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Vacuum arc deposition by using a Venetian blind particle filter

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Abstract

Vacuum arc deposition is a commonly used technology for the deposition of hard coatings and all kinds of metals. The vacuum arc discharge is a simple source of highly ionized metal plasma. Films with a very dense structure and an excellent adhesion can be produced because of the high ion energy inside the vacuum arc plasma. But also a certain number of macroparticles is emitted and deposited. That is why a great number of particle filters was developed in the past, but no one of them has larger industrial usage. A very simple but effective filter design is the Venetian blind filter. The macroparticles are shielded from the substrate but the plasma is guided through the filter by means of magnetic and electric fields. With this type of filter, films with a dramatically reduced number of droplets can be produced. A plasma transmission through the filter of approximately 20% could be reached. Micrographs of the film surfaces were analyzed by a certain method to investigate the droplet distribution in number and size for different materials. A reduction of the droplet number down to 10%–1% of the unfiltered case could be determined. A filter unit for using at the most common vacuum arc deposition machines was developed and tested and is now available. The filter does not reduce the deposition area, so the standard deposition processes can be used furthermore. The filter is in use for metal deposition. A process for the production of hard coatings as metal nitride films is under development.

Such particle reduced coatings are especially appropriate for the surface protection of tools with high demands of surface smoothness and precision, for example forming tools for high precision parts.

The fields of application of the vacuum arc technology can be enlarged by means of this type of plasma filter. The advantages of this filter are the good handling properties and the possibility of retrofitting existing arc coaters.

Keywords: Vacuum arc; Plasma filter; Hard coating

1. Introduction

Vacuum arc deposition is a commonly used technology for the deposition of hard coatings. Typical applications are the coating of tools with very hard and wear resistant thin films as TiN, AlTiN or hard amorphous carbon. The plasma is produced by a vacuum arc discharge. Beside the highly ionized plasma also a certain number of macroparticles is emitted and deposited on the substrate. Especially in the case of lower melting metals a big number of particles is emitted. For certain applications (high precision tools, optical coatings, microelectronics) particles are not wanted. For that reason various principles of particle filters were developed and tested in the past. Most of them are magnetic filters. The plasma is deflected by a magnetic field in a certain angle to the original direction of plasma expansion. The uncharged particles are not influenced by the field. In this way the particles can be separated from the plasma. But

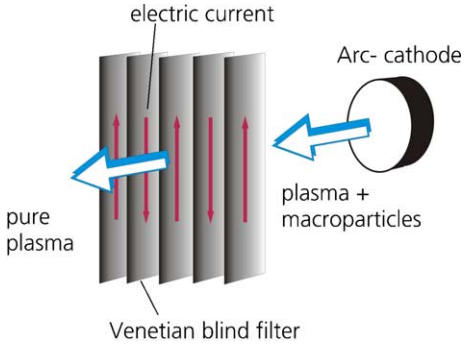

Fig. 1. Principle of Venetian blind particle filter.

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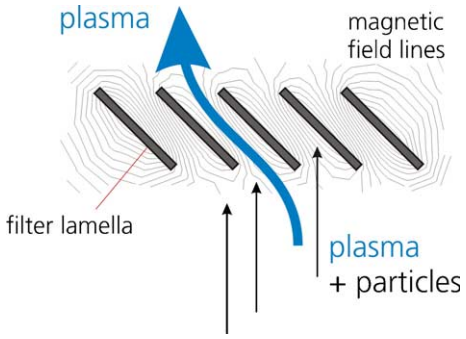

Fig. 2. Cross section of the filter with calculated magnetic field lines.

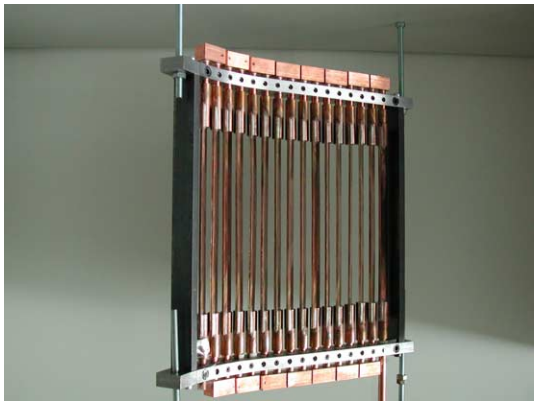

Fig. 3. Photograph of the Venetian blind filter module; this module is suitable for assembling at existing vacuum arc coaters.

no one of these filter concepts has larger industrial usage up to now, because of the high costs and the limited plasma transmission.

A very simple and effective filter concept is the Venetian blind filter [1,2]. Based on this concept an optimized filter was developed and tested [3].

2. Principle and realization of the Venetian blind particle filter

Fig. 1 shows the principle of the filter. The substrate is shielded from the arc evaporator cathode by the filter lamellae. The position and tilt of the lamellae are adjusted in that way, that no direct line of sight exists between the cathode and the substrate. The filter is optically closed. Plasma and particles are emitted by the cathode, the particles get caught on the lamellae. The plasma is guided through the gap between the lamellae by a magnetic field. The magnetic field is generated by an electric current flow through the lamellae (see Fig. 2).

Fig. 3 shows the Venetian blind filter. This filter module is suitable for assembling at existing vacuum arc coaters. The shape of the filter is very flat. The coating volume of a coating chamber is not reduced by this filter. The cathode size that can be covered by the filter has no limit in principle. The filter is water cooled and suitable for continuous operation. A typical plasma transmission ratio of about 20% can be achieved by this filter. This value is comparable to the results with other filter principles [6–8].

3. Coating results

To investigate the filter performance, different metal films were deposited on silicon wafers with and without the filter. The films were analyzed by different ways. Beside SEM investigations also roughness measurements were performed. Additionally a computer aided method for counting the particles was used to investigate the size distribution of the particles. Fig. 4 show PtAu5 films on silicon, deposited by standard arc technology (left) and deposited by using the Venetian blind filter arc technology (right). Such films were investigated by roughness measurements (see Fig. 5). In this example roughness R_z could be reduced by factor 6 and R_a by factor 3. The resulting surface quality is mirror like.

The results of the investigation of the particle size distribution is shown in Fig. 6 for a PtAu5 film and in Fig. 7 for a Cu film. In all cases the number of particles is decreasing with increasing size. That means, there are more small particles than big ones in this range of particle size. Earlier investigations [4] have shown comparable results for Cu. Such a size distribution was

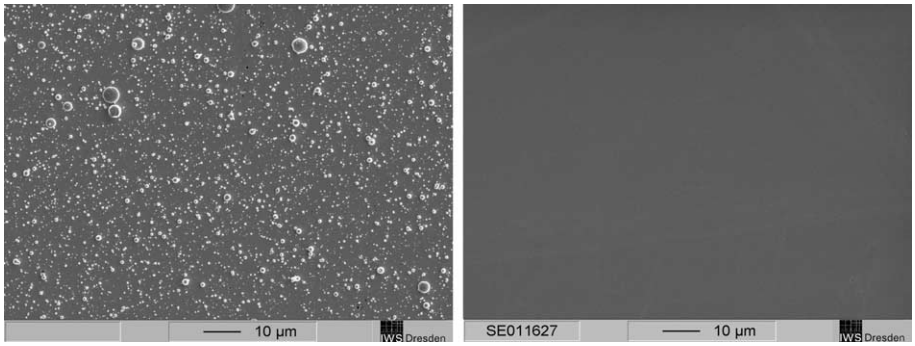

Fig. 4. PtAu5 films on a silicon wafer, prepared by vacuum arc technology (left) and filtered arc technology (right). The film thickness is about 50 nm in both cases.