ION IMPLANTATION, PVD AND CVD AND THEIR EFFECTS ON BAL SEAL® SPRING-ENERGIZED SEAL PERFORMANCE

Technical Report
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1.0 SUMMARY

Various surface modification processes are available for the purpose of increasing the hardness of metal parts. These processes involve creating a layer of very hard material using coatings such as titanium nitride, tungsten carbide and others. A coating of one of these materials creates an average hardness of 84 on the Rockwell C scale. This increased hardness significantly reduces the friction and wear rate of BAL™ Seals in contact with such surfaces. Various surface modification methods are available, ranging in application temperatures from 300ºF (149ºC) to 1900ºF (1038ºC). The surface modification processes available are ion implantation, PVD (physical vapor deposition) and CVD (chemical vapor deposition). These various processes are generally batch processes, which limits their application because of the high cost involved.

BAL™ Seal performance can be substantially improved when used in contact with a very hard and smooth surface finish. These surface improvements provide lower adhesion between the BAL Seal and sealing surface. This lower adhesion causes less abrasion and results in longer BAL Seal life.

2.0 DISCUSSION

Surface modification processes are applicable to certain parts that require an increase in surface hardness or improvement in corrosion resistance with a minimum change in dimension.

Careful consideration must be given to the various processes available and particularly the operating temperature at which such processes take place, so as to minimize possible distortion of metal parts. Ion implantation is applied at relatively low temperatures of approximately 300ºF (149ºC). This lower temperature coating method can usually be used after a part is completed with minimal dimensional distortion to the part. PVD requires heating the parts at a temperature of 750ºF (440ºC) and may result in some changes in the parts dimension or mechanical properties. CVD requires processing at 1650ºF 900ºC) which may result in further changes in dimensions and mechanical properties.

3.0 EFFECTS OF HARD COATINGS ON BAL™ SEAL PERFORMANCE

BAL Seal performance is substantially improved when used in contact with a very hard surface, since adhesion and friction are both reduced.

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4.0 TYPES OF COATING

The materials, which are generally added or implanted to the metal surface, are titanium nitride (TiN), titanium carbide (TiC) and tungsten carbide (W_2C).

Titanium nitride and titanium carbide are generally used in CVD, while the other three materials can use all three types of coatings. Titanium carbide produces the highest hardness, in the order of 3800 Vickers (84 RC approx.). Titanium nitride provides an approximate hardness of 3200 Vickers (82 RC approx.) and tungsten carbide is measured at 1500 Vickers (74 RC approx.).

5.0 SURFACE MODIFICATION PROCESSES

5.1 Ion implantation

This is a process of improving the physical or chemical properties of a metal by embedding atoms into it from a beam of ionized particles. The process temperature is approximately 300ºF (149ºC) and results in a coating thickness of 2 to 3 microns (0.000079 inch to 0.00012 inch or 0.002 mm to 0.003 mm). This process achieves a coating with a Rockwell Hardness of 82Rc. Ion implantation consists of discharging ions, which are introduced as a gas at one end of the implantation system and directed by a series of magnets onto a target or work piece. The beam particles are ionized and directed to the work piece by electrical fields as indicated in Figure 1. The process can deposit a thin layer of titanium nitride or tungsten carbide without modifying the surface finish of the part.

The surface to be treated should have a minimum hardness of RC 41 for the best coating results. This is a batch process that requires a considerable amount of skill resulting in high unit cost.

The materials generally coated are various types of steel, titanium, aluminum, etc.

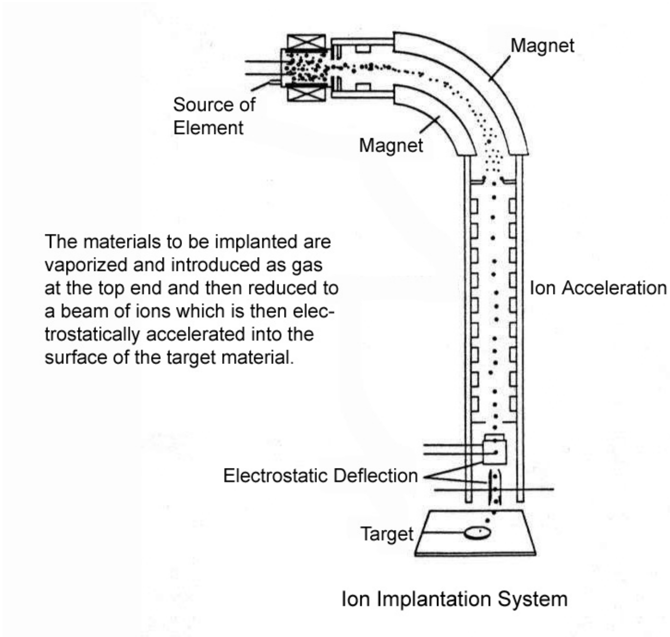

FIGURE 1:
ION IMPLANTATION SYSTEM

5.2 Physical vapor deposition (PVD)

This is a surface modification process that takes place in a vacuum chamber that is heated at approximately 750ºF (400ºC). The process consists of directing a concentrated high-energy plasma to the work piece as indicated in Figure 2. The coating is approximately 2 to 4 microns (0.000079 inch to 0.00016 inch or 0.002 mm to 0.004 mm) thick. This process can be applied to a metal surface, resulting in improved corrosion resistance. Coatings are resistant to most acids except concentrated hydrofluoric and nitric acids. This process requires fixturing because the coating application is done by line of sight and the part to be treated may have to be moved during processing. Because surface pre-treatment is critical in PVD processing, surfaces to be coated are subject to a vigorous cleaning process. Pre-cleaning methods typically involve degreasing, ultrasonic cleaning and freon drying. Materials that can be coated are carbide, steel, aluminum, magnesium, and titanium.

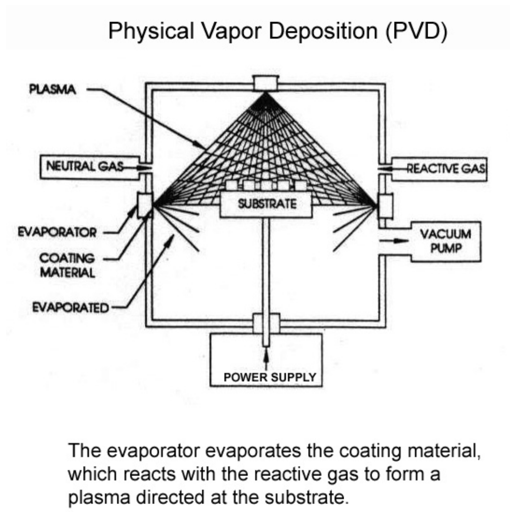

FIGURE 2:
PVD PROCESS

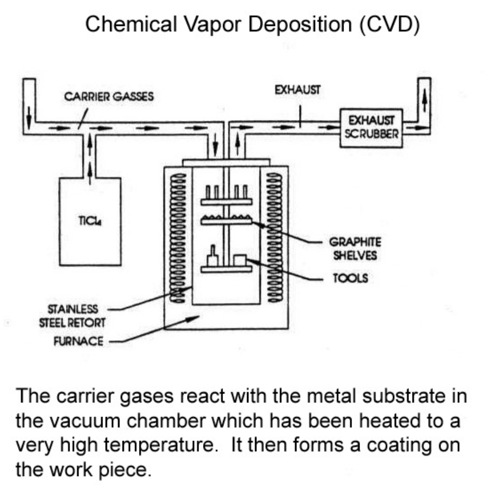

FIGURE 3:
CVD PROCESS

5.3 Chemical vapor deposition (CVD)

CVD is carried out in a vacuum chamber, which is filled with a reacting chemical vapor, which is heated at a temperature of approximately 1650ºF (900ºC). The chemical gases then react to form a coating over a substrate, as indicated in Figure 3. Typical substrates are steel and carbide material while Titanium Carbide (TiC) and Titanium Nitride (TiN) are the coating materials. For steel application, the reactants are Titanium Tetrachloride plus hydrocarbons to produce Titanium Carbide, and Titanium Tetrachloride plus nitrogen to produce Titanium Nitride. A thin layer of approximately 2 to 3 microns (0.000079 inch to 0.00012 inch or 0.002 mm to 0.003 mm) is formed at the surface of the work piece. Since this is a higher temperature process, some distortion and dimensional changes may occur and this must be taken into consideration in using this process. The coatings have a maximum hardness of 3800 Vickers. For wear application, the base material should be Rc 43 minimum. For corrosion applications the surface finish of the base material should be better than 32 RMS.

5.4 Microcoating: a proprietary PVD technique

Surmet-Gold microcoating is a PVD process developed by Intermetallics Inc. It is a physical vacuum deposition process, which is done at low temperature, about 480ºF (250ºC), whereas the conventional PVD process is done at temperatures of about 750ºF (400ºC). This is an advantage, in a way that it minimizes changes in dimensions and mechanical properties associated with high temperature PVD and CVD processes. In this process, a coating of predominantly Titanium Nitride is applied to a metal substrate. The coating is applied in thickness of approximately 1 to 2.5 microns (0.000039 inch to 0.0001 inch or 0.001 mm to 0.0025 mm) and hardness of approximately 3200 Vickers (Rockwell C 84). The process is applicable to most metals, particularly heavy metal, although it is not desirable for items subject to corrosion such as carbon steel, brass and copper. For wear application, the base material should be Rc 43 or harder. For corrosion applications, the surface finish on the part to be coated should be better than 32 RMS.

6.0 THICKNESS OF SURFACE MODIFIED BY DIFFERENT PROCESSES

Described in Figure 4 is a view indicating a typical coating thickness achieved by either Ion Implantation, PVD, or CVD. Chart below describes the various thickness that can be achieved.

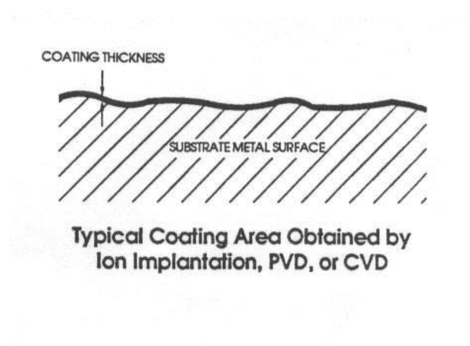

FIGURE 4:
TYPICAL COATING AREA OBTAINED BY ION IMPLANTATION, PVD, OR CVD

Process	Thickness		
	Micron	Inch	Mm
Ion Implantation	2 to 3	0.000079 to 0.00012	0.002 to 0.003
PVD	2 to 4	0.0000709 to 0.00016	0.002 to 0.004
CVD	2 to 3	0.000079 to 0.00012	0.002 to 0.003
Chart showing the thickness of different surface modifying process.			

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7.0 SOURCES OF SUPPLY:

ION Implantation

Eaton Corporation
1111 Superior Ave.
Cleveland, OH 44114-2584
888-386-5750

North Star Research Corporation
4421 McLeod Road N.E., Suite A
Albuquerque, NM 87109
888-291-8566

CVD & PVD

Ultramet (CVD only)
12173-5 Montague Street
Pacoima, CA 91331-2210
818-899-0236

Molecular Technologies, Inc.
5776 E. Camino Del Celador, Dept. TR
Tucson, AZ 85750
520-241-2155

AVS INC./Advanced Vacuum Systems (CVD only)
60 Fitchburg Road
Ayer, MA 01432-1004
978-772-0710

Hi-Tech Furnace Systems, Inc.
50685 Wing Drive, Dept. 5
Shelby Township, MI 48315-3263
810-566-0600

TI-Coating, Inc.
50500 Corporate Drive, Dept. A
Utica, MI 48315
800-262-5166

Multi-Arc, Inc. A Berna Group, Co.
200-T Round Hill Drive
Rockaway, NJ 07866
800-646-5652

Richter Precision, Inc.
1021 Commercial Ave & Coating Place
East Petersburg, PA 17520
800-742-4837

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Ion Implantation, Robert F. Hochman, Associate Director for Metallurgy, Georgia Institute of Technology

Metals-Materials Technology Series, Henry E. Brandolf, Ohio: American Society for Metals, Report No. 8201-081.

ION Bond Physical Vapor Deposition Hard Coating System, Catalog from Multi-Arc Vacuum System, Inc.

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Vagel, Mel and Art Anderson, "CVD and PVD: What these coatings are, and how they are applied," Heat Treating

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