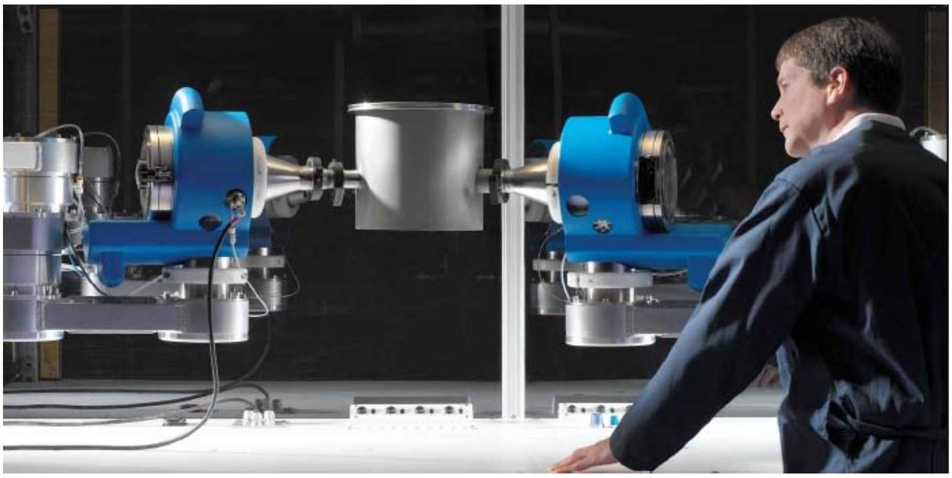
TECVAC
Advanced Surface Engineering

ANTI-CORROSION PROPERTIES OF DLC COATINGS



Tecvac applies DLC coatings to internal surfaces of pipes, valves, pumps, cylinders and bores using the InnerArmor™ process .

<u>I/ Introduction:</u>

Corrosion causes the break down of essential properties in a material due to reactions with its surroundings. In the most common use of the word, this means a loss of an electron of metals reacting with water and oxygen. This type of damage usually affects metallic materials, and typically produces oxide(s) and/or salt(s) of the original metal.

<u>II/ Why is DLC a good coating to prevent corrosion?</u>

1. B**ecause of its composition and structure (Carbon and Hydrogen), DLC is chemically inert**

2. DLC is a dense and low-porosity coating which will impede the penetration of water and ions (DLC coatings are hydrophobic, contact angle: » 80°)

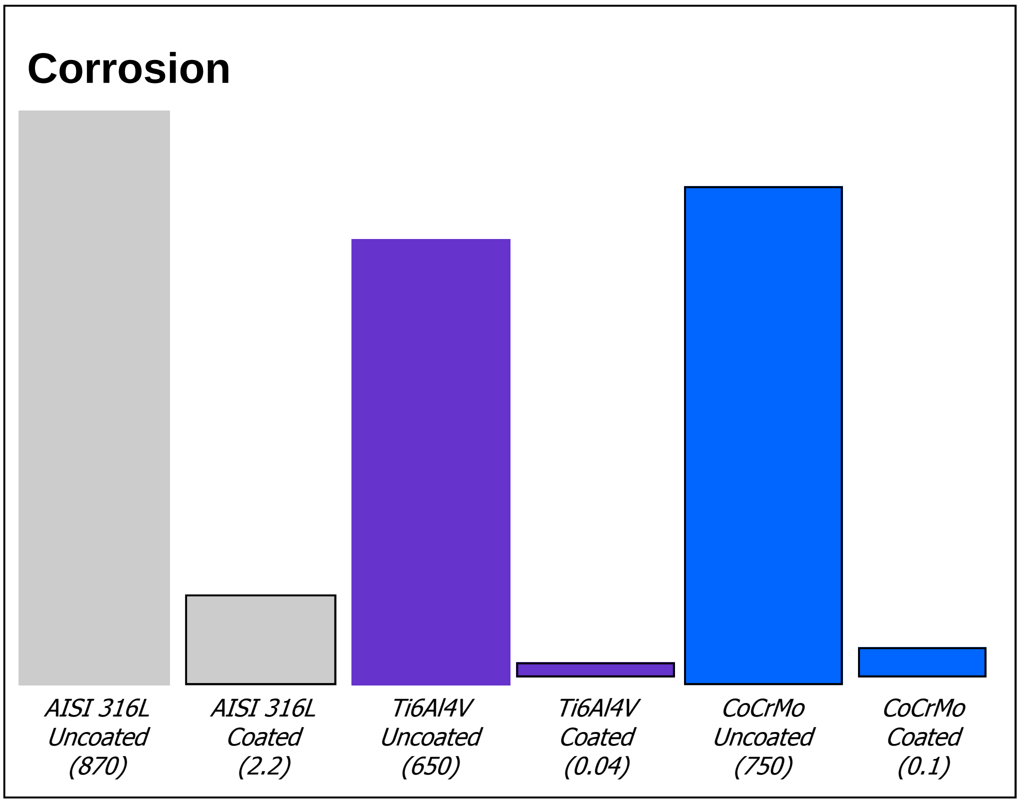
3. Diamolith is insulating (resistivity 10^8 W.cm) and so will avoid the transfer of charge that leads to the corrosion reaction.

<u>III/ Examples of corrosion resistance</u>

In the publication "*Evaluation of diamond-like carbon-coated orthopaedic implants*" [1], a study was carried out using a scanning reference electrode technique to determine the corrosion resistance.

Stainless steel (AISI 316L) cylindrical bars with dimensions (100*15 mm diameter) were immersed in Ringers solution. The DLC-coated bars survived an applied voltage of 2400 mV for a minimum of 4 h. In contrast the breakdown voltage of the uncoated bars 200-600 mV. On a commonly used CoCrMo alloy, 1µm-DLC decreased the corrosion rate of the substrate by a factor of 10^5 when exposed to a saline solution equivalent to the body fluid in 37°C for 2 years. [2]

Fig 1. The results of the static corrosion test in 10wt.% HCl of coated and uncoated AISI316L, Ti6Al4V and CoCrMo (870/2.2, 650/0.04 and 750/0.1µg/cm2 perday respectively. The blocks are directly related to the amount of diluted metal[45].



Laurent Espitalier Anticorrosion properties of DLC 26/10/07

IV Corrosion Parameters, I_{corr}

A comparison of the corrosion rate between coated and uncoated Ti-6Al-4V samples was determined (measuring Icorr in a redox system. The table 4.2 [3]shows uncoated alloys in differing electrolytes. The Ti-6Al-4V alloy Diamolith coated samples show a corrosion rate I corr 1000 times less than uncoated equivalents. Additionally the coated sample yielded a protective efficiency of 99.98%

When Ti-6Al-4V alloys are DLC coated, the currents of corrosion are 1000 times lower (ηA), Table 2 [4].

Engine components coated with DLC

V Conclusion

Corrosion is a Redox reaction where energy is produced by a spontaneous reaction which produces electricity, or where electrical current stimulates a chemical reaction. As DLC is a non-conducting material the transfer of charge with the surroundings is not possible and corrosion will not occur (no electrochemical cell formation). Furthermore, DLC is chemically inert in acids and bases, that allows it to be used in corrosive environments.

Table 2
Results of potentiodynamic polarization tests

Specimen	E_{corr} (mV)	i_{corr} (nA/cm^2)	β_a (V/decade)	β_c (V/decade)	R_p ($\times 10^3$ Ω cm^2)	Protective efficiency (%)
Substrate	−5.48	195.6	0.1142	0.4451	202.2	–
Si–DLC Bias voltage(−400 V)	270.6	0.04099	0.2353	0.6027	1795037	99.98
a-C:H Bias voltage(−800 V)	−120.2	5.477	0.3608	0.1507	8438.4	97.19
a-C:H Bias voltage(−400 V)	−193.4	51.63	0.6045	0.2785	1605.5	73.60

Table 4-2. Corrosion parameters of Ti-6Al-4V for all treatments

MATERIAL	TREATMENT	ELECTROLYTE	βa (mV/decade)	βc (mV/decade)	Ecorr (V)	icorr (µA/cm^2)	C_R (mm/y)
Ti-6Al-4V	Control	3.5 % NaCl	901.55 ± 31.7	1069.33 ± 48.9	-0.655 ± 0.031	3.52 ± 0.27	1.67E-02 ± 0.027
Ti-6Al-4V	Control	Ringer's solution	356.89 ± 28.9	270.04 ± 32.3	-0.599 ± 0.029	0.21 ± 0.42	2.44E-03 ± 0.042
Ti-6Al-4V	Control	Seawater	551.09 ± 36.3	689.5 ± 26.3	-0.635 ± 0.036	1.6 ± 0.25	5.48E-02 ± 0.039

References:

[1] Diamond and related Materials 6 (1997) 390-393.

[2] Diamond and Related Materials 10 (2001) 153-160.

[3] *A study of the corrosion resistance of Gamma Titanium Aluminide in Ringer's solution, 3.5 WT % NaCl and seawater,* Carolina Delgado Alvarado.

[4] Diamond & Related Materials 14 (2005) 35-41

Contact the Technical sales team at Cambridge for more technical information

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CLASSIFICATION OF DLC COATINGS

VDI Classification

Doping Elements	Hydrogen - Free			Hydrogen-Containing			
	carbon only	carbon only	Metal Containing	carbon only	carbon only	Metal Containing	Non-Metal-Containing
Structure	sp2	sp2	sp2/sp3	sp2-sp3	sp3	sp2	sp2
Shortcut	a-C	ta-C	a-C:Me	a-C:H	ta-C:H	a-C:H:Me	a-C:H:X where X= Si, O, N, B, F
Other Designations	DLC	DLC i-C Diamond		DLC		DLC Me-DLC Me-C:H Me:H	DLC X-DLC Si-DLC
Depositing Process	PVD	PVD	PVD	PVD PaCVD	PaCVD	PVD PaCVD	PaCVD

The VDI Classification indicates the coatings as follows:

a-C = amorphous carbon, a-C:H = amorphous carbon with incorporated hydrogen a-C:H:Me amorphous carbon with hydrogen etc For automotive and aerospace applications all the coating groups have been applied. However, the most popular and universal coatings so far have been an a-C:H:W referred to as Hydrogenated Tungsten Carbide carbon (WC-C) and hydrogenated pure diamond coatings a-C:H

Elemental and bond characteristics of DLC coating groups

Coating Group	Metal Content %	Carbon Content %	Hydrogen Content %	sp3 bond %
a-C:H	0	7-85%	15-25%	50 -70%
a-C:H:Me	10-20%	60-70%	10-20%	~ 35%
a-C:Me	5-10%	90-95%	0	20-40%
a-C:H:Si	10%	70%	20%	35-60%
ta-C	0%	100%	0%	60-90%

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