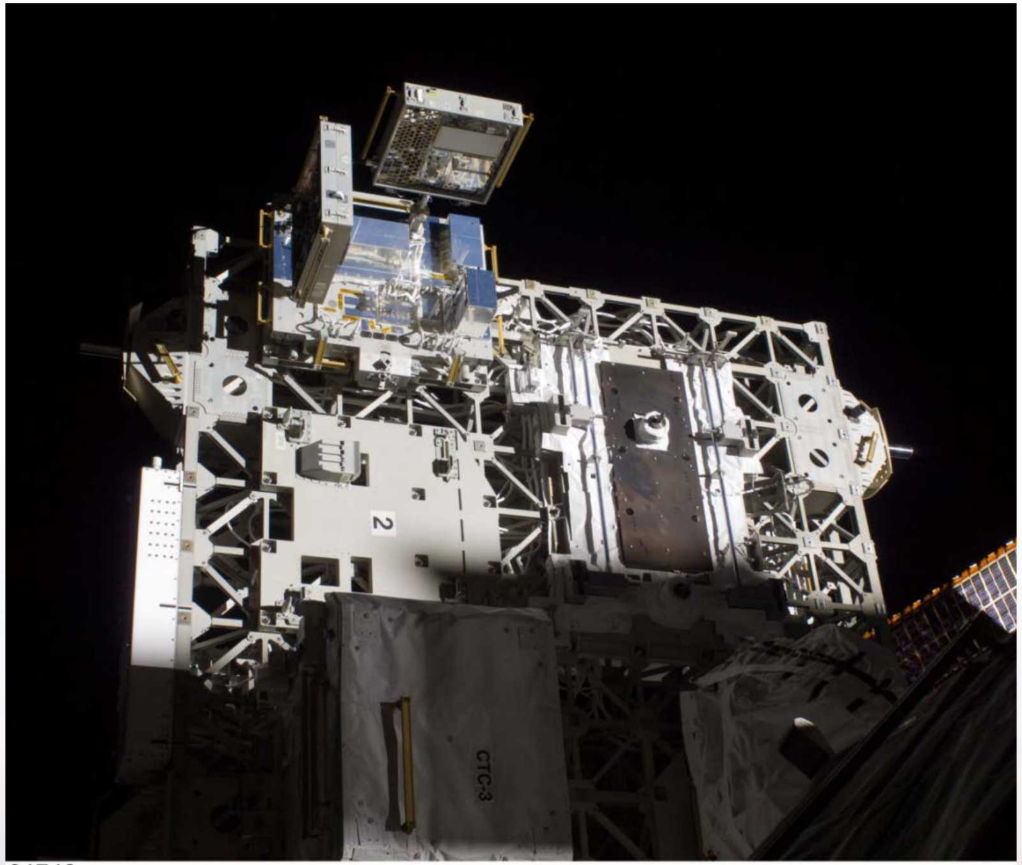
Multi-Layer Architectures may be necessary to mitigate plastic deformation, diffusion



Space: The Final Frontier

Additional Challenges with Space Coatings

Materials on the International Space Station Experiment (MISSE-7)



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STS-129 (November 16, 2009): To ISS
STS-133 (March 1, 2011): Recovery

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