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Advanced ceramic coating methods

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The article is dedicated to put together on data associated with researches which is concerned about advanced ceramic coating methodsand give some detailed information about basic principle of working processes of coating methods as well as investigating advantages and disadvantages of these methods.The main principle characteristics of these methods which determine their possible using on various purposes in machine building are given in the article.
Key words: ceramic coating, coating methods, coating, substrate, deposition, gas.

It is obvious that ceramic coatings are becoming more common in various fields of industry nowadays as with developing technology, metal and metallic alloys are required high performance in different environments, which can be satisfied by using ceramic coatings. Ceramic coatings have been extensively employed in the surface modification field during the last decades due to their excellent properties. The coating of metal surfaces with a thin ceramic layer has always been a useful means to enhance the mechanical performance of metallic substrates. Ceramic materials have many advanced properties such as heat resistance, corrosion resistance, wear resistance and electrical insulation. At present, there exists a variety of ceramic coating methods for protective application ceramic coatings. There are given some of advanced ceramic coating methods:

1.*Physical Vapour Deposition (PVD).* It is functionally, a vaporization coating technique, involving transfer of material at an atomic level (fig. 1). The process involves the following four stages:
1. Evaporation:The material to be deposited is bombarded by a high-energy source such as beam of electrons or ions dislodging the atoms from the surface of the target before vaporizing them.
2. Transport:The movement of vaporized atoms from the target to the substrate to be coated.
3. Reaction:Coatings of metal oxides, nitrides, carbides new metal targets. The metal atoms react withappropriate gases during the transportation stage.4. Deposition:Coating build up on the substrate surface.
Advantages:

- PVD coatings are sometimes harder and more corrosion resistant than coatings applied by the electroplating process. Most coatings have high temperature and good impact strength, excellent abrasion resistance and are so durable that protective topcoats are almost never necessary.

• Ability to utilize virtually any type of inorganic and some organic coating materials on an equally diverse group of substrates and surfaces using a wide variety of finishes.

• More environmentally friendly than traditional coating processes such as electroplating and painting.

• More than one technique can be used to deposit a given film.

Disadvantages:

• Specific technologies can impose constraints; for example, line-of-sight transfer is typical of most PVD coating techniques, however there are methods that allow full coverage of complex geometries.

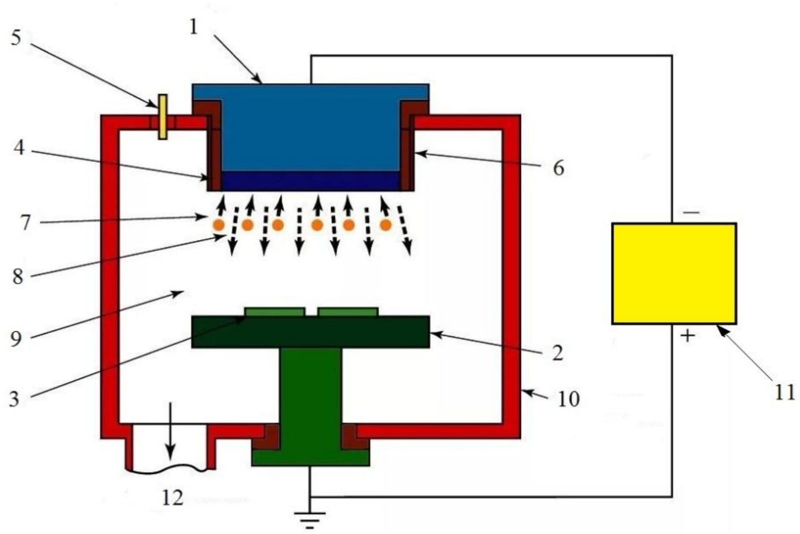

Figure 1 – A schematic of the PVD coating process:

1- Cathode; 2- Anode; 3- Substrate; 4- Target; 5- Working gas feed; 6- Ground shield; 7- Ion flux; 8- Sputtered flux; 9- Plasma; 10- Vacuum chamber; 11- Power supply; 12- to vacuum pumps

• Some PVD technologies typically operate at very high temperatures and vacuums, requiring special attention by operating personnel.

• Requires a cooling water system to dissipate large heat loads [1].

2.*Chemical Vapour Deposition (CVD)* . CVD method ensures dense coating deposits on the materials due to the decomposition of relatively high pressure gases (fig. 2). Gaseous compounds of the materials to be deposited are transported to the substrate surface to achieve deposition due to thermal reaction process. Reaction byproducts are then exhausted out of the system. It is a very versatile process to produce varieties of coatings, powders, fibers and monolithic parts. It is possible to produce almost all types of metallic or non-metallic elements, including carbon and silicon, as well as compounds such as carbides, nitrides, borides, oxides, intermetallic and many others using this technique [2, 3].

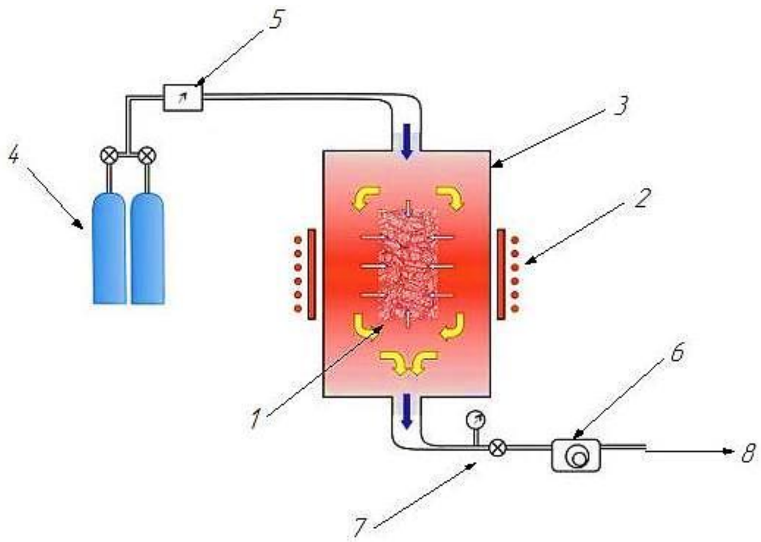

Figure 2 – A schematic of the CVD coating process:
1- Subsrate; 2- Heating system; 3- Reaction chamber; 4- Precursor and carrier gas feed; 5- Flowmeter; 6- Vacuum pump; 7- Pressure regulator; 8- Exhaust

3.*Electron beam-assisted physical vapour deposition (EB-PVD)*. In electron beam-assisted physical vapour deposition, low-pressure conditions are required (fig. 3). Air is evacuated from the chamber and an electron beam is focused on a target of the intended ceramic coating material. The focused electron beam melts the target material that is later evaporated. Above the target material the component intended as substrate is placed to be able to “receive” the evaporated ceramics. When the evaporated atom interacts with the substrate it solidifies and a diffusion driven process creates the coating. Electron beam assisted physical vapour deposition shows a very distinct structure of the deposited coating. The process generates a columnar structure growing perpendicular to the substrate surface, were the porosity arises from the distance between these columns [4]. This structure is far less sensitive to strain than the laminar structure generated by PS, but exhibits a higher thermal conductivity.

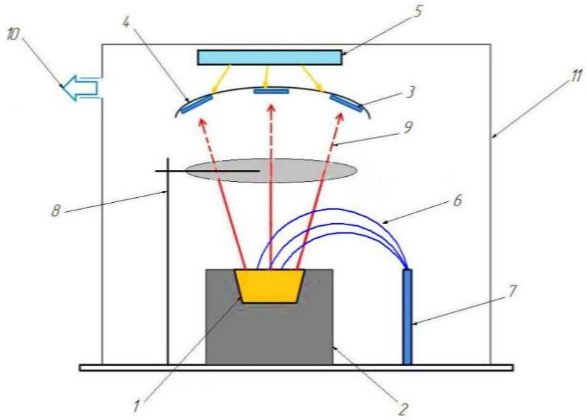

Figure 3 – A schematic of the EB-PVD coating process:
1- Target; 2- Water-cooled crucible; 3- Substrate; 4- Sample holder; 5- Radiation heating; 6- Electron beam; 7- E-beam gun; 8- Shutter; 9- Evaporation flow; 10- Vacuum pump; 11- Vacuum chamber

4.*Plasma Spray (PS).* Plasma is a dense gas which has equal number of electron and positive ion and generallynamed as fourth state of the matter (fig. 4). This method has two primary priorities; It can provide very high temperatures that can melt all known materials and provides better heat transfer than other materials. High operating temperature of plasma spray coating, gives opportunity to operate with metals and alloys having high melting points. Alsousing plasma spray coating in inert surroundings is another positive side of the method. Oxidation problem of the subject material is reduced due to inert gas usage in plasma spray such as argon, hydrogen and nitrogen. All materials that are produced in powder form and having a specific grain size can be used in this method [5].

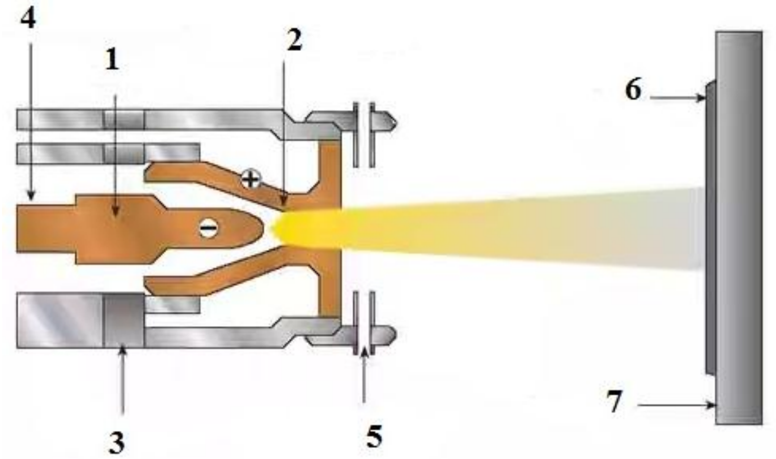

Figure 4 – A schematic of the Plasma spray coating process:
1- Cathode; 2- Water-cooled anode; 3- Insulator; 4- Plasma gas + current; 5- Powder port; 6- Coating; 7- Substrate.

5. *Laser surface alloying (LSA).*Laser alloying of material surface is a advanced material processing technology that produces an extremely dense and crack-free structure in developed material which displays excellent bonding with the base material. Laser coating gives rise to new components with high resistant surfaces against wear even at high temperatures or low temperatures. For different applications, laser alloying offers a wide range of possible coating materials.Laser surface alloying uses a laser beam as the heat source. Special properties of the laser beam, such as its beam directionality, high intensity and high spatial resolution make it an excellent heat source. It heats a specific area very fast followed by faster cooling resulting in a novel microstructure. The desired material can either be added simultaneously along with laser irradiation or laser irradiation is carried out on the surface where the material has already been placed by some of the coatings discussed above. The advantages of material laser alloying include minimal heat input, less impact on material mechanical properties. The laser produces line energy there by melting the material and powder to deposit. Process parameters plays an important role in both surface quality and surface microstructure [6].

Table 1

Advantages and disadvantages of coating methods

Advantages	Technologies	Disadvantages
very high hardness values; good adhesion;	CVD	distortion; coating of sharp-edged geometries is difficult; disposal of aggressive gaseous waste;
dense coatings with high adhesion; low coating process temperature; allows deposition of pure elements, compounds and alloys;	PVD	low growth rate of coating; expensive vacuum process; restrictions in terms of part geometry; poor mechanical bond;
large variety of materials; good adhesion; properties well controllable by choice of materials and process;	Plasma spray processes	residual porosity; deposition efficiency of coating process (overspray);
Material utilization efficiency is high; Availability of structural and morphological control of films; Deposition rate can be controlled well;	EB-PVD	Difficulties in coating of inner surface of complex geometries; Certain materials are not well-suited to evaporation; Non-uniform evaporation rate can be exist as a degradation of filament of electron gun;
Better technique for coating of any shape; Improves upon the materials inherent susceptibility to wear and oxidation; A lot of material flexibility; Improves wear resistance capacity and fatigue resistance; Without imperfections (cracks, porosity…)	Laser surface alloying	Realization of thick layers with a large solute content; Non-homogeneous energy distribution in the laser beam; Very narrow temperature field ensuring the aimed microstructural changes.

So far we have discussed various methods of coating substrates for their use in engineering applications. Although, many of the above methods are in practice, they are not perfect and have several limitations (table. 1). PVD methods are good but usually have a poor mechanical bond and the thickness is often very small. The method requires a vacuum, and coating of large or intricate parts is difficult. Diffusion coating CVD is very common and forms a good metallurgical bond but because of high substrate temperature, the bulk properties are affected because of a change in the microstructure as a result of heating. Moreover the CVD method is used only for a limited number of coatings and the method becomes complicated if alloy coatings or ceramic coatings using a reactive pack are used. Plasma spray coating is perhaps being used extensively these days because they is easy to apply, fast and can be made available at the site, however high porosity, non-uniform surface and mechanical bonding with the substrate, often limit their use in several aggressive environments. Thus new methods which are more universal and do not require vacuum are very much required. One of the methods is laser surface alloying. But there are a number of disadvantages concerning LSA too.

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