FLINT™

Wear Technologies

InnerArmor®

protective surface coating

TOUGH AND TRUSTED™

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InnerArmor®

What is InnerArmor?

InnerArmor is a patented technology which uses a Plasma Enhanced Chemical Vapor Deposition (PECVD) process. The interior of the component acts as a process chamber resulting in very high plasma density. When applied to a substrate, it creates a Diamond-Like Carbon (DLC) surface consisting of carbon molecules with an amorphous structure. A hollow cathode plasma during coating provides a high growth rate, a uniform thickness of coating deposition, and a strong adhesive bond. InnerArmor coatings provide excellent corrosion and wear protection due to their chemical inertness, high density and low porosity.

Characteristics of InnerArmor

Corrosion Resistant: Very hard non-porous coating protects substrate from oxidation and chemical corrosion.
Erosion and Abrasion Resistant: Diamond-like carbon structure is an extremely hard barrier protecting the base metal.
Low Friction Surface: Low coefficient of friction ensures that materials move over the surface more efficiently.
Anti-Fouling: The low friction surface ensures that materials will not adhere or accumulate thus eliminating fouling.
Adjustable Formulation: The composition of the coating can be modified to enhance the qualities listed above.

Metal Wear Concerns

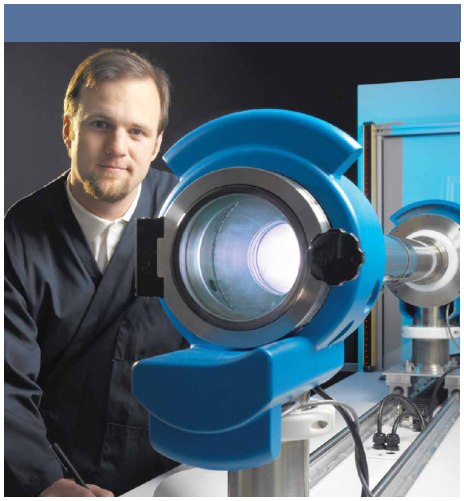
Metals exposed to extensive wear will demonstrate a shortened operating life-span and result in higher capital costs, operating costs and increased maintenance costs. In addition, fouling and scale reduce flow efficiencies and thus require more energy to move products through piping systems.

InnerArmor Coatings are Superior to Conventional Methods

InnerArmor vs. Thermal Spray Coatings

- Thermal sprays such as arc, plasma and High Velocity Oxy-Fuel (HVOF) spray melted or vaporized materials onto a substrate
- Line-of-sight processes cannot reach into small, complex or long cavities; such as pipe
- Spray-coating creates rough surfaces with inconsistent thickness thus increasing friction or requiring additional grinding and polishing
- Often applied by hand; spray coating is expensive and difficult to apply evenly

In contrast, InnerArmor coating is fully automated, smooth and evenly applied, even in long cavities.



InnerArmor vs. Polymer Linings

- Linings are plastics that are sprayed or dip-coated onto the product
- Provide limited corrosion resistance, are not optimal for high-wear components and cannot be used in high temperature environments

InnerArmor coatings prevent corrosion, resist wear and perform well at higher temperatures.

InnerArmor vs. Alloys

- Alloys are effective against wear
- Higher capital costs
- Manufacturing often produces poisonous and environmentally dangerous compounds

InnerArmor can be applied to commonly used and inexpensive substrates and it is environmentally benign and non-toxic.

InnerArmor vs. Galvanizing

- Electroplating and hot dipping are effective methods of inhibiting galvanic corrosion
- Corrosion resistance will be ineffective when subjected to erosive or abrasive media

InnerArmor provides superior hardness, wear and corrosion resistance.

InnerArmor vs. Chrome Plating

- Plating processes regularly use hazardous materials, high energy application processes and face more stringent government regulations
- Chrome plating often requires special pre-coating for use in aggressive environments along with additional honing after application
- Imperfections in surface preparation can cause multiple chrome plating problems, such as micro cracking and delamination leading to substrate corrosion

Alternately, InnerArmor provides superior hardness, wear and corrosion resistance, and it utilizes an environmentally benign process.

InnerArmor vs. Surface Treatments

- Surface Treatment creates a diffusion barrier between the commodity and the material to be protected
- Generally quick to apply and inexpensive
- Limited effectiveness due to often inconsistent coverage and compromised protection against erosion and abrasion

In comparison, InnerArmor provides a diffusion barrier to protect the material, and its coverage is consistent in thickness and composition. It is also designed to provide exceptional protection against erosion and abrasion.

InnerArmor® Material Tests and Results

CORROSION TESTING	
Salt Spray (Standard: ASTM B117)	**Result:** No damage
Sour Autoclave (Standard: NACE TM0185)	**Result:** No undercutting of indent after autoclave test
Ambient HCl (15%)	**Result:** No damage
Hot HCl (18%)	**Result:** No damage
High Temperature and Pressure - Hydrogen Sulfide Exposure Test	**Result:** Hardness increased by 1GPa; Thickness: n/c; Scratch Adhesion: n/c
Ambient HF Acid (50%)	**Result:** No damage
Submerge Sample in Bleach Solution	**Result:** No corrosion, untreated samples noticeably corroded

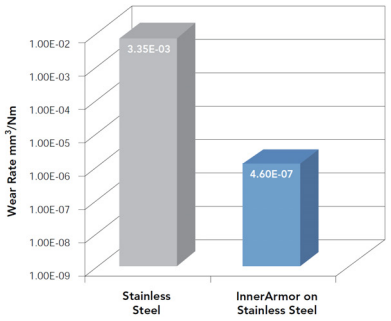
ABRASION TESTING	
Abrasion (Standard: ASTM G65)	**Result**: Passed
Slurry Abrasion (Standard: ASTM G75)	**Result**: 56% less mass loss than hard chrome
Erosion (Standard: ASTM G76)	**Result**: No abrasion damage on surface

EROSION TESTING	
Wear Rate (Standard: ASTM G133)	**Result**: 304 Stainless; one coated with InnerArmor, the other bare metal. Sample treated with InnerArmor, the wear rate was reduced by a factor of 10,000 (based on mass loss) from the untreated piece of 304 Stainless. **Result**: On the samples of 316 Stainless; one was coated with InnerArmor and the other was coated with Tungsten Carbide overlay. For the sample treated with InnerArmor, the wear rate was reduced by a factor of 135 (based on mass loss) from the untreated piece of 316 Stainless. **Result**: On the samples of Carbon Steel; one was coated with InnerArmor and the other was coated with Tungsten Carbide overlay. For the sample treated with InnerArmor, the wear rate was reduced by a factor of 5 (based on mass loss) from the untreated piece of Carbon Steel.

ADHESION TESTING	
Scratch Test with Progressive Load (Standard: ASTM C1624)	**Result**: Strong adhesion

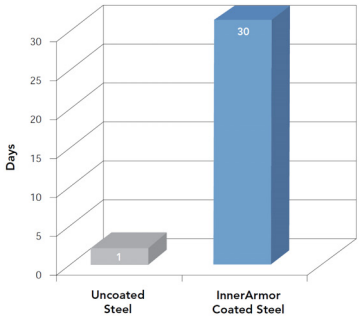
InnerArmor—Reducing Wear

Wear Rate with 25N load, non-lubricated



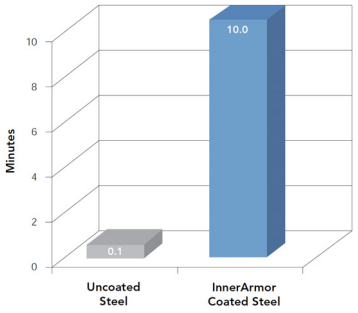
InnerArmor—Blocking Corrosion

InnerArmor Withstands the Maximum 30 Days Of NACE-standard TM185 Sour Autoclave Test With No Attack or Undercut of Coating



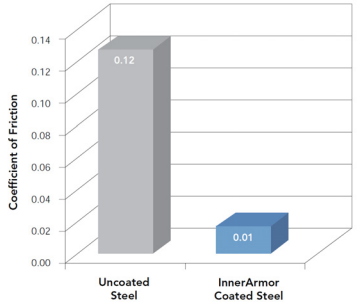
InnerArmor—Resisting Erosion

InnerArmor Withstands the Maximum 10 Minutes of ASTM-standard G76 Abrasive Air Jet Test With No Surface Damage



InnerArmor—Reducing Friction

Coefficient of Friction with 25N load, non-lubricated



InnerArmor® Typical Properties

STRUCTURE
Mixture of sp^3 (diamond) and sp^2 (graphitic carbon)

COMPOSITION
Carbon/Silicon + Hydrogen + (dopants)

DEPOSITION TEMPERATURE
Less than 200°C in most applications

WORKING TEMPERATURE
400°C (600°C with doping)

COATING FINISH
Identical to Substrate

HARDNESS (VICKERS)
900-2000 adjustable (carbon steel=217)

SUBSTRATES
Carbon Steel, Stainless Steel, Aluminum, Titanium and Titanium alloys, Nickel and Nickel alloys

ADHESION
15N to 90N.
Chemically bonded to substrate

MODULUS
100-180GPa adjustable
(carbon steel=200GPa)

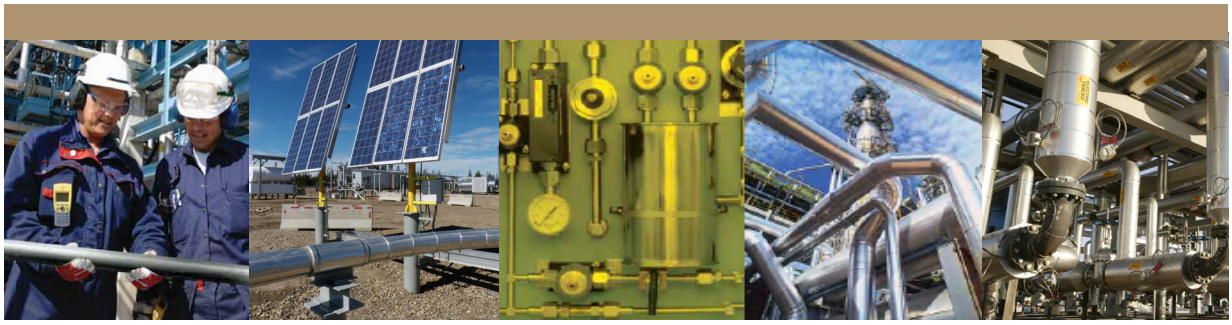
COATING THICKNESS
Adjustable up to 80 µm

COEFFICIENT OF FRICTION
Less than 0.08

WEAR RATE
1E -06 to 1E-08 $mm^3/N{\cdot}m$

CORROSION PROTECTION
Hydrogen sulfide (H_2S), Hydrofluoric acid (HF), Hydrochloric acid (HCl), Nitric acid (HNO_3), Sulfuric acid (H_2SO_4), Salt (NaCl), Methane (CH_4), Carbon monoxide (CO), Carbon dioxide (CO_2)

ENVIRONMENTAL IMPACT
Safe, benign application



Applications for InnerArmor

Sour Fields (H_2S)
Oil Sands/Heavy Oil
Pump Sleeves
Sliding Sleeves
Abrasive Flow Parts
Tees And Laterals
Choke Points and Reducers
Pump Housings
Low Voltage Electrical Isolation
Reciprocating Wear Parts
Valve Bodies

Protecting Your Bottom-Line

Improved Energy Efficiency
Exceptionally low surface friction reduces the amount of energy required for sliding motion or fluid transfer.

Extended Service Life
Protection of internal surfaces against premature failure from corrosion and wear increases operating life.

Reduced Downtime
Improved surface performance reduces downtime and part replacement costs while often eliminating the need for expensive alloys.

Reduced Repair and Maintenance Costs
What are the costs of system failure?

- The cost of system shut-down and start-up
- The cost of new parts
- The cost of maintenance personnel

Reduced Opportunity Costs
Expenditures on repair, maintenance and replacement of worn parts represent funds that could be utilized elsewhere. InnerArmor's greater resistance to operational deterioration results in more continuous hours of operation and reduced opportunity costs.

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