TechnoTalk

Advantages of Filtered Cathodic Arc Depositio

HARD COATINGS FOR TOOLS, DIES AND MOLDS


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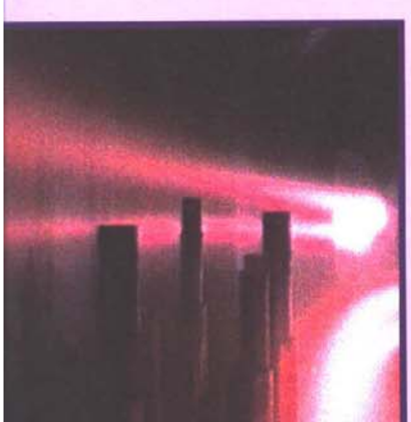
We originally reported on the cathodic arc technology and wear coating in a recent issue of *materials* (see our March 1998 issue, "From Russia with Love"). Here we take a closer look at the advantages of the filtered cathodic arc deposition technology and its benefits for a mass-production environment.

For the past 20 years, the vacuum arc discharge plasma has been successfully used for depositing hard coatings for cutting tools and other tribological applications. But the current evaporation, sputter and cathodic arc processes still suffer from specific limitations. New advances in cathodic arc plasma technology used in a physical vapor deposition (PVD) process can eliminate many of these problems.



he cathodic arc lasma in action.

Development of filtered cathodic arc deposition technology

In the conventional direct cathodic arc source (DCAS), a jet of a highly ionized metal plasma, flowing from the cathodic arc spot transfers coating material from the target to the substrate surface. A significant disadvantage of this method is the formation of droplets, also known as macro-particles, in the cathodic arc jets. There is no simple way to eliminate macro-particles from the depositing plasma flow in the direct arc source configuration, since the operating surface of cathode target lies in a straight line in front of the surface of substrates to be coated. These macro-particles deleteriously influence critical properties of the coatings.

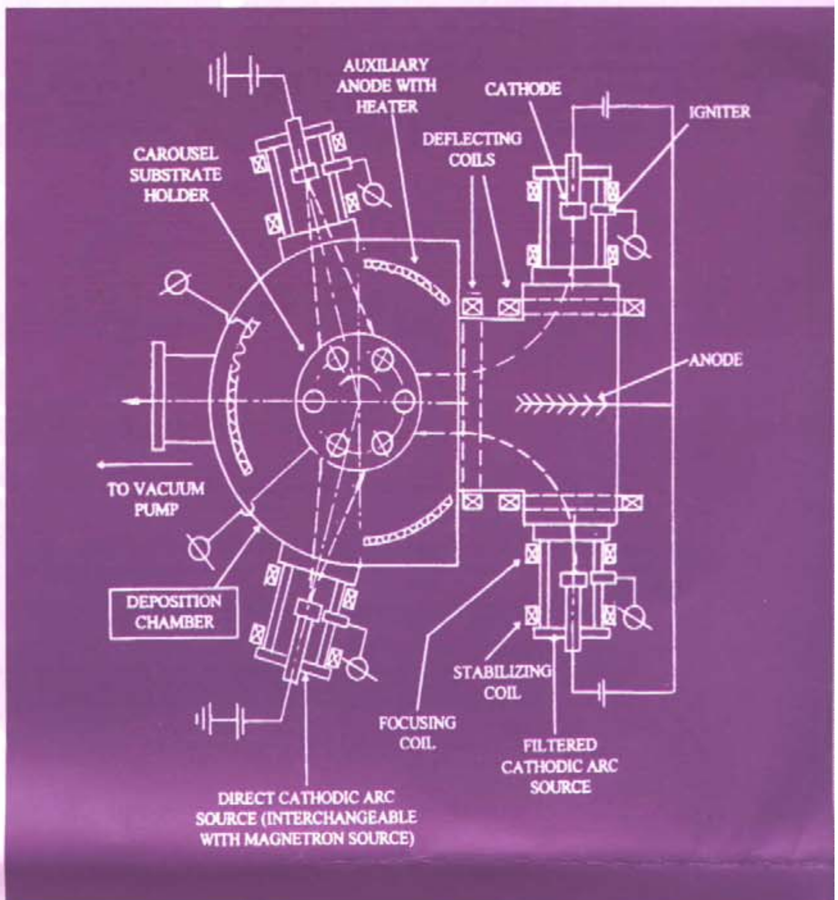
The first macro-particle filter, based on the plasma-optical principle, was a quarter-torus cylindrical electromagnetic plasma guide based on the torus-type plasma traps. These were developed for the controlled nuclear fusion apparatus such as the Stellarator in the USA and the Tokamak in the former USSR. Filtered cathodic arc sources (FCAS) based on this principle removed the macro-particles, and achieved deposition rates for titanium metal films up to 40 µm/hr, but could operate only with small cathode targets and could not be scaled up due to the difficulty of scaling up the cylindrical magnetic coils. This type of FCAS consists of a plasma guide in the form of a quarter torus, surrounded by a magnetic system that directs the plasma current. The plasma guide connects two chambers, one which holds the target and the other, the main chamber, holds a substrate holder. Due to the design of the plasma guide, the substrate holder is installed off the optical axis of the plasma source. The plasma source and the substrate holder are surrounded by focusing electromagnets.

The filtered arc source allows deposition of droplet-free coatings by deflecting the plasma flow along the curvilinear magnetic lines of force towards the substrate, while the droplets, having straight trajectories, are captured on the baffles. Thus, only a fully ionized flow of metal plasma is directed to the substrate. The filtered arc plasma also contains a relatively highly dissociated, ionized and activated reactive gas. This leads to a maximum fluence of bombarding ions within a small energy deviation. As a result, it is possible to produce metastable coatings with highly disordered structures, with unique properties.

The disadvantages of FCAS

The disadvantage of this apparatus lies in the fact that the dimensions of the article to be coated are limited. The torus-shaped plasma guide limits the dimensions of the article to be coated to 200 mm, which significantly limits the range of its application. Another disadvantage of cylindrical quarter torus FCAS is non-uniformity of the deposited coating. The variation of coating thickness with this design can be as high as 50-100% over the deposition area of 100-150 mm. Furthermore, there is no provision in the torus-shaped plasma guide for changing the configuration of the magnetic field. One can only change the magnetic field intensity. The maximum value of the ion current at the exit of the plasma guide does not exceed 1% of the arc current. This relates primarily to the turbulence of the plasma current in the torus, which causes a drastic rise in the diffusion losses of ions on the torus walls.

Another disadvantage of the existing state-of-the-art filtered arc source technology is the relatively low level of ionization of reaction gases such as nitrogen or oxygen. In comparison with the nearly 100% ionization of metal plasma, the gaseous plasma ionization is less than 1%. The degree of ionization of the gaseous component decreases with increasing gas pressure, especially for reactive gases, as a result of decreasing cathode erosion rate. Some improvement of coating properties can be achieved by gaseous ion-assisted filtered arc deposition (FAD), in which the ratio of metal to gaseous ions can be controlled.



Large-area filtered arc source assembly.

The solution – a large area FCAS

These limitations of the conventional macro-particle filter have been largely overcome in an innovative rectangular electromagnetic filter, patented in the former Soviet Union in 1980s. The large-area dual filtered cathodic arc source (LAFAS™) uses a rectangular plasma-guide chamber with two rectangular coils installed on the opposite sides, as shown in the schematic diagram (see diagram on right). Two cathodic arc sources with rectangular or circular target are installed on the side walls of the plasma-guide chamber, surrounded by rectangular focusing and deflecting coils. A quasi-flat deflecting magnetic field configuration significantly reduces plasma losses in the direction close to the plasma-guide walls, while the arc plasma can propagate freely in the transverse direction to reach remote parts of the deposition chamber. This results in a dramatic increase of output arc current, which can exceed 6 amperes for an input current of 300 amperes for two incorporated cathodic arc sources. At the same time ionization rate of gaseous plasma component can reach more than 30%.

The deposition rate of LAFAS™ has been found to be almost the same as for a direct cathodic arc source. This advanced filtered design provides practically droplet-free coating on large areas, ranging from about 250 mm in width to heights on the order of 300 mm to 3 m or more. Typical target utilization rate for a cylindrical filtered arc source of this design is as high as 80-90%, while it is up to 40% for the rectangular source. The main advantage of this design is the uniformity of target erosion as compared to the conventional sources.

The vacuum arc cathode is also a theoretically unlimited electron emitter, thereby providing an efficient source of high-density electron current. In this mode, it facilitates the generation of a uniform, high-density plasma cloud in the process chamber. This results in a "plasma-immersed" environment, which provides a uniform condition for plasma ion etching, ion nitriding, low energy ion implantation and plasma-assisted chemical vapor deposition.

Wide range of applications

Today, the applications for large area filtered cathodic arc deposition technology cover an extremely wide range of industries and end products. Here we list the major applications:

- Cutting and forming tools – printed circuit board drills, round shank tools, die-casting dies, saw blades
- Electronics – photovoltaic coatings, hard disks and thin film heads, conductive photolithography coatings, heat sinks, flat panel displays, large IC substrates, sensors
- Automotive – piston rings, engine valves, decorative trim
- Biomedicine – surgical and microsurgical tools, dental and orthopedic implants
- Decorative – glass and ceramic coatings, cutlery, chrome replacement, costume jewelry, hardware
- Aerospace – bearings, turbine blades, compressor blades, mechanical linkages
- Optics – infrared optics, laser mirrors, X-ray windows, fiber optics
- Machine parts – joints and linkages, sliding and rotating parts, bearings, corrosion control coatings

For more information on the filtered cathodic arc deposition technology and the LAFAS™ source, contact: arcomac@sympatico.ca or dbhat@ues.com

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