Development of a New Chromium Coating Method to Eliminate Hexavalent Chromium

Mandar Sunthankar & Dan Storey
IonEdge Corporation, Ft. Collins, CO

A new coating method is under investigation under the EPA SBIR program to eliminate hexavalent chromium in chromium plating. This technique could provide three dimensional coverage at acceptable rates. Preliminary studies have indicated that the coating rate could be varied methodically as desired and can be as high as 1 μm/min (40 μin/min) for chromium. The chromium coatings indicate dense structure and acceptable adhesion to steel. In addition, it is feasible to obtain high hardness for the coatings for wear applications. The method will allow deposition of decorative as well as functional coatings.

For more information, contact:

Mandar Sunthankar
IonEdge Corporation
513 B, N. Link Lane
Ft. Collins, CO 80524

Phone: 970-491-9942
Fax: 970-491-9945

Introduction

IonEdge Corporation has been developing vacuum based economical vapor coating methods as alternatives to electroplating for several years. In the technique described here, sufficient quantity of a desired metal or alloy is evaporated in a short period to generate a large quantity of vapors which then condenses rapidly on relatively cooler commercial parts. The advantage of the vacuum based methods, also known as physical vapor deposition (PVD), vacuum coating or vacuum metallizing, is there are no liquids involved in the coating process. Therefore there are no spent chemicals to dispose of or fumes to worry about. However, the metal vapors also condense on all surfaces and racks inside the vacuum chamber, and these need to be physically removed periodically. To make this job easier, replaceable wall-liners are routinely used and these lead to a small amount of solid or liquid waste, about a barrel or two a year, depending on dry blasting or chemical stripping used.

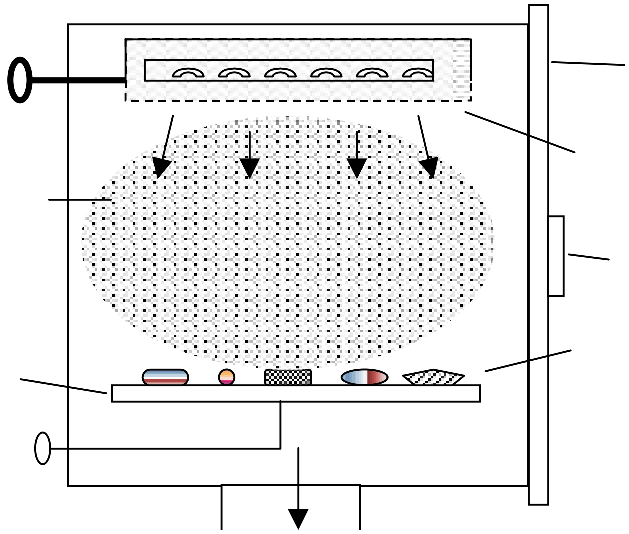
In general, traditional vacuum coating is considerably more expensive compared to electroplating or electroless methods. The major factors contributing to the high cost per part are limited system throughput due to limited size of the chamber, slow and long coating cycles and line-of-site deposition. However, only vacuum based techniques can deposit most metals and alloys, a large number of compounds and polymers as well as ceramic or glassy materials on most types of solid surfaces. Consequently, vacuum coatings have established a niche in the semiconductor, optical, electronics and several other high technology fields.

Recent developments have been targeted toward improving process economics of vacuum coating using innovative and novel approaches. These projects have received funding from EPA and other federal agencies under pollution prevention programs. In one such project, a zero-waste cadmium dry plating process was commercialized and it has been in production since 1997. This presentation describes another such project currently in progress.

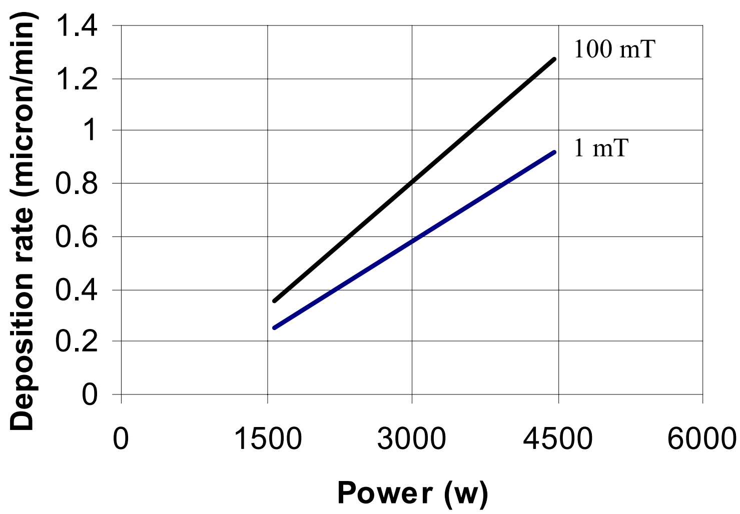
Overview of the Coating Process

Relative simplicity of hardware and process have been emphasized in the pursuit for environmentally safe coating methods. Consequently, the chromium coating method under study is not an exception to this philosophy. The proprietary features of the system and process are not available for disclosure at this time. However, a summary description can be made as follows. The metal or alloy vapors are generated in a vacuum chamber using an evaporative mechanism, i.e., heating and boiling off. The chamber pressure is of the order of 1 milliTorr (mT) or above. The vapors are generated uniformly from a relatively large surface area (> 650 cm^2 or 100 in^2) in an argon glow discharge (plasma). The vapors can be directed vertically or horizontally. The rate of vaporization is proportional to the power input to the vapor source as expected of such a process. Consequently, the control on vaporization as well as deposition rare is excellent.

As shown in the schematic of Fig. 1, the basic process and apparatus consists of a vapor source emitting vapors down on substrates loaded on a rack. Similarly, substrates can be suspended from a vertical rack in front of a vertical vapor source. In that case, all sides of the parts can be simultaneously coated when two vapor sources are located across each other.



The typical process cycle is about 10 to 20 minutes for a load of parts depending on the thickness and the type of metal desired. The graph in Fig. 2 shows deposition rate correlation with the source power and argon pressure.



Coatings of Al, Cu, Ni, and other metals have been deposited from 3 to 10 µm (120 to 400 µin) thickness within a 20 minute load-to-unload cycle on metallic, plastic, ceramic and composite substrates. However, chromium has been deposited on steel up to 120 µm (3 mil) thickness for feasibility studies. The adhesion to most materials appears to be equal or superior as compared to that of other methods.

Preliminary studies of chromium coating integrity, density and hardness on steel substrates have been conducted and some data has been obtained. The data indicated the coating density is above 99% and integrity is acceptable. There is no evidence of columnar crystal structure or porosity in chromium coatings as determined from the SEM cross-section studies. Under certain process conditions, the chromium hardness was measured to be above 1150 on Vickers scale (VHN). On a smooth surface such as that of a plastic material, chromium coatings with highly reflective mirror finish have been obtained up to thickness of about 2 μm indicating viability of decorative finishes. These reflective coatings were deposited directly on plastics such as the ABS.

Conclusion

A vacuum coating method is under development for depositing decorative as well as hard chromium. The significant features of the process are its relative process simplicity, high (>1 μm) coating rates, feasibility of three dimensional deposition and excellent adhesion to most materials including plastics and ceramics. The chromium coatings indicate promise in terms of density and hardness on steel substrates. The process has the potential for batch coating as well as continuous roll coating.