Electrodeposition of Nanocrystalline Cobalt-Alloy Coatings as a Hard Chrome Alternative – WP 0936

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Technical Objectives

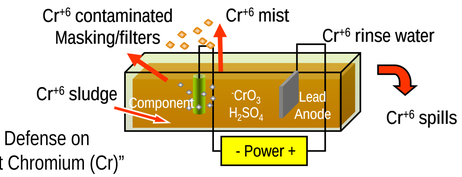
Demonstrate/Validate nCo-P electroplating as an alternative on both LOS and NLOS applications for depot level maintenance

- Acquire performance data (Joint Test Protocol)
- Establish production plating processes (cleaning, racking, masking, activation, pre-plates, etc.)
- Perform & validate field testing
- Develop Eng Tech Data Packages
  - Manuals
  - Specifications
  - Eng. Circular
- Initiate DoD and OEM approval process

Benefits of nCo-P vs. Hard Chrome

Hard Chrome Plating Environmental & Health Hazards

- Hard chrome plating utilizes chromium in the hexavalent state (Cr^{6+})
- Cr^{6+} is a known carcinogen and poses a health risk to operators
- OSHA lowered the Cr^{6+} PEL from 52 µg/m^3 to 5 µg/m^3
- Memo from the Undersecretary of Defense on "Minimizing the Use of Hexavalent Chromium (Cr)" issued on April 8, 2009 which demonstrates the commitment to develop and implement alternative technologies



Performance Benefits of nCo-P as a Hard Chrome Alternative

- Can be applied to both LOS and NLOS surfaces
- Compatible with current plating infrastructure (drop-in technology)
- Reduced power consumption (90% reduction)
- Increased throughput (8x increase in plating rate)
- No constituents on EPA or AFMC lists of hazardous materials

Process

nCo-P produced by electrodeposition

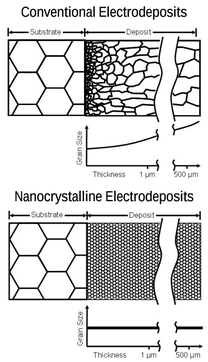
- Pulsed current waveform engineering

Electrodeposited nanocrystalline materials

- Favors nucleation of new grains over growth of existing grains
- Results in an ultra-fine grain structure
- Uniform throughout the entire coating thickness

Leads to unique properties

- ↑ Yield Strength and Ultimate Tensile Strength
- ↑ Hardness
- ↑ Wear Resistance
- ↓ Coefficient of Friction

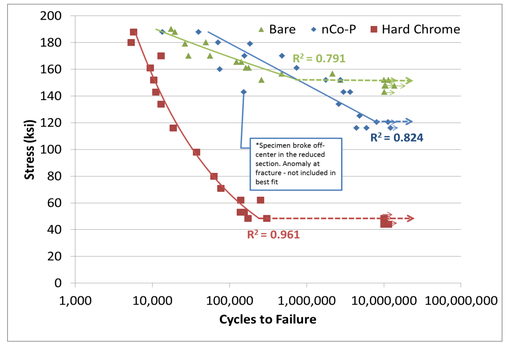


Process Comparison

	nCo-P	Hard Chrome
Cathode Current Efficiency	85-95%	15-35%
Deposition Rate	0.002"-0.008" /hr	0.0005"-0.001" /hr
Emission Analysis	Below OSHA limits	Cr^{+6}
Hydrogen Embrittlement	Post-plate bake required	Post-plate bake required

Properties

		nCo-P	Hard Chrome
Appearance and Porosity		Pit-, microcrack- and pore-free	Microcracked
Grain Size		8-15 nm	-
Hardness		550-600 VHN (as-deposited)	Min. 850 VHN
		600-750 VHN (heat-treated)	-
Ductility		2-7%	<1%
Adhesive Wear	*Wear volume loss*	6-7 x 10^{-6} mm^3/Nm	9-11 x 10^{-6} mm^3/Nm
	Friction coefficient	0.4-0.5	0.7
	Pin Wear	Mild	Severe
Abrasive Wear		17 mg/1000 cycles (CS-17)	4 mg/1000 cycles (CS-17)
Salt Spray Corrosion		0.002" thick Protection Rating 7 (ASTM B537) @ 1000 hours	0.004" thick Protection Rating 2 (ASTM B537) @ 1000 hours



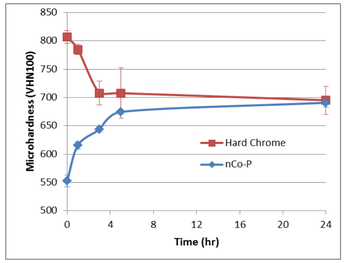
Rotating Beam Fatigue

- Substrates:
  - 4340 steel
  - 52-56 HRC
  - No shot peen
- Coatings:
  - Bare
  - 0.003" nCo-P
  - 0.003" Hard chrome
- nCo-P Performance:
  - Comparable to bare at low loads, small debit at high loads
  - Credit vs. hard chrome

Heat Treatment Study

Heat Treatment of nCo-P and Hard Chrome

- Conducted heat treatment of plated samples at several combinations of temperature and time
- Determined microhardness for annealing temperature of 375°F as a function of annealing time
- At hydrogen embrittlement relief bake-out conditions (i.e., 375°F for 24 hrs), the microhardness of nCo-P and Hard Chrome are comparable



Technology Demonstration at NAVAIR JAX

nCo-P Dem/Val Process Line

250 gal nCo-P Tank (2.5' x 4' x 4')

Pulse Rectifier (1500A Peak)

Remote Controller (Touch Screen)

370 gal Activation Tank

Demonstration Platforms

T-45 Goshawk
Air Vehicle Components
NAVAIR JAX

NAVSEA
Ground support equipment & shipboard machinery

Spotting Dolly
Ground Support Equipment
NAVAIR Lakehurst

Modeling

Phase I: Model Verification

- Validate modeling results by conducting laboratory testing

Phase II: Component Modeling

- Develop and design rack concepts for components using modeling