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REVIEW ON BIOACTIVE CERAMIC COATING

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ABSTRACT

Currently metallic biomaterials like 316L stainless steel, Co-Cr alloys, Ti and its alloys are being used extensively as implantable biomaterials for their good mechanical properties. The necessity for innovation and development of smart materials/coatings with improved functional and bio-compatible properties, either by employing surface engineering or through improving process parameters has been felt. Bioactive HA and Bio-glass coatings over orthopedic & dental implants are used in several applications with the aim of increasing corrosion resistance of the metal and to enhance the biocompatibility & bio-stability. Some of the more commonly used techniques to deposit bioactive coating over implants include plasma deposition, physical vapour deposition, chemical vapor deposition, ion-beam sputter deposition, thermal spraying, sol-gel deposition and dipping. This review is aiming to give a comprehensive summary of bioactive coating, different coating techniques and the advantages and disadvantages of bioactive coating.

KEYWORDS: ***Metallic biomaterials, Bioactive coating, biocompatibility, Hydroxyapatite, Bio-glass.***

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INTRODUCTION

Metallic biomaterials like stainless steel, Co-based alloy, Ti and Ti alloys have been extensively used in numerous biomedical applications over a long time because of their excellent mechanical properties (like high strength, good wear and corrosion resistance), biocompatibility & durability [1]. But most of the implanted metallic biomaterials have a tendency to corrode in the biological environments, which usually cause inflammatory and loosening of the implants [2, 3, 4]. It is reported that wear and corrosion are the major causes for degradation of surgical implants such as hip and knee joint implants, which usually happens after 10–15 years of use [5, 6]. Furthermore, some mechanical properties like low surface hardness, high friction coefficient and poor wear resistance limiting their application [7]. Another problem associated with metallic implants is their biological inertness. Bioinert materials were not capable of inducing osteogenesis or new bone ingrowth, thus only low fixation strength can be achieved between the implant and the surrounding host bones [8, 9]. To protect the metallic implants from corrosion and wear and to improve their bioactivity, various surface modification techniques have been applied to deposit a wide variety of functional bioactive coatings on the surfaces of metallic implants for promoting biological activity, host tissue integration, and/or tissue regeneration [10, 11, 12]. Surface modifications can broadly be categorized into three classes: (a) addition of desirable functional materials onto the surface; (b) change of the existing surface into more desirable compositions and/or topographies; and (c) removal of material from the existing surface to create specific topographies [13, 14]. Surface coating of biomaterials with bioactive ceramics exhibits improve material and biological responses through changes in a material's surface chemistry, topography, energy, and charge, without changing the bulk properties of the implant [15, 16]. The bioactive ceramics used as coating materials includes calcium phosphates like hydroxyapatite and bioactive glass [17]. Bioactive coatings are applied to orthopedic & dental implants to facilitate implant fixation and bone growth [18]. Polymeric coating formulations are used to enhance biocompatibility, bio-stability, thrombo-resistance, anti-microbial action, dielectric strength and lubricity [19]. The efficiency of metallic implants for biomedical applications can be improved by coating with bioactive materials due to their bonding ability with the living bone [20, 21]. Bioactive ceramics exhibit osteo-conduction by formation of biologically active bone-like apatite through chemical reaction of the ceramic surface with surrounding body fluid [22]. Bio-conductive material hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$, (HA)] is widely used as coating on the surface of the metals or alloys because they chemically connect the metal/alloy implant and bone [23]. Due to its structural similarity to CaP minerals found in bone tissues, HA promotes chemical osteointegration through formation of a light bond with bone. Specifically, the biocompatibility of HA and osseoconductivity behaviour of this ceramic material were confirmed and employed in medicine for more than twenty five years. Beside hydroxyapatite there is another potential material for bioactive coating namely bio-glass [24]. Their excellent bioactivity and well-documented biocompatibility make them ideal for biomedical applications, particularly in orthopaedic and dental implants [25]. Bioactive glasses and glass-ceramics can indeed elicit complex, multi-stage interactions with living body fluids and living tissues, whereby the surface of the component undergoes chemical and structural alterations which subsequently favour the growth of bone tissues [26]. The glassy network of these materials can be partially dissolved by body fluids, releasing Ca^{2+} and P^{5+} ions and forming large amounts of bioactive Si-OH groups. Si-OH groups on the coating surface are beneficial for the nucleation and growth of apatite in the body fluids which is supersaturated with respect to HA [27], thus leading to the formation of a surface layer with a chemical and structural affinity to bone tissues. Si ions released from bio-glass can stimulate intracellular reactions and further assist the bone tissue in bonding to the surface of bio-glass [28, 29, 30].

Bioactive coating

The application of coatings is one of the potential approaches that are available to modify the surface of materials [31, 32]. The main reason for coating and modification of metallic biomaterials is to modify biological response of the host tissue in the peri-implant region. The bioactive coating could be a surface profile into which bone could grow or a layer of additional material onto which bone could attach. Bioactive coatings on metallic implants are used in several applications with the aim of increasing corrosion resistance of the metal [33]. Cement-less fixation of orthopedic and dental implants typically requires a bioactive coating over the implants because most metallic orthopaedic and dental implants are bio-inert and do not bond chemically to bone as does hydroxyapatite and bio-glass [34]. The implants are coated with a layer of bioactive material such as hydroxyapatite or bioglass to alter the surface properties of the implants and also to aid the bond with the bone [35]. The bioactive coating could be a surface profile into which bone could grow, or a layer of additional material onto which bone could attach. Coatings of HA and Bio-glass have good potential as they can exploit the biocompatible and bone bonding properties of the ceramic, while utilizing the mechanical properties of the substrates [36]. Several types of bioactive ceramic coatings on prosthesis designed to enhance attachment of implant to tissue have been investigated [37, 38]. Bioactive coating are generally applied over implants to i) defend the implants against chemical attack, ii) separate the implant from the surrounding tissue to avoid inflammatory or other negative reaction by making the implant biocompatible, iii) turn a non-bioactive (inert) surface into a bioactive one to improve stability and functionality of the implants, iv) fix an implant to bone and reduce micromotion, v) produce an intermediate region between bone and the implant to enhance the transition of stress between them [39], vi) New tissue growth on the surface and direct attachment of the implant to the tissue ensures the durability of the coating [40].

Hydroxyapatite coating

Hydroxyapatite is the most wonderful bioceramics in the Ca-P group. It is the most attractive Ca-P compound because its chemical structure and composition resembles with the mineral content of hard tissue such as bone and tooth [41]. Due to its osteconductive property hydroxyapatite is regularly used as a coating material over bio-inert implant to alter the surface properties [42]. Porous hydroxyapatite coating promotes bone formation around the implant [43]. In this manner a bio-friendly atmosphere was created which the hard tissue easily accepts. Some biological advantages of hydroxyapatite coating are: i) enhancement of bone formation, ii) accelerated bonding between the implant surfaces and surrounding tissue [44] and iii) the reduction of potentially harmful metallic ion release. Hydroxyapatite has been used to coat many types of implants such as hip and dental implants. It also establishes strong interfacial bonds with Ti implants and this has been attributed to some chemical bonding between hydroxyapatite and the Ti substrate [45].

Bio-glass coating

Bioactive glasses were originally introduced as an improved type of bone implant material. Designed to have a specific biological activity when in contact with the body, bioactive glasses have the ability to bond with both hard (bone) and soft (subcutaneous) tissue. This “tissue bonding” response of the body contrasts with the encapsulation and eventual rejection of other standard “inert” implant materials such as metals and plastics. Implanted into a bone defect, the surface of bioactive glass remodels to form hydroxy-carbono-apatite (HCA), the chemical and structural equivalent of bone mineral. Additionally, bone growth markers and bone repair cells are increased in the presence of bioactive glass, thus accelerating the overall healing process. Like all glasses, bioactive glasses are an amorphous state of their molecular constituents. In the original form currently approved for medical use, the glass is a four-component system of oxides of silicon, calcium, sodium and phosphorus. The relatively low silicon and high alkaline content lead to a rapid ion exchange in aqueous environments. This exchange generally leads to an increase in solution pH, which can be substantial for finely grained powders having high surface to volume ratios. The initially rapid release of sodium is accompanied by a somewhat slower release of other ion species, predominantly calcium and silica. Under certain conditions in solution, these ion species will precipitate onto the glass and onto other nearby surfaces, to form calcium-containing mineral layers. In this case, the outer glass surface itself can transform to HCA [46, 47]. The ability to build such a surface is sometimes referred to as a measure of the “bioactivity” of the glass.Bio-glass is a special type of glass. Bio-glass is able to form carbonated hydroxyapatite in vivo. It has both osteo-conductive as well as osteo-productive properties. For these properties bio-glass is also used as coating material over orthopedic and dental implant [48].

Biomedical Coating Techniques

Surface treatment or surface modification is considered as one major concern on recent developments in metallic biomaterials [49]. Medical coatings and surface modifications are as diverse as the products they seek to enhance [50]. There are many coating techniques that have been used to create a bioactive coating on metallic implant materials. There are quite a number of processes to apply coatings, as well as a nearly unlimited number of coating materials. Some of the more common coating techniques include plasma deposition, physical vapour deposition, chemical vapor deposition, ion bombardment, ion-beam sputter deposition, thermal spraying, sol-gel deposition and dipping have been used to deposit bioactive coating [51, 52]. By incorporating a bioactive coating the qualities that can be altered include hardness, wear resistance, lubricity, wettability, bond strength and resistance to bacterial attachment. A brief outline of the different coating techniques are given below highlighting their merits and demerits.

a) Dip Coating

Dip coating is one of the oldest and simplest coating technique where the substrate to be coated is immersed in a liquid and then withdrawn with a well defined withdrawal speed under controlled temperature and atmospheric conditions [53]. Vibration-free mountings and very smooth movement of the substrate is essential for dip systems. An accurate and uniform coating thickness depends on precise speed control and minimal vibration of the substrate and fluid surface [54]. The withdrawal speed, the solid content and the viscosity of the liquid mainly define the coating thickness [55]. In dip coating the substrate to be coated is initially heated and then the heated article is dipped in a tray containing powder and the powder splashed on it, or dipped in a fluidized bed of powder for 2 to 5 seconds [56]. The powder will stick to the hot article. Once the article is coated, care should be taken to ensure that it does not rub or come into contact with any surface, to prevent damage to the coating. At this stage, a rough powdery, but uniform coating (0.05-0.5mm) on the substrate is obtained (Figure-1). The excess un-melted powder is shaken off with a slight jerky motion or light tapping [57]. The coating thickness increases with the duration of dipping in the powder medium. The merits of this technique are inexpensive, very fast and applicable to complex substrates whereas some demerits are there such as this technique requires high sintering temperature and there is a possibility of thermal expansion mismatch.

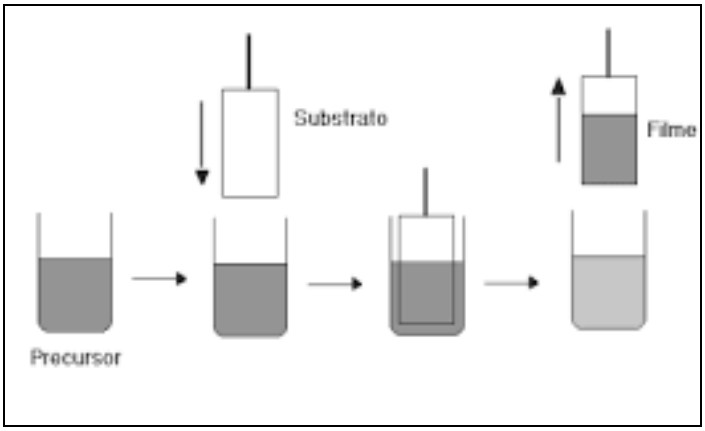

Figure 1
Schematic Representation of Dip coating process

b) Sputter Coating

Sputter coating is a vacuum coating process that involves the use of ions from the gas generated plasma to dislodge coating atoms or molecules from a target made from the material that is to become the coating [58,59]. The plasma is established between the target and the substrate by the application of a DC potential or an alternating potential (RF) between the system electrodes (target and substrate) [60,61]. The dc process is used when the target and the substrate are both electrical conductors. An inert gas such as argon is introduced into the vacuum chamber to form the glow discharge plasma between the electrodes [62]. Sputter coating for SEM is the process of applying an ultra-thin coating of electrically-conducting metal – such as gold (Au), gold/palladium (Au/Pd), platinum (Pt), silver (Ag), chromium (Cr) or iridium (Ir) onto a non-conducting or poorly conducting specimen. Sputter coating prevents charging of the specimen, which would otherwise occur because of the accumulation of static electric fields. It also increases the amount of secondary electrons that can be detected from the surface of the specimen in the SEM and therefore increases the signal to noise ratio. Sputtered films for SEM typically have a thickness range of 2–20 nm. The main advantages of this coating process are uniform coating thickness (0.02-1μm) on flat substrates, unaltered transfer of atoms and molecules, enhancing coating strength by sputter cleaning of the substrate [63]. Some disadvantages include line of sight technique, expensive, time consuming, produces an amorphous coating and can't coat complex substrates. The principle behind the sputter coating is shown in Figure-2.

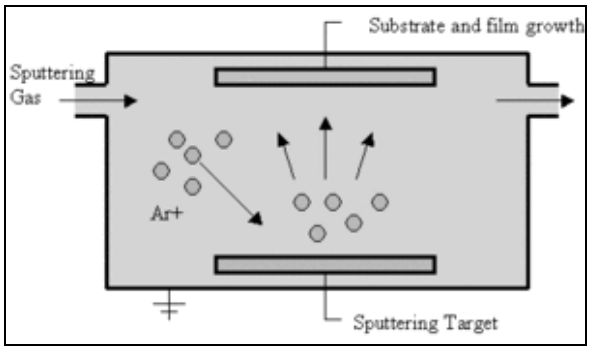

Figure 2
Principle of Ion Beam Sputter Coating

c) Pulsed Laser Deposition

Pulsed laser deposition (PLD) is a wonderful technique for thin film deposition which has been successfully applied to an extremely wide range of materials [64]. This technique was based on the interaction of a high power density laser beam with a solid target and presents several unique advantages over other conventional physical vapour deposition techniques, especially when using pulsed lasers [65]. This process utilizes a pulsed laser such as KrF to ablate the target material, forming a highly energetic plume that deposits the film onto the substrate [66, 67]. The laser is completely isolated from the actual deposition chamber. During the experiment, the laser beam is pointed onto a target inside the chamber through a viewpoint in alignment with the target (Figure-3). The pulsed laser deposition technique involves three main steps: a) ablation of the target, b) formation of a highly energetic plume, and c) the growth of the film on the substrate [68]. When the laser radiation is absorbed by a solid surface, electromagnetic energy is converted into electronic excitation as well as chemical, mechanical and thermal energy to cause evaporation and plasma formation. The ablation of the target forms a plume of energetic atoms, electrons, ions and molecules. The merits and demerits of this technique are same as sputter coating. Coating thickness by this process is 0.05-5 μm. A typical set-up for PLD is schematically shown in the following figure (Figure-3). The main advantages of Pulsed Laser Deposition includes simple, versatile, cost-effective, fast and scalable.

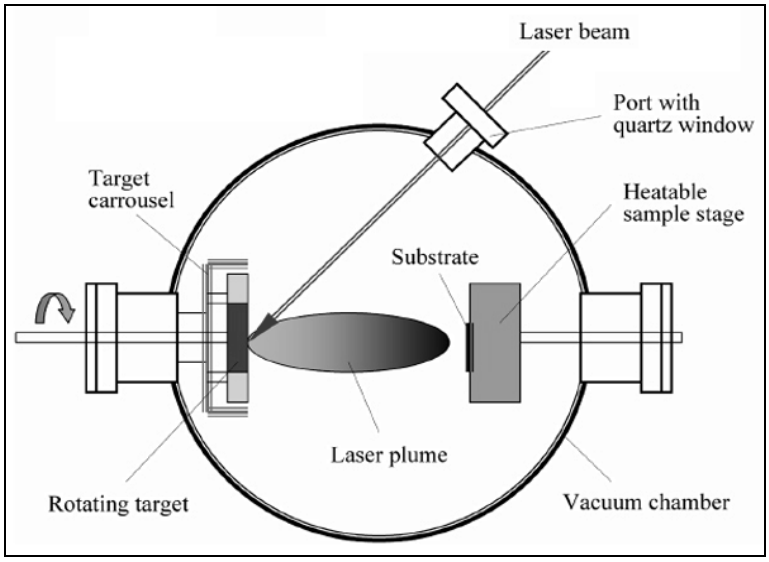

Figure 3
Schematic view of a PLD-System

d) Thermal Spraying

Thermal spraying is one of the most useful coating techniques for enhancing the corrosion and wear resistance of biomedical metallic implants [69]. Fundamentally, thermal spraying is a process in which melted or semi-melted particles are sprayed onto a substrate surface through impact [70, 71]. A large proportion of thermal spraying is conducted in air or uses air for atomization. Chemical interactions occur during spraying, notably oxidation. Metallic particles oxidize over their surface forming an oxide layer [72, 73]. This is evident in the coating microstructure as oxide inclusions outlining the grain or particle boundaries. Some materials (such as titanium) interact with or absorb other gases such as hydrogen and nitrogen. Coatings generally have poor strength, ductility and impact properties [74]. These properties tend to be dictated by the "weakest link in the chain" which in coatings tend to be the particle or grain boundaries and coating/substrate interface [75]. The load carrying capacity of the coatings is limited, and thus requires a substrate for support. Some typical advantages of thermal spraying are able to coat complex substrates, produce uniform coating and cost effective [76]. Poor coating strength, high processing temperature and line of sight techniques are the main drawback of this method. The set up for thermal spraying is shown in the following diagram (Figure-4).

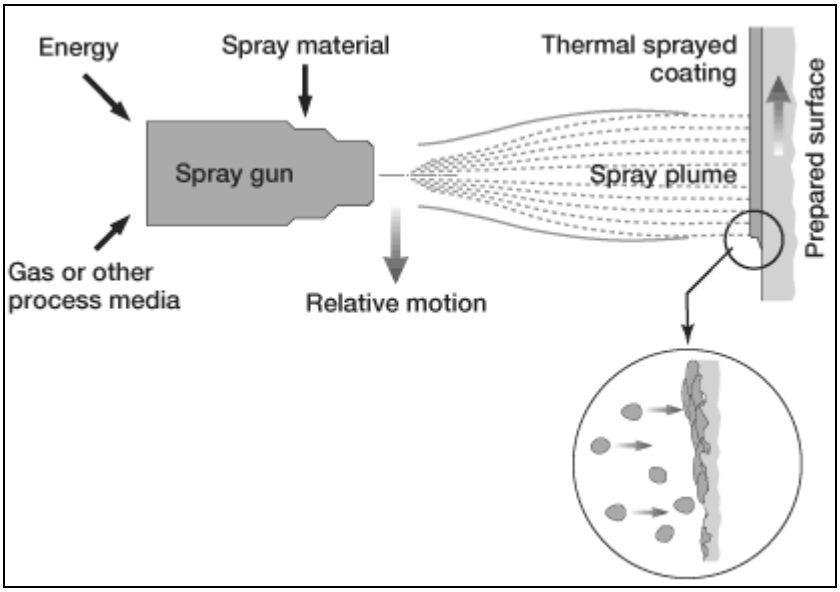

Figure 4
Working Principle of Thermal Spray Coating

e)

f) Sol-Gel

Sol-gel method is one of simplest techniques to deposit thin layer over substrates and sol-gel method can provide single or multilayer coating over metallic implants [77]. The use of sol–gel-derived coatings on surgical implants offers the potential for surface modification to achieve desired characteristics for tissue–implant integration (both hard and soft tissue) [78],

protection against and inhibition of implant degradation and degradation product release, and controlled release of bactericidal agents for improved infection resistance and all at relatively attractive processing costs [79]. Materials produced in a sol-gel process, possess a wide range of physical attributes, the nature of which depends on the type and amount of substrate used and other variables (including the preparation conditions like pH, temperature etc.) [80]. The sol-gel technique offers a low-temperature method for synthesizing materials that are either totally inorganic in nature or of both organic and inorganic. The process, which is based on the hydrolysis and condensation reaction of organometallic compounds in alcoholic solutions, offers many advantages for the fabrication of coatings, including excellent control of the stoichiometry of precursor solutions, ease of compositional modifications, customizable microstructure, ease of introducing various functional groups or encapsulating sensing elements, relatively low annealing temperatures, the possibility of coating deposition on large-area substrates, and inexpensive equipment [81]. Sol–gel protective coatings have shown excellent chemical stability, oxidation control and enhanced corrosion resistance for metal substrates. Further, the sol–gel method is an environmentally friendly technique of surface protection and had showed the potential for the replacement of toxic pretreatments and coatings which have traditionally been used for increasing corrosion resistance of metals [82, 83]. Various materials may be coated with liquid sol-gel hydrolizate, thus changing their characteristics, preventing corrosion, improving biocombatibility or electrical insulating properties [84]. The sol-gel method offers several advantages such as better control of the chemical composition of the coating, the possibility of preparing homogeneous films (Thickness <1μm), control of the film microstructure, and a reduction in the densification temperature of the ceramic layer. In addition, the sol-gel method requires less equipment than most available techniques and is potentially less expensive [85, 86]. Expensive raw materials and the controlled atmospheric processing are the disadvantages of such simple coating technique. The actual process of the sol gel coating technique is shown here (Figure-5).

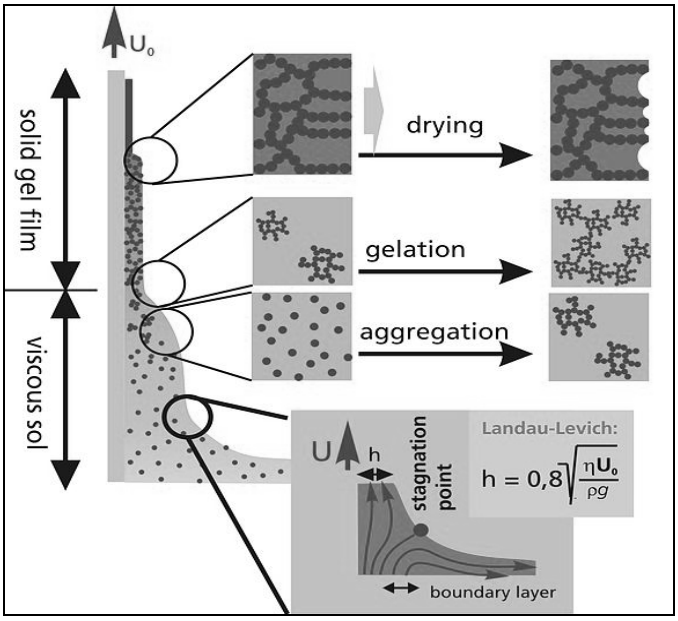

Figure 5
Diagram of Sol-Gel Process

g) Plasma Spraying

Plasma spray is the most versatile of the thermal spray processes [87]. Plasma is capable of spraying all materials that are considered sprayable material in the form of powder is injected into a very high temperature plasma flame, where it is rapidly heated and accelerated to a high velocity [88]. The hot material impacts on the substrate surface and rapidly cools forming a coating. This is the most widely used successful coating technique of various investigators in USA, Holland, Japan and in India for coating of metal implants using hydroxyapatite. In plasma spray devices, a DC electric arc is formed in between two electrodes to generate a stream of high temperature ionised plasma gas, which acts as the spraying heat source. The coating material, in powder form, is carried in an inert gas stream into the plasma jet where it is heated and propelled towards the substrate [89]. The hot, high-speed flame of a plasma gun can melt a powder of almost any ceramic or metal and spray it to form a coating for protection against corrosion, wear or high temperature [90]. The technique carries much less risk of degrading the coating and substrate than many other high-temperature processes do, because the gas in the plasma flame is chemically inert and the target can be kept fairly cool [91]. The plasma spray gun comprises a copper anode and tungsten cathode, both of which are water cooled. Plasma gas (argon, nitrogen, hydrogen, helium) flows around the cathode and through the anode which is shaped as a constricting nozzle. Plasma spraying produces a high quality coating by a combination of a high temperature, high energy heat source, a relatively inert spraying medium and quite high particle velocities [92]. In this method the hydroxyapatite or ceramic particles are softened by being propelled through a high temperature flame so

that they fused together to form a coating on striking of the substrate. In plasma spraying the high temperature (20,000-30,000^{o}C) is generated by striking an arc between two electrodes to produce ionized gas (H_2) and a carrier gas (N_2 or Ar) which carries the molten powder and sprays it on to the substrate surface uniformly (Shown in Figure-6). The major advantages of this coating technique is to coat a wide range of coating materials to meet many different needs, with virtually all materials available in a suitable powder form, produce good quality coatings than other conventional thermal processes such as flame or electrical arc spraying, many types of substrate material, including metals, ceramics, plastics, glass, and composite materials can be coated using plasma spraying and he high temperature of a plasma jet makes it particularly suitable for spraying coatings of ceramics over metallic implants. Several disadvantages of this techniques includes the process requires high temperature, non-uniform coating thickness, line-of-sight process, expensive and possibility to change of crystalline coating layer into amorphous phase.

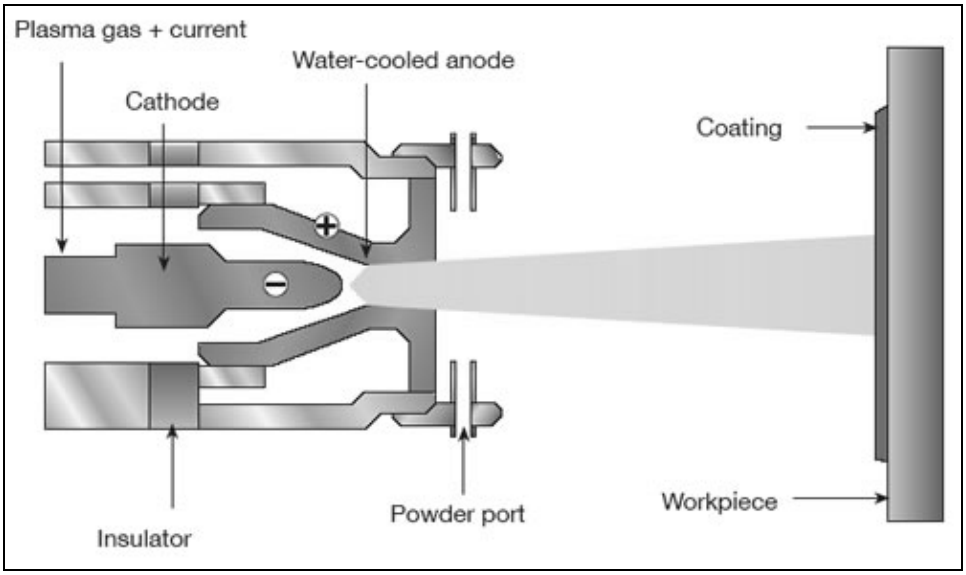

Figure 6
Schematic diagram of the plasma spray process

h) Spin Coating

Currently Spin coating is the predominant technique employed to produce uniform thin films. Spin coating is one of the most common techniques has been used for several decades for for the application of thin films to substrates and is used for many applications where relatively flat substrates or objects are coated with thin layers of material [93]. Usually a small amount of coating material is applied on the centre of the substrate, which is either spinning at low speed or not spinning at all. The substrate is held flat by a chuck, the solution is poured onto the substrate, and the substrate is then spin at high high-speed foe 20-30 seconds to obtain a uniform film. The applied solvent is usually volatile, and simultaneously evaporates. So, the higher the angular speed of spinning, the thinner the film. The thickness of the film also depends on the viscosity and concentration of the solution and the solvent [94]. It seems counterintuitive that a high-speed spin would give uniform film thickness, but the method works remarkably well. The concept behind spin coating is that as the substrate spins, the solution spreads to cover the entire substrate, and is pushed outward by the spinning [95]. Ideally, the atmosphere above the substrate will saturate with solvent, preventing the film drying before spinning is complete. The benefit of *spin coating* is its ability to quickly and easily produce very uniform films from a few nanometres to a few microns in thickness. The schematic diagram (Figure-7) highlighted the spin coating technique.

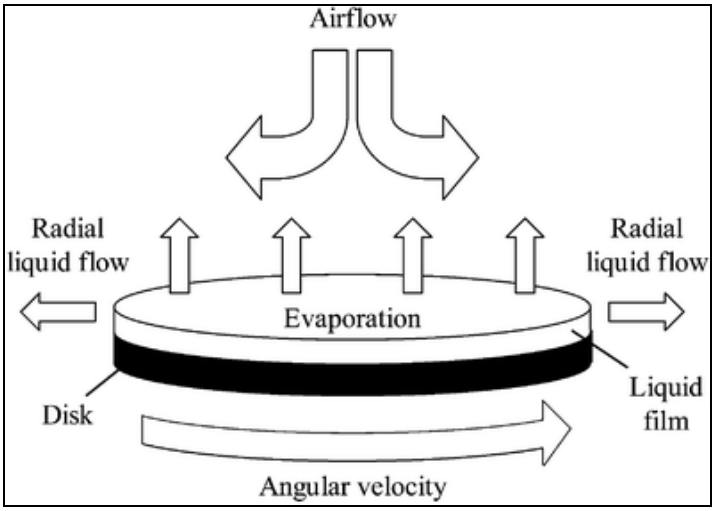

Figure 7
Schematic Process of Spin Coating

i) Electrophoretic Deposition

Electrophoretic Deposition (EPD) is one of the most outstanding coating techniques to be based on electrodeposition [96, 97]. Nowadays, increasing interest has been gained both from academic and industrial payers, due to its wide potential in ceramic coating processing technology. This is very similar to dip coating in which charged ceramic particles suspended in solution are uniformly deposited on the metal substrate by the applied voltage [98]. Then the coating is densified and bonded to the metal by sintering. This method is applied for the preparation of the films, for example the electrodepositing painting of metal, polymers, composites [99, 100]. The coating thickness of this process is in the range of 0.1-2.0 mm. The main advantage of this technique includes simple process and easy to scale up, can coat complex substrate, high coating rate and versatility when used with different materials and their combinations; produce uniform coating thickness, its cost effectiveness as it requires simple and cheap equipment [101, 102]. This process has some limitations such as difficult to produce crack free coatings and it requires high sintering temperatures. The Figure-8 shows the principle of electrophoretic deposition.

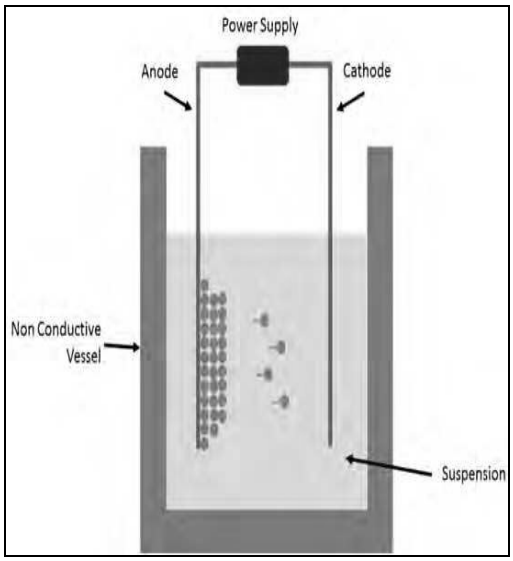

Figure 8
Working Principle of Electrophoretic Deposition

j) Hot Isotatic Pressing

The Hot Isostatic Pressing (HIP) production method is a relatively new and demanding technology that uses high pressure and high temperature to fuse powdered materials into solid substrate [103]. The production method makes it possible to produce metal components with mechanical properties and a geometric shape, unobtainable by other means. HIP-components are used in applications that have especially high performance demands within industries like: the aerospace industry, the oil and gas industry, the nuclear industry and chemical industry [104]. During the process, a powder mixture of several elements is placed in a container. The container is subjected to elevated temperature and a very high vacuum to remove air and moisture from the powder. The container is then sealed and hot isostatic processed (Figure-9). The application of high inert gas pressure

and elevated temperatures results in the removal of internal voids and creates a strong metallurgical bond throughout the material. Through this method deposition of clean uniform coating layer (0.2-2.0 mm) with fine grain size is possible. But the main drawback of this methods include coating of complex substrate is not possible, chance of thermal expansion mismatch due to high processing temperature.

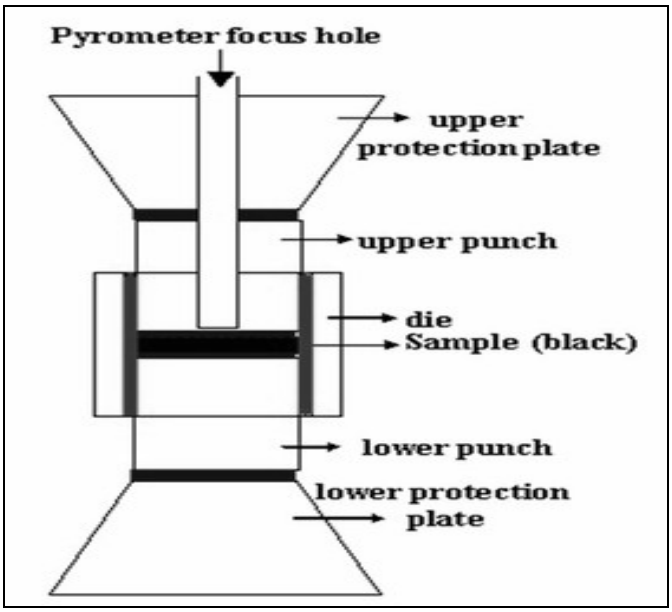

Figure 9
Hot Isostatic Pressing technique for coating

Advantages of Bioactive coating

To increase the long-term stability of the implant and improve the integrity of the bone replacement implant and surrounding tissue, bioactive materials is generally used as bioactive coating on the implant surface. The bioactive coating on implants provides a variety of advantages include.

a) Biocompatibility

Coatings need to exhibit long-term compatibility and a non-reactive relationship with body fluids and tissues. The coatings should not undergo any chemical interaction with the substrate to which it is being applied, nor should it produce any toxic byproducts or extracts that could be harmful to a patient or the function of the item being coated. Bioactive coatings have excellent biocompatibility. There are no adverse reaction reported to the bioactive coatings and no tendency of the body to wall of the coated surfaces with a fibrous encapsulation.

b) Bioactivity

The HA coatings release Ca and P ions. These ions are the raw materials from which bone is constructed. On the other hand bio-glass is able to form a carbonated hydroxyapatite layer which is similar top that of bone apatite. Osteoblasts deposit bone on the surface of HA coatings. That is bone begins to grow from the implant surface outward, and not just from the existing bone to the implant, reducing healing time.

c) Bone Bonding

Because bone grows directly on the implant surfaces, the surface bonds directly to the bone. The tendency of bone to grow on to and bond to the Ha surfaces means that supporting bone forms sooner in contact with HA coated implants. The bone bonding ability of the bioactive coating ensures the durability of the coating. Nearly 20 years of clinical experience and 18 years of published results show the unsurpassed excellence of Ha coatings for both orthopedic and dental applications.

d) Reduced the wear properties of implant

Wear of the orthopedic implant materials is another serious issue. Bioactive materials have the properties so similar to natural bone that the osteoclasts cells tear down these materials and replace them with natural bone. So migration of the particle from the implant surface is reduced.

Disadvantages of bioactive coating

In most of the coating technique, elevated temperature is required to anchor the bioactive particle onto the implant surface which limits the choice of substrate material. The promotion of bone growth on the surface of implants using coatings of bioactive glass or hydroxyapatite is expensive. The coatings are frequently thick and brittle and are subjected to fracture at the interface between coating and implants, thereby releasing large particles in the body. Moreover the coating is unsuitable for the polymeric implants because of high temperature involved. Mechanical methods of promoting bone to implant adhesion have only a temporary effect, as the bone does not grow onto the implant. These drawbacks limit the working life of current implants, which requires additional operations to fit new implants when the old ones loosen.

CONCLUSION

Bioactive coatings over metallic implants have been applied with variety of surface modification techniques to protect the metallic implants from corrosion and wear and to improve their bioactivity. However, few studied

coatings have multi-functions and few of them have come into clinical use. This review provides only a brief summary of the bioactive coating followed by some of the commonly used coating techniques available and advantages and disadvantages of bioactive coating. Therefore, tremendous work should still be done to validate the existing potential coatings & explore new potential candidates. Multi-functional coatings may be one of the major research goals. In addition to that in depth durability study on bioactive coating and the stress strain characteristics of such coating layer during insertion of the implants within bone or teeth is another area to require attention. Hence bioactive coating over metallic implants removes the barriers of inertness as well as improves the functionality and biostability

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