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Adsorptive polymer coating techniques and their application

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Abstract

Coating is a covering that is applied to the surface of an object, also known as the substrate (layer under something else), Functional coatings change the surface properties of the layer underneath. It can be applied for adhesion, wettability, corrosion resistance and wear resistance. As it has been well known for a long time, UV radiation is among the most severe factors causing damage to organic materials of which objects of coatings are typically made. Polymer coating degrades when expose to UV lights and thus fail to protect the layer. Therefore, to dominance the degradation of polymers, a new path of adsorptive polymer coating has been employed. The present review describes the salient features of adsorptive polymer coating and their coating techniques. Moreover, adsorptive polymer coating applications in various fields are briefed.

Keywords: Coating, polymer coating, adsorptive polymer coating, coating techniques, coating applications

Introduction

Coating is a covering that can be applied to the surface of an object completely or partially, normally called as substrate. The purpose of application of coating is the value enhancement of the substrate by improving its appearance, corrosion resistant property, adhesion, wettability and wear resistance, etc. [1]. The main role of coatings is in decoration, protection, and providing functionality. The different fields have different coatings requirements. For example, in adhesion, the required properties are wettability and scratch resistance. For outdoor applications, the coatings are required that can withstand the changing environmental conditions. In electrical industries, conductive coatings are required. In food industry, the coatings are required that do not allow water to permeate and absorb humidity. In membrane industry, porous coatings are required for selectivity of gases. In other words, coatings can be utilized for a variety of purposes and performance requirements [2,3]. Global demand for industrial coatings is projected to touch $105.5 billion by 2022, growing by a rate compounded annually at 6.1% between 2016 and 2022 [4].

1. Components of coatings

All coatings consist of two major components: the vehicle and the pigment. The vehicle consists of the basic resin portion of the coating, which is usually dissolved in a solvent. This component of the coating is called the "binder" it binds the pigment together and is the basic film-forming portion of the coating [5]. The pigment portion of the coating contains not only those pigments that impart colour to the coating, but may also include extenders and reinforcing agents such as silica flour, flake glass, mica etc., inerts, thixotropizing agents, ultraviolet screening pigments, corrosion inhibitors, and other activities necessary to yield specific properties to the coatings or lining [6,7]. When the coating is applied to a surface, the volatile portion of the coating evaporates, leaving only the non-volatile binder and pigments to form the protective film. This is normally referred to as the "solids" of "non-volatile" portion of the coating [8].

2. Types of coating

In order to protect the materials from degradation/corrosion and get the desired properties, selecting the most appropriate coatings for each application is key to a long-lasting coating job [9]. Coatings may be distinguished as organic or inorganic, althoughthere is overlap. For example, many coatings consist of inorganic pigment particlesdispersed in an organic matrix (the binder). A confusing situation results from multiple meanings of the term coating. The most common generic types of coatings are [1,10] :

2.1.Organic coatings

These coatings contain carbon, refined and/or modified petroleum products as well as different solvents, pigments, additives, and fillers. This category includes products like alkyd coatings, epoxy coating systems, polyurethane coatings .

2.2. Inorganic coatings

In order to provide protection against various stressors in industrial environments, inorganic coatings are formulated with ingredients like enamels, additives and pigments.There are three inorganic coatings commonly used in industrial applications acrylic coatings, ceramic coatings, intumescent coatings

3. Polymer coating

Coatings have become one of the most ubiquitous end applications for polymeric materials. A typical industrial coating formulation is composed of binders (polymers), fillers, solvents, pigments, and additives. The term "polymeric coatings" is used here to refer to coatings in which "organic polymers" act as binders and are the main components of the formulation and can be applied on a number of substrates using a variety of methods such as extrusion/dispersion and solution casting techniques [11,12].

Polymeric coatings provide excellent adherence to and protection from the environment. They are so designed that they adhere well to the substrate and not peel off easily, nor degrade due to heat, moisture, salt, or chemicals [12]. All coatings, when exposed to UV radiation, start degrading due to complex photochemical process. This degradation is enhanced by the weather conditions such as temperature, pollutants, and moisture, etc.; however, polymer coating do not degrade as they do not absorb UV radiation greater than 295 nm wavelength [13]. Thus, polymer has been extensively been employed as coating material in various fields. Polymer coating enhances mechanical strength, thermal stability, biomedical properties, separation characteristics, chemical resistance, and other various functional properties [14]. Polymer coating has various applications in the field of painting, storage media, semi-conductors, optical devices, fluorescent devices, and etc. [15]. Polymer coatings also perform the protection of material from ambient conditions, abridged fragmentation, and protect from dusting [16].

4. Types of polymer coating

Polymer coatings are classified for different types of consumables depending on the preferable properties in terms of stiffness, strength, thermal stability, cost, and light weight as shown in Figure 1. In general, the polymer coating is a type of coating that is composed of a polymer that has high cohesion and resistance to corrosion and damage [17].

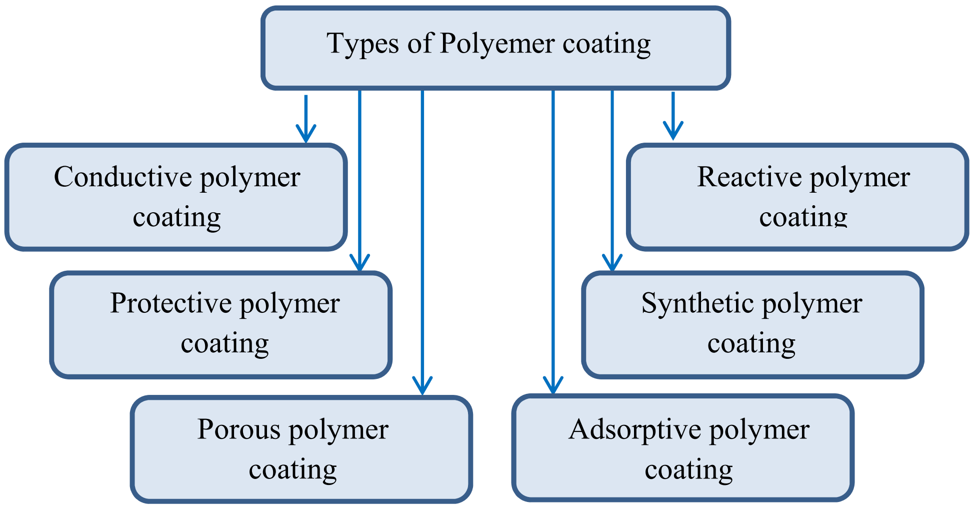


Figure 1. Types of polymer coating [17]

5. Adsorptive Polymer Coating

Adsorptive polymer present unique surface chemistry features, excellent porosity, good mechanical strength, and hydrophobic surface area and propose large surface/volume ratio. Polyethylene, polypropylene, polyethylene terephthalate, and nylon, etc., are common adsorptive polymers being widely used as coating material [18]. adsorptive polymer has been suggested as an alternative coating materials in pharmaceutical, cosmetics, environmental, personal care products, food safety, and etc. [19,20]. Increased consumer concern to food safety led to the development of adsorptive polymer coating, a renewable coating suitable for food, and pharmaceutical, etc. In food packaging, adsorptive polymer film perpetuate and insulate food from extrinsic chemical, physical, and microbiological elements [21].

6. Adsorptive Polymer Coating Techniques

Adsorptive polymer coatings are formed by simply introducing a polymer containing solution into the capillary where the polymer adsorbs to the capillary surface. Adsorption occurs through the formation of physical forces with the capillary surface, such as hydrogen bonds, electrostatic or hydrophobic interactions. In contrast to covalent polymer coatings, the generation and regeneration of a coating is a fast process as no time consuming synthetic procedures are involved. numerous synthetic, natural, neutral, and charged polymers have been used in the pursuit of dynamic coating [22,23]. Some suitable coating techniques are shown in Figure 2.

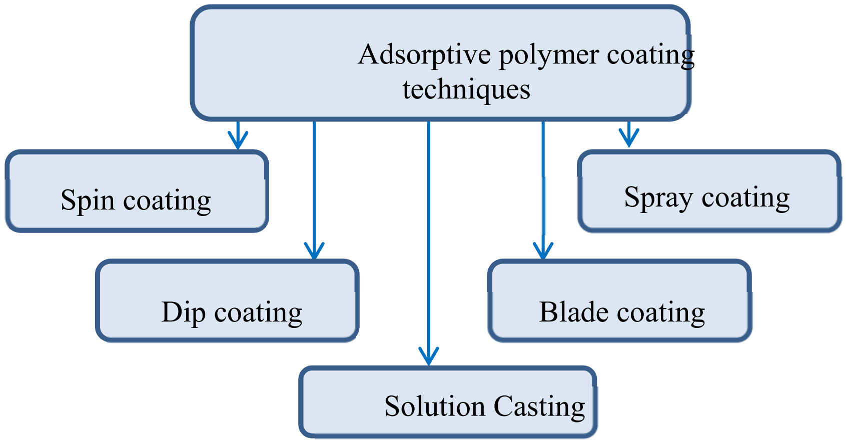


Figure 2. Adsorptive polymer coating techniques [23]

6.1. Spin coating technique

Spin coating technique is widely used to prepare fine thin polymer coatings on a flat surface. In this technique, coating is performed in four steps, deposition, spin up, spin off, and evaporation, as shown in Figure 3 [24]. In the first stage the material is deposited on the turntable and then spin up and spin off occur in sequence while the evaporation stage occurs throughout the process. The applied solution on the turntable is distributed via centrifugal force. High spinning speed results in thinning of the layer. This stage is followed by drying of the applied layer [25]. One of advantages to the technique of spin coating: it is a relatively inexpensive technique and less loss of materials than with vapor-phase deposition, while one of the main disadvantages of spin coating difficulty of creating multilayer structures (> 2 layers) and possibility of the presence of contaminants (traces of solvent, oxygen, humidity, etc.) [26].

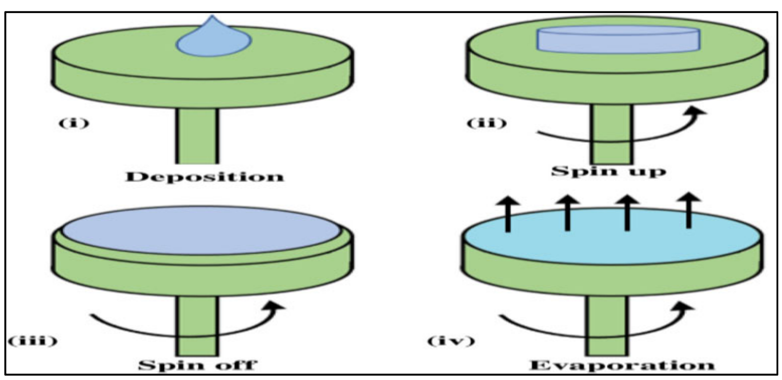


Figure 3. Stages of spin coating on substrate [24]

6.2.Spray coating technique

Spray coating technique is considered to be the most effective for coating of nonplanar and 3D surfaces and a facile and unique approach for applying a coat over a substrate. In this process, first suitable adsorbent is dissolved in polymer and then dissolved or melted polymer is sprayed onto a substrate as shown in Figure 4 [27]. Spray coatings are used in various fields, such as in coating of solar cells, piezoelectrics, pyroelectrics, corrosion prevention, aerospace, and automobile industries. There are various methods of spray coating: cold spray (CS) coating , thermal spray coating (Mostaghimi et al., 2003), etc [28,29]. Spray coating technique is shown to be better than spin coating technique; even though the spin coating method produces fine thin films, it is limited to flat or planar surfaces. On the other hand, the spray coating method has advantage of covering any kind of surface, planar or nonplanar. Further, spray coating enables to form coatings in a larger area, which is an advantage over other polymeric coating methods. The coatings can be formed in both dry and wet environmental conditions [30]. However, this technique has some issues due to adsorbent materials tend to be deposited mainly on the external surfaces, becoming scarce and not well distributed inside them, leading to an irregular and homogenous coating deposition [31].

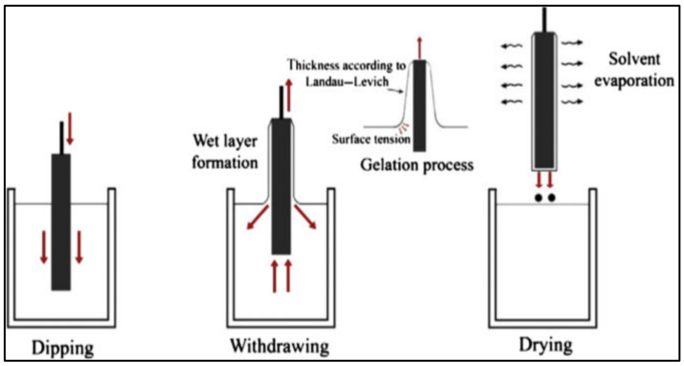


Figure 4. Steps of spray coating technique on substrate [27]

6.3. Dip coating technique

The dip coating technique is a very simple, popular method for creating thin films and suitable for the production of high quality and uniform thickness coatings, This technique is used to coat the three-dimensional object. The substrate is fully immersed in polymer solution containing dissolved adsorbent, withdrawn and then dried as shown in Figure 5 [32]. The film properties and film thickness depend on a number of parameters, such as: immersion time, withdrawal speed, number of dipping cycles, solution composition, concentration and temperature, environmental humidity, etc.[33]

This coating showed a high antireflective and superamphiphilic properties that are of high interest in, for instance, the production of solar panels. In addition, surfaces with tunable wettability for guiding water droplets can be produced by dip coating [34]. On the other hand , this technique requires the high consumption of solution which sometimes makes it economically unaffordable. Moreover, some limits can be represented by the need for constant control of the viscosity of the solution and of immersion/extraction speed [35].

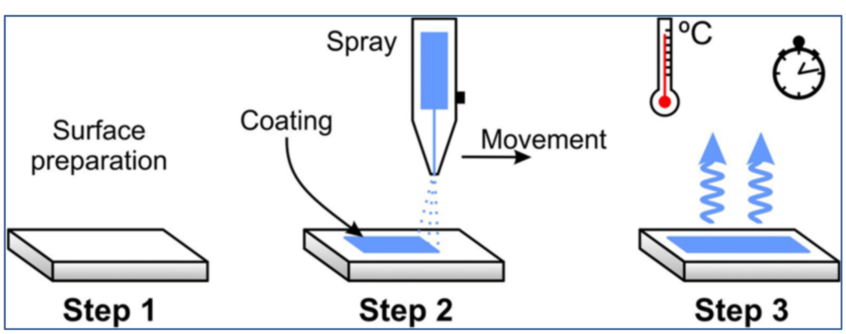
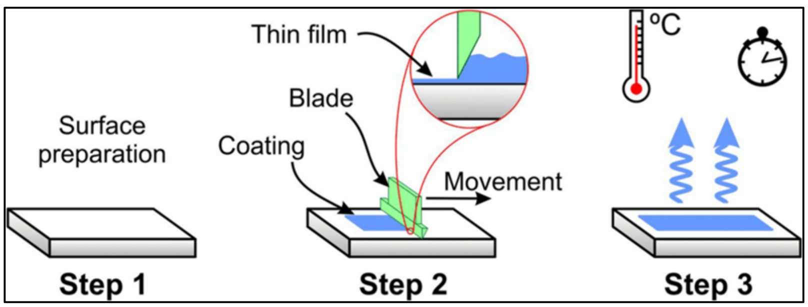


Figure 5. Steps of dip coating technique [36]

6.4. Blade coating technique:

Blade coating is a popular method among the many techniques used to obtain thin film coating on substrate. The technique works by placing a sharp blade at fixed distance from the surface that needs to be covered. The coating solution is then placed in front of the blade and the blade is moved across in-line with the surface, creating a wet film. The final thickness of the wet film influence by the viscoelastic properties of the solution and the speed of coating, Figure 6 [37].

One of advantages to the technique of blade coating: it is fast process, creating thin films quickly and efficiently, inexpensive to set up and produces a high throughput [38]. However, this technique has some disadvantages due to not as precise as other techniques (e.g. spin coating). It is also very difficult to reach the same levels of uniformity and any contamination with the system can lead to streaks being formed in the wet film as the blade is dragged close to the substrate [39].

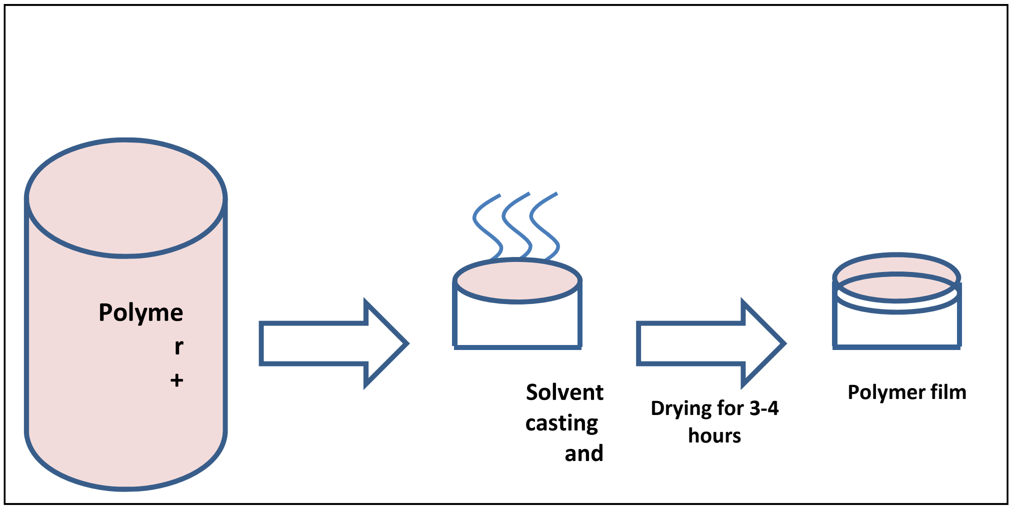


Fiqure 6. Steps of blade coating technique [37]

6.5.Solution casting technique:

Solution casting is a simple coating technique and one of the oldest as well as the versatile and easy techniques used for the preparation of polymer coating. This technique was developed to coat adsorptive polymer solution on a substrate. In this approach, the softened adsorbent in polymer solution is simply casted on the solid object and allowed to evaporate at desired temperature as shown in Figure 7. The obtained film on substrate or solid object acts as a coat and protect from external environment [40].

The main advantage of this technique is that in solvent cast films, a liquid on a surface is dried without introducing any external factor such as thermal or mechanical stress. Also, this method offers a variety of additive options to the polymer. The additive can be added to any polymer-solvent solution, which then will be mixed together to form a homogeneous solution[41]. This method, however, also has few' disadvantages. The film formation is highly dependent on the solvent volatility. If the solution is less volatile, it will take more time to evaporate and hence the drying of the polymer film is also delayed. Also, the less-volatile solvents will tend to leave more residual solvent in the formed film at the end. Solvent recovery in this method requires high energy and consequently high cost. Despite all disadvantages, the polymer films formed using solvent casting has high qualities as compared to those formed by any other methods[42].



Fiqure 7. Steps of Solution casting technique [42]

7. Adsorptive Polymer Coating Applications:

Adsorptive polymers coatings change the surface properties of the layer underneath due to excellent thermal, chemical, and mechanical resistance and protect the material from deterioration. Due to these properties, there are Some important and common applications.

7.2. Biomedical:

Adsorptive polymer coating is considered as one of the promise candidate for variety of biomedical applications. The vast range of biomedical application of these polymers is basically attributed to their functional properties such as biocompatibility, elasticity, corrosion protection and mechanical strength when compared to other materials [43]. The major categories include the application of polymers in In drug delivery antibacterial surfaces, drug delivery, tissue engineering, orthopedic materials, cardiovascular stents, and biosensors coating among others [44].

7.3. Corrosion Protection:

Corrosion is the gradual destruction of materials by chemical and/or electrochemical reaction with their environment. In situations where the surface is submitted to chemical corrosion, an extra layer of protection is needed [45]. Equipment and structures of metals are often protected from the environment by a barrier between the substrate and the aggressive environment, such as marine or industrial environments. the coating technology is the main method of protecting steel and iron from corrosion. However, adsorption polymers have excellent corrosion inhibiting properties [46].

7.4. UV Protection:

All coatings degrade when they get exposed to UV radiations due to the complex photochemical process. The weather conditions like moisture, temperature and pollutants, etc. enhance this degradation process. The polymer coating degrades when it absorbs UV radiations and that is sufficient enough to break the bonds of polymer [47]. The loss of surface gloss and significant deterioration of coating are resulted due to this degradation of chains as free radicals are produced during the oxidation process which reduces the molecular weight of polymer [48]. However, adsorptive polymer material has ability to absorb UV radiations which fall on the coating and, hence, stop the photo oxidation of the coating since it does not allow UV radiations toreact with the binder used in the coating [49].

8. Conclusion:

Polymer coatings and technology is growing exponentially. Coatings can be utilized for a variety of purposes and performance requirements. In this review a comprehensive overview of adsorptive polymer coating and their techniques and applications , were fully discussed. on the other hand, adsorptive polymer coating present unique surface chemistry features, excellent porosity, good mechanical strength. Proper mixing of adsorbents in polymer and random aggregation of adsorbent is still a problem. Thus, this is indispensable to recognize the in vitro and in vivo approach for equalization of these coverings.

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