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REVIEW ON SOLVENTLESS COATING TECHNOLOGY

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ABSTRACT

Coatings are an essential part in the formulation of pharmaceutical dosage form to achieve superior aesthetic quality (e.g., color, texture, mouth feel, and taste masking), physical and chemical protection for the drugs in the dosage forms, and modification of drug release characteristics. Most film coatings are applied as aqueous- or organic-based polymer solutions. Solventless coatings are the alternative coating technologies for solid pharmaceutical dosage forms in which coating materials are directly coated onto solid dosage forms without using any solvent and then cured by various methods to form a coat. As a result, these technologies can overcome the disadvantages which are caused by solvents in conventional liquid coating. This review discusses and compares six solventless coating methods - Compression coating, Powder / dry coating, Hot-melt coating, Supercritical fluid spray coating, Magnetically Assisted Impaction Coating' (MAIC), Solventless photo curable coating that can be used to coat the pharmaceutical dosage forms. Powder coating also called as dry coating which include plasticizer-dry coating, electrostatic-dry-coating, heat-dry-coating and plasticizer-electrostatic-heat-dry-coating. This review summarizes the fundamental principles and coating processes of various solventless coating technologies.

Keywords: Solventless, Photo curable, Impaction, Supercritical

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INTRODUCTION

Pharmaceutical Coating Techniques

Coating in pharmaceutical industry is an essential process in the formulation of pharmaceutical dosage form to achieve superior aesthetic quality, quality in terms of color, texture, mouth feel, and taste. With coating physical and chemical protection for the drugs in the dosage forms is achieved. Pharmaceutical coating machines make use of various coating techniques, some of which are described below:

Today, many forms of coating are used, one of them is Enteric Coating, which actually delays the release of the drug until the pill reaches the intestines.

Sugar coating is done for a variety of reasons on tablets and pills, which include, to give a pleasant taste or prevention of bitter taste, to improve stability and to modify the release of the drug.

A film-coating is a thin, polymer-based coat applied to a capsule or tablet in which cellulose derivatives such as hydroxyproply methylcellulose or other cellulose polymers are used. Most film coatings are applied as aqueous or organic based polymer solutions. Both organic and aqueous film coating have their own disadvantages.

SOLVENTLESS COATING TECHNOLOGY

To overcome the disadvantages of film coating, Solventless coating technology has come up with the use of solvents like solvent exposure, solvent disposal, and residual solvent in product in pharmaceutical coating. It reduces the cost by eliminating the tedious and expensive processes of solvent disposal/treatment. Moreover, the technology can significantly reduce the processing time because there is no drying and evaporation step and the entire process goes environment friendly, as it is done without any heat in most cases and thus can provide an alternative technology to coat temperature-sensitive drugs.[1-3]

There are six solventless coating techniques being actively investigated that are used to coat pharmaceutical tablets and capsules.

- 'Compression coating'
- 'Powder/ dry coating'
- 'Hot-melt coating'
- 'Supercritical fluid spray coating'
- 'Magnetically Assisted Impaction Coating' (MAIC)
- 'Solventless photocuring'

1. Compression Coating

It involves the compaction of granular materials around a preformed tablet core using specially designed tableting equipment. Compression coating is a dry process.[2] Finished product is a tablet within a tablet. Advantages of the method include the capability to physically separate two incompatible drugs within the same dosage form, which is commonly achieved using multilayer tablets or compression coated dosage forms. In addition incompatible ingredients can be conventionally separated by this process. However this process has disadvantages of mechanical complexity and therefore has not proven the preferred method for the tablet coating. The only requirement for producing the compression-coated tablet dosage form is that the core material should possess the ability to flow into a die during production.[4] Microcrystalline cellulose, colloidal silica, mannitol, lactose are some directly compressible excipients.[5, 6] Modified compression coating machine is also available which has specially modified punches to carryout the coating process. At first stage the punches forms the cup of coating material in lower die, then in second stage drug is filled in that cup with compression using another modified punch and finally coating material compressed on the top to cap the drug filled cup.[7]

2. Powder/Dry Coating:

Thin film powder coating, also referred to as a 'dry painting" process, eliminates volatile organic compounds (VOCs), hazardous air pollutants (HAPS), and solvents, and produces superior surface finish.

There are four basic powder coating application processes: electrostatic spraying, fluidized bed, electrostatic fluidized bed, flame spray.

In electrostatic spraying, an electrical charge is applied to the dry powder particles while the component to be painted is electrically grounded. The charged powder and grounded workpiece create an electrostatic field that pulls the paint particles to the workpiece. The coating deposited on the workpiece retains its charge, which holds the powder to the workpiece. The coated workpiece is placed in a curing oven, where the paint particles are melted onto the surface and the charge is dissipated.

In a fluidized bed, powder particles are kept in suspension by an air stream. A preheated workpiece is placed in the fluidized bed where the powder particles coming in contact with the workpiece melt and adhere to its surface. Coating thickness is dependent on the temperature and heat capacity of the workpiece and its residence time in the bed. Post heating is generally not

required when applying thermoplastic powder coatings. However, post heating is required to completely cure thermoset powder coatings.

Electrostatic fluidized beds are similar in design to conventional fluidized beds, but the air stream is electrically charged as it enters the bed. The grounded workpiece is covered by the charged particles as it enters the chamber. No preheating of the workpiece is required. Curing of the coating is, however, necessary. This technology is most suitable for coating small objects with simple geometry.

Only workpiece that can be oven heated can be coated by the electrostatic, the fluidized bed, and the electrostatic fluidized bed application methods. These technologies are, therefore, most suitable for relatively small, metal objects.

The flame-spray technique is suitable for application of thermoplastic powder coatings. The thermoplastic powder is fluidized by compressed air and fed into a flame gun where it is injected through a flame of propane, and the powder melts. The molten coating particles are deposited on the workpiece, forming a film on solidification. Since no direct heating of the workpiece is required, this technique is suitable for applying coatings to metal, wood, rubber, masonry, plastic and to large or stationary structures. This technology is also suitable for coating large or permanently-fixed objects**.**

It has some benefits over ordinary coating techniques

- Powder coating eliminates the need for expensive and often toxic solvents, the control equipment, employee exposure, disposal requirements liabilities associated with liquid coating (wet solvent) use.
- Because the powder is dry when sprayed, any overspray can be readily retrieved and recycled, regardless of the complexity of the system, resulting in shorter cleanup times.
- In all cases, the dry powder is separated from the air stream by various vacuum and filtering methods and returned to a feed hopper for reuse.
- Powder efficiency (powder particles reaching the intended surface) approaches 100 percent[8,9]

2.1 Plasticizer Dry Coating:

In the plasticizer-dry coating technology, powdered materials are spread onto dosage surface simultaneously with the plasticizer spraying from separate spraying nozzle. The sprayed liquid plasticizer would wet the powder particles and the dosage surface promoting the adhesion of particles to dosage surface. The coated dosage forms are then cured for predetermined time above the glass transition temperature (Tg) of the polymer, forming a continuous film.[10]

The polymer is passed as dry powder via a powder feeder to the three way nozzle which secures a homogeneous application of the coating material onto the pellets. [11] Dry powder coating can be used for extended release coating with Eudragit- RS and ethyl cellulose powders, and for enteric coating with shellac powder. By means of plasticizer-dry coating technology both tablets and pellets could be coated. The former (tablets) were generally coated in a pan coater. For latter (pellets) a fluidized bed coater is required in order to avoid the formation of agglomerates caused by the smaller size and higher specific surface area of pellets and thus strong interaction.[12] The adhesion of the particles to dosage surface is mainly by the wetting of particles and dosage forms by the plasticizer, and the film formation is the combined response of improved viscous flow and particle deformation resulted from plasticizer and heat. In addition the capillary forces exerted by the liquid plasticizer prior to the polymer particles may also contribute to the particle deformation in the interstitial capillary system between particles and thus to the film formation.[13] The heat-humidity curing condition suppresses the evaporation of the plasticizer, resulting in higher plasticizer levels remaining in the films, as compared to the heat-only curing condition. The heat-humidity curing also significantly increased the mechanical strength and decreased the water vapour permeability of the films.[14]

Various formulation and process parameters affect the coating process like type of plasticizer and its concentration, curing temperature. [15-17] Coat thickness increases with plasticizer concentration but higher amount of plasticizer itself causes the formation very soft and sticky films. Very low concentration of plasticizer causes the formation of brittle films.

2.2 Heat Dry Coating:

This method is named as heat dry coating by Y. Luo et al. (2008), as only heat was used as a binding force to realize the dry coating of tablets.[19] This method was developed by Cerea et al. (2004). In this coating technology ,Eudragit E-PO (a polymer based on dimethylaminoethyl methacrylate and methacrylates) particles were continuously spread onto the tablet contained in a lab scale spheronizer by way of motorized single screw powder feeder, with an infrared lamp positioned on the top of the spheronizer as a heating source, without using any solvent and plasticizer.[20]

The heat dry coating process occurs in the three stages: 1. Pre-heating: In this stage the uncoated tablets are heated to the predetermined temperature. 2. Powdering: In this stage the powder is transferred into the coating equipment and distributed onto the cores. 3. Curing: Here polymeric particles adhere to the surface of the substrate to form a polymeric film coating. The polymer

having lower glass transition temperature (Tg) generally requires no plasticizers. The polymer having higher Tg pre-plasticization was employed by blending polymers with plasticizers using the hot melt extrusion method.[21] Generally, film formation of the plasticized polymer particles is expected to occur already at temperatures below the pure polymer's glass transition temperature. This is caused by the plasticizer reducing the polymer's Tg which results in elevated mobility and softness of the polymer molecules. Thus, the film formation temperature should be lower in comparison to the glass transition temperature of the pure polymer. [22] The advantage of heat dry coating includes abandoning plasticizers for lower Tg film forming polymers, or avoiding high concentrations of plasticizers because of pre-plasticization. However it is a challenge for heat dry coating to get a smooth, uniform and thick coating only by the help of heat based adhesion.[23]

2.3 Electrostatic Dry Coating:

The main method in use today for the application of powder coatings is the electrostatic process, and very useful in paint technology, food technology, metal coatings, finishing industry, coating of living cells. It is also useful in the coating of tablets as well as capsules. [24-29] The principle of electrostatic powder coating involves spraying of a mixture of finely grounded particles and polymers onto a substrate surface without using any solvent and then heating the substrate for curing on oven until the powder mixture is fused into film. According to the charging mechanism, there are two types of spraying units: 1. corona charging, 2. tribo charging.[21]

Steps in the deposition of charged particles onto the substrate are

a) Charged particles are uniformly sprayed onto the earthen substrate in virtue of mechanical forces and electrostatic attraction,

b) Particles accumulate on the substrate before the repulsion force of the deposited particles against the coming particles increase and exceed the electrostatic attraction,

c) Finally once the said repulsion becomes equivalent to the said attraction, particles cannot adhere to the substrate any more, and the coating thickness does not increase any more.[19]

Properties of powder such as particle size distribution, chemical composition, tribo and corona charging characteristics, electrical resistivity, hygroscopicity, fluidity and shape distribution play significant role on the performance of powder coating such as transfer efficiency, film thickness, adhesion and appearance. [30-32] Also deposition temperature, nozzle-to-substrate distance, nozzle geometry, and composition of the precursor Solution plays an important role in the electrostatic coating process.[33]

Measurement of the electrostatic powder coating properties for corona and triboelectric coating guns can be done by using the Electrostatic Powder Coating Diagnostic Instrument (EPCDI), which was designed and manufactured in the University of Dundee. EPCDI analyses the electrostatic powder coating deposition efficiency by measuring the powder adhesion properties in the pre-cured state and it also measures the uniformity of the powder coating by moving the powder sample and measuring the infrared light transmission through it.[34] Another methods of adhesion measurements are Drop Test Rig and Virtual Oscilloscope.[35]

2.4 Plasticizer-Electrostatic-Heat Dry Coating:

Plasticizer-electrostatic-heat dry coating (PEH dry coating) is named here mainly because this technology is featured by combined usage of plasticizer, electrostatic attraction and heat.

In this technology, the coating process comprises the steps of

a) Positioning preheated solid dosage form in a chamber of the rotatable, electrically grounded pan coater

b) Spraying powdered coating materials and plasticizer on the solid dosage forms in the pan coater, during rotation using an electrostatic sprayer,

c) Curing the coated solid dosage forms to form continuous, uniform and flexible coats.

During the whole coating process the solid dosage forms and the chamber are always kept in hot state by heating the air in the coater or directly heating in the coater.

PEH-dry-coating is characteristics of integration of five kinds of forces,

- Softening or melting effects of particles by heat,
- Wetting of dosage surface by a plasticizer,
- Electrostatic attraction forces,
- Hydrodynamic force due to spraying and
- Mechanical force due to rotation of pan coater.

They are combined to enhance the adhesion of powdered coating materials to solid dosage surface.

FIRSTLY, the moment of the powdered materials from the charged gun to the dosage is promoted by the combination of electrical and hydrodynamic forces. The adhesion of the powders on to the dosage surface is the synergic contribution of electrostatic attraction between the charged powders and earthed dosages. Softening effect of the powder is due to heat from preheating and heating during coating. Wetting effect is by plasticizers.

SECONDLY, the hydrodynamic forces from compressed air and mechanical forces from the tumbling effects of the pan coater are both helpful to the adhesion of powders on the solid dosage surface due to the synergetic contribution of electrostatic attraction and heat- and wet-induced adhesion is so strong that it not only can withstand the tumbling and colliding of solid dosage surfaces with each other and with the inner surface of the coater but the tumbling and colliding actually also help make the coating more compact and uniform.

FINALLY the repulsion between the same charged particles on the dosage surface promote the uniform distribution of the particles on the dosage surface and prevent the coalescence between solid dosage forms even between solid dosage forms such as beads or pallets.[19]

3. HOT MELT COATING:

In hot melt coating method, the coating material is applied in its molten state on the substrate then solidified by cooling. Hence, the necessity of the application of any solvent is fully eliminated. The choice of the coating excipients depends primarily on its function (e.g., retarding the drug-release rate, preventing environmental degradation and masking unpalatable taste) in the dosage form. Lipid, waxes, fatty bases and hydrogenated vegetable oils are the most suitable coating material in hot melt coating. It offers several benefits and potential for a wide variety of application in pharmaceutical formulation like tablets and pellets. [36-39] During the hot melt coating method, the required weight gain with lipid materials are less than those commonly employed with polymers to achieve the same effect. As the lipid based coatings are less expensive and processing time is short, hot melt coating is also cost effective. [40]]A difficulty in hot melt coating is maintaining adequate operational safety, as high temperatures, close to 200^0C, are employed. The choice of coating excipients depends primarily on its "functional" (such as retardation drug release rate, prevention of environmental degradation, and masking of unpleasant taste) in the dosage form. [41,42] For sustain release applications, coating excipients of special interest can be divided broadly as natural and synthetic waxes, hydrogenated vegetable waxes, polyglycolysed glycerides. Examples of some marketed hot melt coating excipients are Gelucires, Precirol, Stearines, Myvaplex, Compritol 888 ATO.[39, 43, 44]

The various technologies of hot melt coatings are 1. Fluidized bed coating (top spray and bottom spray), 2. Spray congealing/ coating, 3. Pan coating (pan spray and pan pour).[39]

Fluidized bed coating method proved capable of coating nonpareils from 10 to 35 mesh [0.500 to 2.00 mm) and tablets up to 1 g. Spray coating/congealing, whereby slurry of molten matrix material and substrate is sprayed through into a cooling chamber, where the droplets solidify

rapidly. Atomization methods for spray coating are Ultrasonic atomization, Hydraulic (airless) atomization, and Pneumatic atomization. [45] Third approach is pan coating; conventional pan coater can be used for the hot melt coating. Only the difference is that the coating agent is in molten state instead of solution state. There are two types of pan coating processes, one is pan pour another is pan spray. It was observed that the pan spray coating technique is the best technique to control the release due to uniform film formation, while pan pour technique shows variation in the release of drug from the same batch this was due to non- uniform coating and very low coating efficiency. Various key factors should be considered during the hot melt coating like molecular weight of the excipients, thermal behavior of the excipients, rheology of excipients in molten state.[37]

Molecular weight of coating agent is a key physiochemical parameter and can provide information about the strength, flexibility, and rheological behavior of the coating material and it can also be correlated to the ability of the excipients to retard drug release.[46, 47]

4. SUPERCRITICAL FLUID COATING/MICROENCAPSULATION:

The 'supercritical fluid spray coating' process consists of dissolving the coating material or drug in supercritical carbon dioxide, and gradually reducing the solvent power of carbon dioxide to enable the coating material to precipitate onto drug particles dispersed in the medium. Although this process is technically a solvent-based coating process, the use of carbon dioxide as the supercritical fluid avoids some of the challenges associated with traditional solvent-based processes. In the absence of co-solvents, the coating materials used in supercritical fluid coating are limited mainly to lipids (fats and waxes).[48-51] Microencapsulation using supercritical fluid technology combines a liquid- like density and solvating power with gas-like transport properties (like viscosity, diffusivity). Carbon dioxide is the most widely used supercritical fluid because of its relatively low critical temperature (31°C) and pressure (74 bar). The use of supercritical fluid technology, especially CO_2 for encapsulation purposes is mainly due to the mild processing condition, allowing microencapsulation of sensitive ingredients for cosmetics, pharmaceuticals.[52] Supercritical fluids are especially suitable for particle formation, as they display a large change in density near the critical point which enables their solvating power to be carefully controlled by small changes in temperature or pressure. The coating material must have sufficient solubility in liquid or that a coating of sufficient thickness to provide the desired level of protection is formed when conditions inside the autoclave are adjusted to insolubilize the coating material. Ideally, deposition should occur as a defect-free film or coating.[53]

Rapid expansion of supercritical solutions (RESS) is a method of solventless coating based on supercritical fluids. The RESS technique can be applied to process a wide range of materials including ceramics, polymers, biopolymers, pharmaceutics, and organic compounds. Microencapsulation takes place when a pressurized supercritical solvent containing the shell material and the active ingredient is released through a small nozzle; the abrupt pressure drop causes the desolvation of the shell material and the formation of a coating layer around the active ingredient. Limitation of this technology is that the compounds effectively dissolve in the supercritical fluid.[54] In case of conventional fluidized bed coating of fine particles (70µm) agglomeration is the major problem due to the higher cohesive force, in such cases supercritical fluid coating is very useful in prevention of the agglomeration during coating.[55]

5. MAGNETICALLY ASSISTED IMPACTION COATING (MAIC):

This method is studied by Michelle R. (2000) by coating the fine silica particles onto the surface of larger cornstarch and cellulose particles.[56] Many food and pharmaceutical ingredients, being organic and relatively soft, are very sensitive to heat and can quite easily be deformed by severe mechanical forces. Soft coating methods that can attach the guest (coating material) particles onto the host (material to be coat) particles with a minimum degradation of particle size, shape and composition caused by the build up of heat are the better candidates for such applications.

The magnetically assisted impaction coating (MAIC) devices can coat soft organic host and guest particles without causing major changes in the material shape and size. The rise in temperature is negligible; this is an added advantage when dealing with temperature sensitive powders such as pharmaceuticals.[57] Apparatus for MAIC consists of processing vessel surrounded by the series of electromagnets connected to the alternating current. The host and guest materials are placed in the vessel along with the measured mass of the magnetic particles. When a magnetic field is present, the magnetic particles are agitated and move furiously inside the vessel, resembling a fluidized bed system. These agitated magnetic particles then impart energy to the host and guest particles, causing collisions and allowing coating to be achieved by means of impaction or peening of the guest particles onto the host particles.

The magnetic particle motion studies suggests that the primary motion due to the magnetic field is the spinning of the magnetic particles, promoting de-agglomeration of the guest particles as well as the spreading and shearing of the guest particles onto the surface of the host particles.

However, the effect of the translational speed is also significant as it allows for the impaction of one particle onto another, promoting coating.

Mechanism of coating in the MAIC process is

(a) Excitation of magnetic particle,

(b) De-agglomeration of guest particles,

(c) Shearing and spreading of guest particles on the surface of the host particles,

(d) Magnetic-host-host particle interaction,

(e) Magnetic–host–wall interaction and

(f) Formation of coated products.

The system parameters have to be considered are magnetic particle size, mass ratio of magnetic particles to powder host and guest particles, guest particle size. The operating parameters are processing time, current or voltage, frequency.[56-58]

6. PHOTOCURABLE COATING:

Unlike other solventless coating techniques that rely on changes in the physical state of the coating material to obtain a coating, photocuring is a chemical approach proposed to rapidly coat tablets at or below room temperature with an extremely rapid rate.[59, 60]

Photocuring systems generally consist of 4 major components:

- UV/visible light source,
- Specially functionalized liquid pre-polymers or monomers
- An initiator.
- Pore forming agents.[61]

It is common to define photocuring as a process of rapid conversion of specially formulated (usually liquid) solventless compositions into solid films by irradiation with ultraviolet or visible light.[62-65] A large proportion of the curing reactions described above are carried out with light in the ultraviolet region. This is due to the fact that ultraviolet light is more energetic and, therefore, more efficient in rupturing chemical bonds. On the other hand, the use of visible light has many attractions, such as safety and ease of handling. So, lately, curing with visible light is receiving attention as well.[66] Photocuring can be divided into two groups, those that cure by free-radical mechanism and those that cure by an ionic mechanism viz. cationic (mostly), anionic mechanism. There are also some compositions that cure simultaneously by both mechanisms.

6.1 Pre-polymer or monomer:

- They should be stable to UV exposure during the entire coating process.
- They should be able to polymerize by UV-curing process while maintaining acceptable film firmness, integrity and stability.

- They should be in the liquid state so that they can be easily spread on the tablets, granules.[67]

Two major classes of photocurable siloxanes are acrylic acid derivatives and enethiols. Most important resins and reactive diluents used in photocurable coatings are epoxy acrylate, polyester acrylate, polyurethane acrylate, hexanediol diacrylate, unsaturated polyester, trimethylolpropane triacrylate, tripropyleneglycol diacrylate.[66-70] Co-polymerizable liquids with relatively low viscosity are used as reactive diluents. Photo curable polydimethylsiloxane is widely used as a photocuring material due to its good thermal stability and extraordinary flexibility in addition; photo curable siloxanes are used in transdermal drug delivery systems, composite dental fillings and other medical products.[68] Acrylic siloxanes are prone to inhibition by oxygen and moisture present in the atmosphere hence system needs to purge with nitrogen. However, ene-thiol systems are not affected by either oxygen or moisture. This characteristic allows the use of such photocurables in open systems such as pan coaters. In addition, it was previously shown that the ene-thiol system cures faster and more completely than acrylate siloxanes.[71]

6.2 Photoinitiators or catalysts:

Photoinitiators start a reaction which results in the formation of a solid coating. Their reaction products add to the unsaturated components and become a part of the polymer layer. They are generally stable against temperature increase. Such formulations are applied as a layer under normal room light conditions and they cure only when exposed to intensive UV light. Most of the photoinitiators contain a benzoyl group, which is mainly responsible for the absorption of the energy from the light. By the absorption of radiation energy formation of a radical pair takes place. During UV curing these radicals add to the double bounds of the unsaturated reaction partner. [66, 67,71] The photochemical formation of a radical pair can be monomolecular reaction or bimolecular reaction. Photoinitiators of the monomolecular type are more effective than bimolecular combinations (for instance benzophenone/amine). Photoinitiators derived from phosphine oxides (mono- and bisacyl phosphine oxides) are of special interest these days.

The mechanism of the photochemical curing process can be described in following three steps Initiation, Propagation, Termination. Examples of monomolecular-type photoinitiators are Benzoin ether, Diethoxy acetophenone, Hydroxyketones, Aminoketones, Bisacyl phosphine oxides,etc. [67,73]

6.3 UV/Vis light source:

An often-used lamp type is the 80 W/cm medium-pressure mercury lamp, which emits a broad spectrum in the short wavelength range from 200 to 320 nm but also at discrete wavelength numbers of 360, 410, and 430 nm.[66, 67]

6.4 Pore forming agents:

The initial study performed by Wang and Bonger, where UV light was used to cure derivatized silicon polymer films on non-pareil beads in small-scale coating equipments, but film formed by this method is complete and almost perfect barrier to drug diffuse, such drug release depend on defects or weak points in the coating. Therefore they found need to incorporate pore forming agents in the polymeric film to prepare functional coatings (e.g. Immediate, sustained, or delayed release). Example of pore forming agents are Lactose, sodium chloride, Explotab, Ac- Di-Sol, PEG 800, etc.[66, 74]

MECHANISM:-

Light generates a polymerization reaction that involves free radical, cationic, or anionic mechanisms, depending on the functional groups of the prepolymers or monomers and the initiators or catalyst used.[75] Chemical reaction of the functionalized liquid prepolymers or monomers results in transition from liquid to solid film. Oxygen can slow down and/or reduce the extent of curing in some acrylate-functionalized silicone systems by quenching excited states and scavenging free radicals from the initiator and the growing polymer network.[76] Thus, photocurable systems are usually purged with nitrogen to reduce this complication. Photocuring is a common solvent-free technique used in the paint, adhesive, and photo-imaging industries. Although photo curing is used widely in the medical, dental, and chemical industries, it has few, if any, commercial applications in pharmaceutical manufacturing.

Photocuring has wide commercial application in dental and medical fields.

- Composite dental fillings,
- Preventive treatment for caries,
- Assembly of medical devices,
- Wound dressing.
- This is used to form films of varnishes, paints, and coatings for paper, plastic, wood, metal surfaces.
- Utilized in dental restorative fillers and in preparations of some contact lenses.

The initial study was performed by Wang and Bogner, In that report, norbornenyl polydimethylsiloxane prepolymers along with a photo initiator, benzoin methyl ether (BME), were used with UV light to cure the derivatized silicone polymer films on nonpareil beads in small-scale coating equipment.[77] After curing, coatings of sufficient integrity were obtained in which chemical reaction of the functionalized liquid prepolymers resulted in a transition from liquid prepolymer to solid coating film. However, these silicone polymers were inherently useful only for preparing a complete and almost perfect barrier to drug release. In a related study, Savage and Clevenger developed water-soluble photo curable polymer systems for coating pharmaceutical dosage forms using visible or UV light. Their process involved depositing the coating by an aqueous-based process before photocuring [78,79] Functional pharmaceutical coatings (eg, immediate, sustained, or enteric coatings) composed of powdered pore-forming agents (superdisintegrants or simple pore formers) added to an acrylate silicone matrix. That study evaluated different formulation and processing factors to delineate the design space for manufacturability of this solventless coating system.

Using a variety of pore-forming materials, we found that

- The ratio of the amount of solid pore-forming agent (S) to the volume of liquid prepolymer (L), or the S/L ratio;
- The particle size of the pore-forming agent;
- The concentration of the initiator;
- The light intensity;
- the exposure time of light
- Ratio of solid pore forming agent(S) to liquid pre-polymer (L) is the most significant parameter which determines the coating efficiency and coating uniformity.
- When wider range of S/L ratio was investigated, good coating efficiency was favored by the lower particle size, while there is sharp decline in the coating efficiency at low S/L ratios in case of larger particle sizes. were critical to the coating efficiency (ie, the percent of coating material incorporated into the coated beads) and the uniformity of the coating.[80]

CONCLUSION:

All the coating methods reported above are solventless coating methods which eliminates or minimizes the various drawbacks associated with the conventional solvent based coating methods. The conventional pan coater, fluidized bed coater and spray dryer can be used with

slight modification for most of the solventless coating methods. But electrostatics coating magnetically assisted coating and supercritical fluid coating needs specialized designed apparatus. Plasticizer dry coating and heat dry coating have to overcome difficulties in obtaining uniform and smooth coating before their commercial application, rest of other methods are able to produce coat with sufficient thickness and smoothness. Electrostatic coating is capable of applying different coating colors on the same formulation. Though these methods have greater advantage over conventional coating methods, before commercialization of these methods further work should be focused on scale-up tests, functional detection of coated solid dosage forms such as drug release profile and clinical tests to make them more useful, economical and safe.

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