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Review Article

Coating Processes of Pharmaceutical Applicability: A Glimpse

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Abstract

Presentation of manuscript is aiming to furnish glimpse on coating processes. Coating is process of snugly covering substrate surface with coating materials (CoM). In due course coating process has gradually developed from sugar-coating to non-aqueous film-coating to aqueous film-coating to specialised-coating processes. In second half of past century sugar-coating was first choice for pharmaceutical industry. Lengthy and tedious processing along with issues of skilled-operator inherited to sugar-coating compelled them to spring-up and improve film-coating. From past five decades, volatile organic solvent (VOS) are preferred over water in film-coating. Momentum for using aqueous solvent in film-coating gets accelerated from past few decades. Nowadays these replacing the VOS based film-coating processes as later inherit issues relating toxicity; safety; worker hygiene & safety; environmental pollution; etc. During process of finding novelty of coating another exploited sphere is coating of particulate substrate surfaces with CoM is to confer them worthy functionalities and applications. In this area both wet- & dry-coating process finds applicability thru modifying and/or altering innate properties of substrate, physically and/or chemically. Dry-coating process basically comprises specialised and novel process & technologies. Nowadays there available numerous conventional, specialised, and novel coating processes. Amongst them state-of-art process are hot-melt coating (HMC) process, aqueous film-coating process, aerosolized coating process, Supercell® coating process, gas-/ vapour-phase process, photo curable coating process, electrical-electrostatic deposition process, Resonant acoustic coating process, thermal and mechanical process, thermo-mechanical process, fluidised-bed processes, etc. Herein conventional, specialised, and novel coating processes are briefed, to update professionals.

Keywords: Coating, film-coating, novel, process, specialised.

INTRODUCTION

Solid dosage forms are the most popular forms of pharmaceutical products [1-3]. During their manufacturing processes most inevitable is their coating or coating of their formulation ingredient that are in particulate state [1-3]. Their coating involves deposition of CoM, as a layer, that is snugly affixed on their surface [2, 3]. Said coating is aimed for imparting functional and/or non-functional (protective) attributes to the final product [1, 3, 4]. Through coating achievable attributes are changes in visual properties, masking of odour and taste, improved appearance, enhanced mechanical properties, stabilization, and defined drug release profile in biological system [1-3].

Till 1950, sugar-coating is the first preference in coating operation [5]. During said period much effort is to perfect sugar-coating techniques & processes [6]. The productivity & quality of sugar-coating is dependent on operator-skill, while longer processing time is another cons [5-7]. Issues associated with skilled coating operator chief contributor to spring-up and improve film-coating process & technology [8, 9]. In due course of development and improvement film-coating made amenable to improve stability, aestheticism, and marketability; and modify and/or control release profile of active(s) [5, 6, 9].

In film-coating process, during early period, VOS is preferred as solvent-system over aqueous solvent [6, 9]. The preference is to avoid possible degradation of active(s) and combat diverse processing problems associates with aqueous solvent based one like picking, sticking, over wetting, and may more [5, 8]. Later on issues/ concerns like regulatory concern, residual VOS, environmental safety & concerns, safety of operator, and cost had been providing momentum for springing-up, improving, and perfecting aqueous film-coating, as preferred alternative [5, 6, 8-12]. Aqueous film-coating processes are in most instances are aqueous dispersions based systems [5, 13]. Said dispersion comprises low level of film former & large quantity of water [5, 14]. They are thus energy and time consuming reasoning from evaporating large quantity of water [5, 13-15].

Modifying surface properties/ attributes of particulates and fine & ultra-fine particle (FiUlFiP) was most inevitable in some instances [1, 12]. Strategies of particle engineering methodology thru surface modifications were developed and improved to find new functionalities and worthy properties/ applications of FiUlFiPs and particulates, by coating their surface suitably [1, 12]. Most of techniques/ process for modifying surface attributes/ properties of particulates and FiUlFiPs are for receiving assorted advantage [3, 16]. Said surface modifications and alterations in surface properties of FiUlFiPs and particulates are frequently for protective (non-functional) and/or functional purposes [16]. The surface modifications alter their innate properties either physically or chemically [3, 12].

In this regard physical and chemical deposition methods ware exploited [1, 12]. These methods alter innate properties of FiUlFiPs and particulates either physically or chemically [3, 12]. Physical methods realises physical deposition of coating material particles (CMPs) at surfaces of FiUlFiPs and particulates thru coating [1, 3, 12]. Exploited physical methods are thermal, thermo-mechanical, mechanical, electro-mechanical, thermodynamic, many other [2, 11, 12]. Chemical methods realises chemical changes at surface of FiUlFiPs and particulates thru a liquid/ gaseous precursor, thereby realising coating [5, 10, 12].

Technologies of physical deposition processes involve usage of high pressures, elevated temperatures, high shear, and/or solvents [1, 2, 12]. Solvent based wet-coating methods inherits issues like cost, unwanted waste stream, and regulatory restrictions on VOS relating their use & residual solvents; and energy & time requirement, reduced stability, and particle agglomeration of aqua-solvent based coating processes [1, 4, 5, 6, 11, 12]. These thus are not preferred [11, 12]. The strategy of chemical deposition processes inherits issues of complexity, relatively expensive, and challenging scale-up [1, 3, 12]. Thus most processes are not-suits active(s) that labile to said ambient conditions [2, 3, 12]. These facts had leaded to developing and improving specialised dry-coating processes/ techniques, over few decades [6, 17-20].

Dry-coating techniques are solventless coating process [1, 15]. Technique of these processes directly attaches/ fixes CMPs, as FiUlFiPs, onto relatively larger substrates [1, 3, 15]. Applied mechanical forces realises said fixing and does not requires binder(s) and/or solvent(s), even water [3, 4, 15]. Methodology of these enables combining powders of diverse physical and chemical properties to realise composites, a new-generation tailored materials [3, 15]. Resulted composites bears new functionality and/or have improved characteristics, comparing that of component materials [1, 3, 15].

Coating processes, in present scenario, are of diverse type & origin; refer Figure-1 [5, 6, 16]. These associated and inherited with complex processing steps [5, 6, 16]. Inherited complexities are of diverse type and origin [6, 16]. Their generalisation in broader term is wispy task [5, 16]. Available literature with summarising information, as a glimpse, in broader area of coating is rare [5, 8]. Thus it seemed requisite to summarise information in said area and to present them as glimpse, for convenience & enrichment of professionals.

Presented information will provide a glimpse on the coating processes. Recent developments on the coating techniques having pertinences in pharmaceutical sector are briefed and outlined. The effort in turn will enable to find suitable process for the candidate pharmaceutical and to find improved/ new industrial applications and consequence is improved profit & productivity, ultimately benefits of mankind.

BASIC PRINCIPLE OF COATING/ DEPOSITION PROCESS

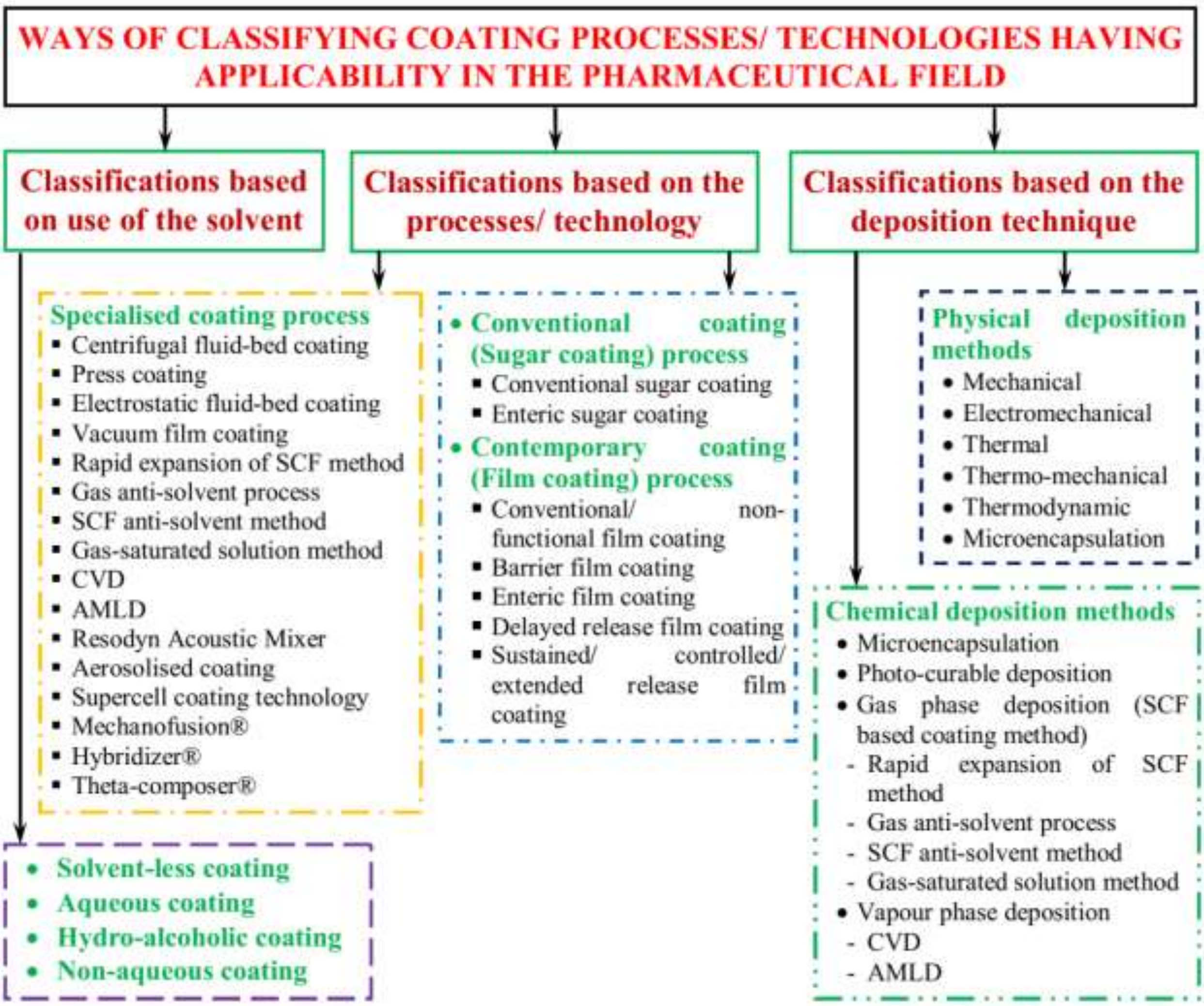

Figure 1: Diverse coating process with pharmaceutical applicability, as adapted from [10, 16].

In present days available coating process are of diverse type & origin [16]. Involved basic principles with them are complex one, as these associated with complexity of processing steps [16]. Their generalisation in broader term is wispy attempt [16]. However, general principle is: deposition involves application of CoM to a moving substrate-bed with an involvement of concurrent process to facilitate fixing of CoM on substrate-surface [1-3, 10, 11, 16].

The process and processing equipment must have proviso for [1-3, 10, 11]:

1. *Application and distribution of CoM*: for distribution of the coating formulation (in liquid form) over the whole of the available surface of substrate (by ladling, spraying) [1, 2, 10],
2. *Rotation of substrate-bed*: for continuous movement of substrate-surface for facilitating uniform deposition of CoM [1-3, 11],
3. *Fixing/ Curing*: to fix CoM on substrate-surface to have evenly and firmly coated product [1, 2, 10], and
4. *Removal of process-waste*: generated dust and vapour are the process-waste calls for removal to facilitate formation of a uniform coat and product free from impurities [1-3, 11].

SUGAR-COATING

Sugar-coating involves successive treatment of the substrate cores with aqueous coating medium of sucrose that may contain other functional ingredients like fillers, colours, etc [1]. Inclusion of other functional ingredients is done depending on the stage of coating reached [1]. A multi-step process with duration of processing ranges from few hours to few days and is out coming in an elegant highly glossed finished products [1]. The ideal shape of substrate for sugar-coating is deeply convex core with minimal edges, usually tablets [1]. The process increases substrate weight by 50-100%. However the quality of coating depends upon the operator's skill [1].

Traditional sugar-coating pan with a supply of drying air and a fan-assisted extraction device is suitable one [1]. The supply of drying air is preferably of variable temperature and thermostatically controlled while the extraction device to remove dust and moisture-laden air [1].

The build-up of coat is due to transference of coating medium from one substrate to another [1]. Typically a single liquid (coating medium) application is be made [1]. Applied liquid be allowed to spread on the entire substrate-bed utilising blending capability of the particular equipment [1]. At this point of time drying operation is usually performed with hot air, to dry the applied liquid. The whole cycle then is successively repeated [1]. Steps of sugar-coating are as follow:

a) Sealing
b) Sub-coating
c) Grossing/ Smoothing
d) Colouring
e) Polishing
f) Printing

Sealing: It is a step for water proofing of substrate cores [1]. Seal coat acts as a moisture-barrier film, minimises attrition effects, and prevents migration of certain materials [1, 10]. In general, the sealants are water-insoluble polymers (film formers) are applied as solution in VOS [1, 10]. Useful polymers are shellac, cellulose acetate phthalate, zein, polyvinyl acetate phthalate, and many others [10]. Sealant quantity is primarily determined by tablet porosity [1]. For instance, highly porous tablets will tend to soak up the first application of solution [1]. Thus prevent its uniform-spreading across surface of every substrate within the batch [1]. Effectual sealing of substrate cores calls for application of sealant solution once or further [1]. After application of sealant liquid substrates are allowing to dry for 15-20 minutes, between each application [1]. If the substrates become tacky, sufficient talc is applied to avert sticking [1].

The process description comprises of pan speed: 10 rpm, supply air temperature: 30 ^{0}C [1].

Sub-coating: The sugar-coating process actually starts from this step [1]. Sub-coat is applied to provide rapid build-up that is necessary to build up substrate size and to round product edges [1]. Usually sub-coat media is gelatine/ acacia in less concentrated sucrose syrup with or without sub-coating powder (a filler material like talc, calcium carbonate, etc.); refer Table-1 for major components [1]. Process of sub coating is either lamination process or suspension process [1].

Lamination process: Herein a volume of sub-coat media free from sub-coating powder is applied to the moving sealed substrate, in coating pan [1]. Once sub-coat media spreads, sub-coating powder is dusted into the pan [1]. After even distribution of powders, drying air is applied [1].

Drying process necessitates careful controlling to prevent too rapid/ too slow evaporation of water [1]. Evaporation of water at an optimum level will result a smooth coat, as much as possible [1]. Thus will reduce time required to smooth the coat, in final stages of the process [1]. Excessive rapid drying yields very uneven surface, whilst too low rate of evaporation may brings danger of adhering together of cores and makes the process lengthy [1].

Table 1: Composition of coating formulations used in different steps of sugar-coating [1]

Seal coating	Syrup-coating	Sub-coating	Polishing
Zein / shellac	Colorant	Gelatine	Carnauba wax (yellow)
Oleic acid	Sub coating powder	Acacia	Bees wax (white)
Propylene glycol	Calcium carbonate	Sugar cane powder	Paraffin wax
PEG	Cane sugar powder	Corn syrup	Naphtha
Methylene chloride	Corn starch	Syrup	
Alcohol	Syrup	Distilled water	
	Distilled water		

Suspension process: Automation of sugar-coating process outcome suspension process that calls use of liquid sub-coat media containing sub-coating powder [1]. Sub-coat media is usually suspension of sub-coating powder in the solutions of gelatine/ acacia in less concentrated sucrose syrup [1]. Herein the formulation of sub-coat media contains approximately 23 percent water thus dries quickly [1].

The process parameter comprises of pan speed: 10 rpm, turn OFF the inlet-air and heater, use exhaust air only [1]. Apply 3-9 coats and dry substrates at least for 20 minutes after each application [1]. In first coat higher quantity of sub-coat media be using, gradually reduce its quantity, in accordance to have required weight and to round edges [1]. At the end of process, dust with sub-coating powder [1]. After last coat, run pan for at least 2-4 hours for ensuring complete dryness [1].

Grossing: The end product of sub-coating is too rough as there irregularity on the surface [1]. It is unsuitable to continue with colour coating [1]. Thus there a grossing step, that is specifically for smoothing and filing the surface irregularity [1]. Further this step increases size of substrate to a preset dimension [1]. The grossing syrup, a dispersion of sub-coating powder syrup, is used for this purpose; refer Table-1 for major components [1].

Process outline comprises of removing excess dust from pan, turning ON exhaust air assembly [1]. Setting pan speed at 15 rpm and apply grossing syrup coat of 5-15 coats [1]. Adjust temperature to achieve exhaust air temperature of 45-48 ^{0}C [1].

Following this apply several coats of heavy syrup maintaining above parameters [1]. The heavy syrup is the grossing syrup containing colour [1].

Smoothing: Herein few coats of regular syrup containing colour is applied to achieve final smoothness, wished size, and colour [1]. Regular syrup is usually 70 % w/w syrup containing colour but free from sub-coating powder, refer Table-1 for major components [1]. However unevenness of large degrees will calls for some sub-CoM, in initial coats of smoothing [1]. Products with well carried out sub-coating step calls approximately ten applications of regular syrup that will be sufficient for product that is fit for next stage [1].

The process steps are comprises of turning OFF the heater and reducing the inlet and outlet-air [1].

Finishing: It is the most important stage of sugar-coating process, as is having immediate visual impact [1]. The stage is often critical in successful completion of process [1]. As this step will give depth to colour and will enhance elegance of coat [1]. This stage involves the multiple application of coating syrup [1]. Said syrup contains 60-70 % w/w sugar, and requisite colour, for achieving desired shade; refer Table-1 for major components [1].

The process parameters are, keep the heat and inlet-air supply OFF, maintain pan speed at 12 rpm, reduce exhaust air, and rapidly apply 3-4 coats of coloured regular syrup. Shut OFF exhaust-air, then apply last coat of regular syrup free from colorant. Then stop pan while products are damp and swiftly be shifting to run pan for 15-30 minutes [1]. Leave the product overnight for its complete drying [1].

Supra is the water soluble dyes thus used usually to give wished shade, as these stick to product-surface during drying process [1]. Mottling problem is the problem of supra, as they may migrate onto surface of product during drying, can be overcoming by preferring use of certified lake pigments, as are aqua insoluble [1].

Polishing: Colour coating of substrate makes them somewhat matt/ dull in appearance [1]. Thus requires polishing step, final step, to impart them higher degree of glossiness [1]. The substrates can be polishing with blend of waxes in canvas lined polishing pan or standard coating pan [1]. Usable waxes are Beeswax, Candelilla wax, Carnauba wax, hard paraffin wax; refer Table-1 for major components [1].

The process parameters includes pan speed is be maintaining at 12 rpm, inlet-air and outlet-air to be turned OFF. Then after apply 3-4 coats of polishing solution (wax in naphtha), in warm condition [1]. Apply subsequent coat of polishing solution when solvent evaporates out [1]. Sometimes powdered wax(es) can also be applied [1].

Printing: Finally surface of product can be printed using edible ink for product identification and/or for complying regulatory requirement [1].

Enteric sugar-coating: For having enteric sugar-coating the sealcoat is modified [1]. The modification is that the sealcoat comprise one of enteric polymers [1]. Applied sealcoat be in sufficient quantity so as to pass enteric test for the disintegration [1]. Herein subsequent coating steps including sub-coating are as followed in conventional sugar-coating process [1].

Table 2: Differences between film-coating and sugar-coating [1, 5, 10].

Area	Features	Film-coating	Sugar-coating
Tablet	Appearance	Retain counter of core. Usually dull comparing sugar-coated one.	Rounded with high degree of polish. Usually highly shiny.
	Logo or break lines	Possible	Not possible
	Other solid dosage form	Coating of multi-particulates is very important in modified release form.	Coating feasible with little industrial applicability.
	Weight increase (in %)	2-3	30-50
Process	Compliance to Good Manufacturing Practice	High degree of compliance.	Difficulty may arise.
	Functional coatings	Easily adaptable for delayed/ sustained/ controlled release.	Not usually possible apart from entering coating.
	Operator training	Requires easy training.	Requires special training.
	Process automation	Tends itself to automation.	Not possible.
	Process stages	Multistage process.	Usually multi stage process.
	Typical batch coating time.	1.5 to 2.0 hours	8 hours, but usually longer.

FILM COATING

Reducing processing time & overcoming requirement of skilled-operator in sugar-coating, are chief amongst the reasons, refer Table-2, for developing film-coating [5, 6]. There after film-coating can protect substrate from humidity, temperature, and light thus improve stability; can mask obnoxious odour and/or taste, can improve appearance, can facilitate swallowing thereby improve aestheticism; can provide product identity; and can control and/or modify release of active(s) [5, 8, 9]. The film-coating finds application for achieving modified release profile are modified release film-coatings while that achieving conventional release are conventional film-coatings [5, 6]. Conventional film-coatings are for immediate release [9]. The modified release film-coatings are either for enteric/ delayed release or extended/ control release, where release is tailored by film-coat membrane that is a barrier controlling/ tailoring drug release [5, 8, 9].

In film-coating spraying of film-forming polymer onto the substrate surface realises thin layer/ coat [5, 8]. The coating compositions comprising film-forming polymer, in liquid state, is sprayed onto a small portion of moving substrates using one or more spray guns [5, 9]. Substrates are kept moving ether by rotating or by fluidising them using panning equipment that is either conventional or sophisticated one or fluid-bed processor; to accomplish efficient drying and automation, to reduce coating time, and to improve efficiency and reproducibility [5, 8, 9].

Herein using is the coating composition comprising film former, plasticisers and other excipients (like pigments) in a solvent system, either aqueous or VOS [5, 6, 8]. The coating fluid formulated either as aqueous solution or dispersion or as non-aqueous solution or dispersion [5, 8]. This in turn changes overall process and processing requirements [5, 6]. In broad the film-coating process can be [5]:

- Aqueous film-coating process.
- Non-aqueous film-coating process.

Use of VOS as solvent system in film-coating is preferred over aqueous system in earlier days due to assorted issues, as discussed earlier [5, 6, 8]. Latter on use of VOS invoked follow major concerns [8, 9]:

1. ***Venting of untreated VOS***: Venting of VOS vapours into atmosphere is ecologically restricted by regulatory authorities [5, 6]. Treatment of gaseous effluent as mandated by regulatory authorities is costly [5, 6].
2. ***Compliance of fire hazard and safety hazard***: Use of VOS, as are flammable, toxic, and explosive, calls for infrastructure with flame-proof & explosive-proof, and chemical-hazard proof facilities [5, 6].
3. ***Cost***: VOS are relatively costly and have higher storage cost [5]. It is likely that in future they will be costlier [6]. Insurance premium nowadays is much higher for the manufacturing facility using VOS [5, 6].
4. ***Residual solvent***: Quantifying residual VOS for film-coated product is must [5, 6].

VOS invoked major concerns restricted their use to the process demanding rapid drying characteristics, especially when [5, 6]:

- The process unable to accommodate use of water; for instance causes like instability, poor drying rate, attained adhesion is unacceptable, and many other [5, 6]; and
- Most suiting candidate film former is aqua-insoluble and is unavailable as pseudo-latex/ latex system [5, 6].

Process basis of film-coating: Processing involves spraying the liquid coating composition, using spraying/ atomising system, on to the moving substrate-bed [5, 6]. Spraying/ atomising system is to atomise the bulk coating liquid as fine-droplets and deliver them on to the moving substrate-bed [5]. Said delivery is to be in such a state that fine-droplets retain sufficient fluidity [6]. The droplet's fluidity is be sufficient enough to wet substrate surface, spreads out, and coalesces to form film [5]. The drying conditions permits solvent removal from the applied film [6]. Thereby leaving thin deposition of CoM, as a film of 20-200 µm, around each substrate-core [5, 6]. High quality film-coat to be smooth, uniform, adheres satisfactorily to substrate-surface, and ensures product's physico-chemical stability [5, 6].

Aqueous Film-Coating

Increased degree of understandings relating toxicities of VOS accompanying with worldwide tightening-up of regulations on Foods & Drugs, exposure of workers to VOS, and industrial hygiene is limiting their usage [5, 6, 8]. To these add-on issues/ concerns are increasing cost of VOS, today's competitive business environment, and cost-cutting attempts to improve product's market viability and success [5, 9]. Thus as substitute and combat these adverse situations, last few decades evidenced wide exploitation of aqueous film-coating systems [5, 9].

During earlier days the aqueous film-coating processes were seen with scepticism [5, 9]. This is due to facts of inferior appearance, lengthy processing time, possible decomposition of active, and difficulties during coating [5, 9]. Research along with industrial experience has revealed aforesaid issues are of low concerns in practical application [5, 9]. These problems/ issues can be addressed thru evaluating reasons, scientifically, and making significant advancement in the process technology & the equipment design [5, 8]. Most of the associated problems/ issues could be categorising as related to process, material, and instrument/ equipment [5, 9].

Introduction following development of latex & pseudo-latex system side-by-side development & introduction of improved equipment designs had been broadening spectrum of aqueous film-coating [5, 6]. In present days, said development and improvement along with correct settings of processing condition had made possible to realise aqueous film-coating of fine particulates without agglomeration and of tablets containing superdisintegrants without their surface-dissolution & core penetration [5, 6, 9]. Advancement in aqueous film-coating formulations is aqua enteric-coating system [5, 6]. Said systems eliminate separate inclusions of detackifiers, plasticisers, pigments, other process additive, and process aids [5, 9].

Aqueous polymeric dispersion: The advantages of the aqua polymeric dispersion are that these permits aqua-processing of the aqua-insoluble polymers [5, 6]. Thus consequents benefit of aqua-processing is made achievable [5, 8]. Specialised dispersion of water-insoluble polymers are commercialised [5, 6]. Commercialised products of ammonium methacrylate copolymers and ethyl-cellulose having applicability in aqueous-media are often encountered in film-coating of granules & beads for using in modified-release products [5, 8, 9].

However performance of aqua-dispersion is affected significantly by conditions set during coating processes [5, 8]. Variable results like ultimate drug-release feature(s) may often attributing significantly from choice of processing parameters that is incompatible and/or to lack of controls on processing parameters rather to any variability in aqua-dispersion used [5, 8].

WET AND DRY COATING PROCESSES

Application of coating on the substrate surface is achievable by method based on wet coating process or dry coating process [1-5, 10, 11, 15]. Wet processes are primarily useful to have a barrier-film between surrounding environment and substrate core [1-5, 15]. Resulted barrier-film overcomes incompatibilities; controls/ extends/ sustains/ delays release [1-4, 15]; improves stability/ shelf-life and/or aesthetic property; and many others [4, 5]. Enhancement of aesthetic property is achievable by odour/ taste/ colour masking. Improved stability is achieved by protecting the product from light, atmospheric oxygen, water vapour [1, 5].

Comparing wet process, the dry coating process makes achievable in tailored surface properties apart from forming a barrier-film [4, 21]. Said tailored surface attributes are by improving or modifying surface properties of substrate core to diverse degree [4, 21]. Amongst tailored attributes, surface attributes of pharmaceutical importance are wettability, dispersibility, solubility, hydrophilic & hydrophobic properties, flowability [4, 21, 22], particle shape, sphericity, solid phase reactivity, electrostatic & magnetic property, sinterability, optical activity, odour, colour, flavour, taste, and many others [1, 3, 22].

Wet coating processes: The process typically involves spraying solution/ dispersion of CoM onto the substrate surface, kept in motion or fluidised state [1, 3, 10, 11, 15]. After that surface of substrates are wrapped by the film of coating-liquid, in individual level [3, 5, 10]. Upon evaporation of solvent from the coating-liquid film a new solid layer is formed. Thereby realises coating of individual substrate [4, 11].

The process basis in wet method usually comprises successive steps that include droplet formation, wetting, spreading, evaporation, and drying [1, 4, 5]. However there might slight variations in process [1, 4]. Said variation depends on nature of CoM and substrate, processing conditions, and apparatus [4, 5].

Available wet process based coating method are fluidised-bed coating, pan coating, wet-chemistry based techniques (coacervation, interfacial polymerisation, formaldehyde/ urea deposition, etc.), and many others [1, 5, 10, 11, 23].

Coating processes following wet methods become less preferable as can reason reduced stability [10, 11] and particle agglomeration [1, 5], might leave residual VOS [1, 11], and may arouse environmental concerns [4, 5]. These facts are arousing may be from emissions of VOS and unwanted waste streams [1, 4].

Dry coating processes: Methodology of the dry-process involves directly attaching CoM (as FiUlFiPs) onto substrate cores that are relatively large [1, 3, 15]. Herein the CoM, as FiUlFiPs, is brought in close proximity with substrate cores either by thermo-mechanical energy or by involvement of chemical and/or electrical interactions [3, 4, 12]. Said interactions realises the coating or deposition [3]. Involved processes are mechanical deposition process, thermo-mechanical deposition process, electrical or electrostatic deposition process, or chemical deposition process [1, 12, 16]. The chemical deposition processes is either gas-phase deposition processes or vapour-phase deposition processes [4, 16]. Thermo-mechanical deposition process realises embedding & layering of CoM particles thru strong mechanical force and/or impaction force accompanied by generated heat [3, 12-14].

In some exempla, the dry-process might either deform particles of CoM or cause them to get embedded onto surface of substrate particle [1, 3]. Said embedding and/or deformation realises firm coating vis-à-vis alters surface morphology and reduces adhesive forces of substrate particle [1, 3]. Thereby process creates engineered particulates, value-added composite particulates, with tailored surface attributes [3, 4]. Said composite particles are with new & exciting applications [1, 4].

Comparing wet one the dry-process does not calls for any binder(s), solvent(s), or even water [1, 3, 4]. Further dry-process does not produce effluents like any organic gas, aqueous, liquid waste [3, 4]. The process is alternate to wet method, environmentally benign, and cost effective [1, 3, 4]. From past few years, methodologies of dry-processes steadfastly established them as viable methods to realise composite solid particles [1, 3, 22].

PARTICULATE COATING PROCESSES

In majority manufacturing processes of solid formulations most inevitable is handling of particulate matter [3]. Modification of their surface and surface attributes can be achieved by coating their surfaces [1, 2]. Most of techniques/ process for surface modifications alter innate properties of particles either physically or chemically [1]. The process is useful for active(s) which are difficult to formulate [1, 3]. Further coating is exploited for finding new and/or worthy functionalities/ properties attributed FiUlFiPs, as drug carriers/ delivery systems [2, 3].

AEROSOLIZED COATING PROCESS

It is a one-step dry coating process involves principle of co-aerosolization under ambient temperature for realising coating of particulates [1-3]. Said aerosolised state results clouds of individual particles [1, 3]. In said cloudy state intimate contact of individual particles clouds occurs [1, 2]. Such interaction facilitates attachment of CMPs (as FiUlFiPs) onto surfaces of coarse substrate particle [2, 3]. Further, involved interaction can confer engineered attributes to substrate particles, without their unwanted physico-chemical modification, even of extremely sensitive active(s) [2, 3].

Since herein in aerosolised state coating happens thru particle-particle interaction thus there no exposure to mechanical attrition, thermal energy, and solvent during processing [1, 2]. Further, precise control of parameters during processing can realise consistent product performance even from commercial grade excipients [2, 3].

VACUUM FILM COATING PROCESS

A novel wet method based coating technique is suitable for tablet substrates using non-aqueous coating formulations [17]. It uses specially designed jacketed-pan inbuilt with baffle [17]. Airless spraying nozzle is there for spraying coating media [17]. The jacketing is for heating & cooling and the pan have facility to get sealed for creating vacuum [17]. During processing, contented air in the pan is displaced thru purging of nitrogen till realising desired vacuum level [17]. Evaporated solvent vapours are removed by vacuum system [17]. Equipment & process have design featured with environment safety of highest degree [17, 18].

SUPERCELL® COATING PROCESS

Conventional coaters, in most instances, are outcome inaccurate/ non-homogenous coating [6]. The methods based on these coaters causes tablet's grounding off and filling in of intagliation [17]. Further said methods fail to consistently coat edges/ corners/ faces of tablets with flat & other odd shapes [6]. In nutshell, said methods are unsuitable for modified release coating and for friable and/or extremely hygroscopic tablets [17]. As solutions to talk over issues "Supercell coating technology" is devised [6]. A novel and gentle fluid-bed processor (Wurster type) based wet method to realise coating of friable/ hygroscopic/ flat & other odd shaped tablets [6, 17].

PHOTO CURABLE COATING PROCESS

Photo-curing or photo curable coating is chemical approach devised to coat substrates rapidly at/or below room temperature, at very-fast rate [1-3]. The process realises rapid conversion of solventless compositions (liquid pre-polymers or monomer, specifically formulated one), into solid film thru photo-curing [1, 10]. Photo-curing is done by irradiating the product with visible or ultraviolet light [3, 11].

Radiant energy of light generates free radical that initiates polymerisation reaction of functionalised liquid monomers or pre-polymers [1]. Said polymerisation of liquid monomers or pre-polymers causes their transition to solid film [1-3]. Ultraviolet light is more energetic than visible light thus is more effective to rupture the chemical bonds [1, 11].

HEAT DRY COATING PROCESS

Inclusion of plasticiser commonly practiced in dry-processes [1, 3]. Said practice not-suits film-forming polymers having low glass transition temperature (*Tg*) [1, 3]. Further, high level of plasticiser causes pre-plasticization [1, 3]. Combating of said issues are done with devised heat dry coating that uses heat only to realise coating while abandons plasticiser usage [1, 3].

Herein, screw powder feeder used to spread CMPs continuously onto substrates contained in spheronizer [1, 3]. The top of spheronizer is positioned with infrared lamp, a heating source [1, 3]. Spheronization coupled with heat realises melting of CMPs and their spreading on substrate surface [1, 3]. The heat realises curing of spread coating layer [1, 3].

Eudragit® E PO is a CoM suits this process [1, 3]. Major challenges overcoming herein to get smooth, uniform, and thick coating, only by help of said heat-based adhesion [1, 3].

PLASTICIZER DRY COATING PROCESS

These are the dry-methods that make usages of plasticiser(s) for realising coating [1, 3]. Said coating method are suitable for process that calls for usage of film-forming polymer (of low *Tg*) [3]. The process suits where essential is for protecting actives from getting damaged during their processing, at high temperature [1].

Upon spreading CoM (powdered) onto substrate surface, plasticizer is sprayed simultaneously from a separate spraying nozzle [1, 3]. Thus then sprayed plasticiser wets substrate surface and CMPs [3]. This thus promotes adhesion of CMPs onto substrate surfaces [1]. Coated substrates are then cured for preset time above *Tg* of coating polymer, to realise continuous film [1, 3]. The substrates suitable are tablets, particles, FiUlFiPs, and many others [1, 3].

HOT-MELT COATING PROCESS

This process involves depositing meltable CoM, in molten state, onto the substrate core [1, 3]. As the product is subjected for cooling solidification of meltable CoM realises coating [24]. Usually lipid, fatty acid, glycerides, waxes with low melting point suits as meltable CoM [25, 26]. Involves simple technique and don't require complicated and sophisticated equipment [1]. The process can be performed with conventional pan coater, spheronizer, fluid-bed processor, and spouted-bed processor [1, 3, 6]. Process is suits moisture labile drugs also for enhancing dissolution rate and water solubility of poorly aqua-soluble drug [27-29]. The process finds applicability for wider range of substrate with diverse particle size and for realising coating in multiple layers [1]. Absence of solvent evaporation phase in this process realises nonporous & strong particles [1, 24, 27-29].

Spray congealing: A highly versatile technique of HMC method suiting for particles [1]. The process realises particles having diameter within range of 10-3000 µm [1]. The process involves atomising/ spraying a hot-melt containing substrate and CoM into the air-chamber [1]. The temperature of the chamber is maintained below melting point of meltable material(s) or at the cryogenic temperature [1]. Granular particles realises upon cooling of atomised/ sprayed droplet [1].

HMC using fluid-bed processor: Herein powdered mix of meltable & non-meltable materials applied onto starting seeds (starting particles or powdered particulate cores) in a fluid-bed processor for realising coating [30-32]. The meltable materials can apply onto seeds as either molten liquid or solid particles [33]. Procedure wherein used particulate meltable binder melts during process is termed *melt-in procedure* [1, 30]. Process wherein meltable binder is a molten liquid that sprayed on starting seeds is termed *spray-on procedure* [1, 31]. From industrial point of view procedure of melt-in process is the simpler one comparing spray-on process, is favoured over the spray-on process [30, 32].

Hot-melt granulation and hot-melt pelletization: These processes call for meltable materials with high viscosity and small particle size [34, 35]. High viscosity grade meltable materials are required for improving mechanical strength of coating [1, 36]. Smaller particle sized meltable materials are required to prevent realisation of coating with rough surface [1, 36].

Solid dispersion hot-melt fluid-bed coating: Said process is termed *Tumbling HMC* a modified version of HMC. It is fluid-bed processor based system that eliminates spraying step but realises coating by solid dispersion [1, 31, 32]. Thus the process does not demand steam jacket, heating assembly, and/or nozzle [1].

Herein the nonpareils and powder of poly ethylene glycol (size 1.41–3.36 mm) were fluidised together [31, 32]. Nonpareils are the powdered substrate particles [37]. During processing inlet-air temperature is increased [37]. By this the poly ethylene glycol melts and thereby get transferred onto nonpareils [37]. Then typical steps of HMC are followed, like cooling & congealing [37].

Following this method, multiple coatings can be realised by applying coatings as multiple layers [37]. For this, CoM with descending rank order of these's melting point be using [31]. Thus is to realise additive coating layers resulting multiple layer of coatings [37].

Turbo-jet coating process (modified): A modified version of Turbo-jet coating process. Modification is for adaption of process to coat particulates and FiUlFiPs [1]. Modification is, suspending particulates in the spiral of ascending-air [1]. Said spiral air-flow provisos homogeneous distribution of particulates as individual particle [1]. The molten CoM is lipidic one [1]. Same be dispersing from bottom of the tank & tangentially to particle-flow [1].

The lipid crystallisation, inside the nozzle expansion, is prevented thru use of micro environment, surrounding the nozzle out-let [1]. Said technique enables coating of FiUlFiPs [1].

MECHANICAL DEPOSITION PROCESSES

A simple dry-method, wherein realising direct deposition of CoM onto substrate is thru compression/ compaction [3]. It involves compacting CoM around a substrate core, usually tablet, using specialised instrumentation, designed/ devised specifically for said purpose [2, 6]. The process is well suited for components that labile to VOS, heat, and moisture; but calls functional or non-functional coating [6, 17, 38]. This coating process suits tablet substrates, for moisture-proofing or for separating incompatible ingredients [17, 18, 39].

Resulted tablets are two/ three component system [17, 18]. Two component systems are tablet-within-a-tablet [6, 38]. Three component systems are tablet-within-a-tablet-within-a-tablet [17, 39]. The process may result non-uniform coating due to off-centre positioning of core tablet [17]. Said issue is short out with "one-step dry-coated tablet manufacturing method" design approach [17, 39].

THERMO-MECHANICAL DEPOSITION PROCESSES

These comprises group of processes that realises coating thru use of impaction force and/or thermal energy or by application of ambient shearing stress [3, 6, 12, 16]. Herein applied ambient mechanical/ impaction force accompanied with generated heat realises embedding and layering of CMPs onto substrate surface [3, 13, 14]. In some exempla, coating of substrates realises thru deformation of CoM along with embedding of them onto substrate surface [1, 3]. Said embedding and/or deformation in several instances realise much stronger coating [1, 3, 4]. Thereby these processes realises engineered particles with complete unlike functionality & surface attributes [1, 4]. Thus these are value-addition process, as results value-added composite particulates with tailored properties [1, 3]. Thereby confer composite new & exciting applications [3, 4]. Thus said processes are exploited in instances requiring significant changes in functionality and/or properties of substrates [1, 3, 4].

MECHANICAL DRY COATING PROCESS

These are the group of dry coating processes involving high-shear & high-energy interactions amongst the particle-device wall and/or particle-particle for realising coating [1-3, 16, 22]. Said interactions aimed to realise coating thru fixing of CMPs on surfaces of substrate cores [1, 40]. In some instances mechano-chemical interaction, physico-chemical binding, might contributes fixing/ adhesion [3, 41, 42]. Thereby these processes modify substrate surface attributes [1, 2]. These processes are faster, single-stepped, simpler, potentially cheaper, safer, and environment-friendly [1-3].

Important processes of this group are Magnetically assisted impaction coating, Hybridization, Mechanofusion, Theta composing, and many others [1, 3, 12, 16, 41, 42]. These are mostly single-stepped straight forward process [1]. Herein load powder mixture into processing vessel of machine, then turn it ON [1, 3]. Operate it for preset time and speed, and then turn it OFF [1]. Then unload coated powders [3].

These processes bear ability for designing them to have continuous processing [1, 3]. Operator's skill is of minimal concern in these processes [1, 3].

Mechanofusion®: Herein embedding is realising thru mechano-chemical-reaction that merges CMPs on substrate particles by inputting mechanical energy of high degree [1, 3, 4, 12, 16, 21, 43]. During processing, materials in mechanofusion reactor are subjected to compression & simultaneous stress, by intense shear [1, 3]. Thus realises composite particulates with differing properties and controlled particle size & shape [21, 40-45]. In this regard, process is arguably grabbing much attention, specifically in pharmaceutical field [40, 44, 45].

Hybridization®: Herein employed high impaction force induces particulates to undergo legion collisions and builds-up temperature [1, 12, 16]. Said collisions realises breaking-up of fine agglomerate(s) and coating thru embedding and/or filming of CoM onto substrate surface [1, 3]. The embedding or filming is aided by built-up temperature [1, 12, 16].

A batch operated dry coating process makes use of Hybridizer® machine for realising particulate coating [41, 42]. It enables embedding of the CMPs onto substrate particles very fast, within 1-5 minutes [3]. Jacketing facility is there to facilitate control of local build-up temperature [3].

Theta-composing: A novel dry-process to coat particulate substrate using Theta-composer® [12, 16, 41]. Herein the powder blend comprising CMPs and particulate substrate is subjected to strong shear stress with simultaneous compaction force while their pushing-up through a narrow gap, within the processing chamber of the machine [41]. The formation of narrow gap is with concurrent attrition results due the peculiar rotation of inner elliptical rotor and rotating outer elliptical vessel [41, 42]. The inner rotor rotates inside the rotating outer vessel [42]. Inner rotor rotates, very fast in anti-clockwise direction inside the slowly rotating vessel in clockwise direction [41, 42].

Magnetically assisted impaction coating process: A dry-process based soft coating technology wherein coating is realised thru mechanical impaction using oscillating magnetic beads [1, 3, 12, 16]. The process warranted for handling thermolabile, easily deformable, and relatively soft product [6, 17, 41]. Coating is realised with minimal degradation of components and minimal deformation in particle shape & size [6, 17].

Generated oscillating magnetic field, surrounding processing vessel agitates magnetic particles [1, 3]. Magnetic particles upon agitation causes collisions among CMPs & substrate particles, magnetic particles & CoM/ substrate particles, and substrate particles/ CoM & vessel wall [1, 3]. Thereby peening of CMPs onto substrate surface thus realises coating [1, 41].

RESODYN ACOUSTIC COATING PROCESS

A dry-process realises particulate coating following "Resonant Acoustic Technology" using "Resodyn Acoustic Mixer" [16, 46-50]. Said mixer is a sophisticated bench top mixer [46, 47]. Employed technology creates low-frequency high-intensity shear field, within processing vessel [48, 49]. Thereby generated acoustic energy realises coating of particulate substrates as they collide with each other [46, 47]. Coating is resulted in very short time-span [49, 50].

ELECTRICAL - ELECTROSTATIC COATING PROCESSES

Involved technology of these processes results electrostatic deposition of charged CMPs onto surfaces of charged substrate [16, 51]. Processing involves applying strong electrostatic charge onto the substrate, make their surfaces electrically conductive [17]. This then followed by spraying CMPs that comprise oppositely-charged conductive ions [1, 17]. Then the product is cured by heating it suitably until applied CMPs fuses to form film [6, 51].

An optimised process can realise coated substrate having excellent coating uniformity [5]. Resulted coating is smooth surfaced continuous film that releases drug with similarity of significant degree to that of cores [18, 51]. A novel technology is to realise coating of capsules, tablets, powders, and living cells [6, 18].

Plasticiser electrostatic coating: Feature of this process, herein coating is realised by combined use of plasticiser, heat, and electrostatic field [1, 3]. Herein, inclusion of suitable liquid plasticiser, in adequate amount, reduces *Tg* of polymeric CoM and increases substrate's electrical conductivity [51, 52]. Plasticiser's inclusions promote adhesion of CMPs, encourage film formation, lower-down curing temperature and shorten processing time [51, 53]. The process is called-upon when processing under lower curing temperature is warranted [1, 17, 18, 51].

Electrostatic fluidised-bed coating: Herein, coating realised in fluid-bed processor using electrostatic field [54]. During processing the powders blend comprising CMPs & substrate particles are kept in fluidised state by passing fluidising dry-air through the porous base-plate [3, 52]. In fluidised state powder particles subjected to electrostatic field [16]. Fluidisation along with repulsive effects of charged particulates creates clouds of charged particles, above the bed [16]. Through said cloud unheated and/or heated charged particulates makes several passes, thus realising coating [16, 54]. The process does not suit substrates that are elongated or passes axially or vertically across through powder-cloud and/or powder-bed [16, 54].

GAS-PHASE DEPOSITION/ COATING PROCESS

These comprises group of dry coating method are based on Supercritical fluid (SCF) and aerosol flow reactor, and these suits FiUlFiPs and particulate substrates [1, 3, 55-57]. Herein formulation of CoM is prepared using SCF as solvent/ medium [2, 3, 55]. Coating strategies following gas-phase deposition are complex, relatively expensive, and challenging during scale-up [3, 56, 57]. SCF based coating processes with broader applicability in pharmaceutical's coating are follows [1]:

a. Rapid expansion of SCF process [58].

b. SCF anti-solvent process [58].

c. Gas anti-solvent process [59].

d. Gas-saturated solution process [58, 60, 61].

Rapid expansion of SCF process: Rapid expansion of SCF vis-à-vis rapid super saturation is underlying principle of this approach [1, 3, 55, 56]. Rapid expansion of SCF is consequence rapid changes in density along with solvent power of SCF [2, 3, 55, 58]. This translates into rapid crystallisation rates thus resulting precipitation of CoM thereby realising coating [1, 3, 57].

SCF anti-solvent process: Process has synonym '*Aerosol solvent extraction systems*' [2, 3]. '*Solution-enhanced dispersion by supercritical fluids*' is its reported variation [3, 55, 58]. Design approach of the process is for handling CoM and substrate that are soluble in VOS; whilst they are insoluble in SCF and solution of VOS and SCF [2, 3]. The SCF be miscible with VOS [1, 3].

Gas anti-solvent process: Design approach of the process is to handle substrate and CoM which are soluble in the SCF but insoluble in the inert-gas [1]. Herein process basis is interacting solution of substrate and CoM in SCF with an inert-gas [3, 59]. The inert-gas is non-solvent for substrate and CoM [3, 59]. Rapid mixing of SCF solution with inert-gas lowers SCF's solvent power and causes substrate and CoM to precipitate [1, 3]. Said precipitation realises deposition of CoM on substrate surface [3]. During processing the inert-gas may be keeping at elevated pressure par to the pressure of SCF solution [1].

Gas-saturated solution process: Herein the process basis is mixing of polymeric CoM contained in SCF and substrate particles, at elevated pressure [3, 58, 60]. During processing SCF penetrates polymeric CoM causing CoM's swelling [60, 61]. The resulted mix is then heated at a temperature higher than *Tg* of polymeric CoM thus for liquefying polymer [3]. Hereafter the pressure is released [1, 3]. When pressure is released the CoM gets deposited on substrate particles [2, 3]. Herein both substrate and CoM may be insoluble in SCF of choice [1].

VAPOUR-PHASE DEPOSITION/ COATING PROCESS

These comprises group of process, up-roused as a novel dry coating process for solid dosage forms, FiUlFiP, and particulates; wherein electro-deposition is the underlying principle for realising coating [3, 62, 63]. Said electro-deposition generates vapour of desired CoM thru electro-dispersion and then permeate them onto substrate particles, for realising deposition of CoM [64, 65]. The CoM in most cases is powder but liquid is in minor instances [1]. Process has ability to realise uniform and durable coating of controlled thickness, on particulates at individual level, which is slow dissolving [1, 3, 20]. The terminal product has orchestrated surface, surface-topography, and functionalities [1, 3, 62, 64-67]. Major cons associated with these strategies are involvement of vacuum generation that requires huge investments arising from immense overhead costs, in process equipment [3, 4].

Electro-dispersion is the process of dispersing powder or liquid thru application of electrostatic field [20, 62, 66, 67]. Herein, process comprises of dispersal-phase & maintenance-phase [3]. In dispersal-phase intense electric-field realises dispersal of a part of static-bed, comprising substrate & CoM, into a stable cloud [2, 66]. Said cloud is of fast moving particles herein termed dispersed phase [62, 66]. A dynamic equilibrium is maintained between static-phase and dispersed-phase, in the maintenance-phase, wherein electro-deposition effected [1, 3, 66, 67].

Methods based on these processes are follows [1, 4].

a. Chemical vapour depositions (CVD) process [3].

i. Plasma enhanced CVD process [3].

ii. Initiated CVD process [3, 63].

b. Atomic/ molecular layer deposition (AMLD) process [3, 67, 68].

c. Fluidized-bed CVD process [3].

Both CVD and AMLD realises film coating using gaseous reagents [55, 66-69]. Even though AMLD is relatively expensive which often require toxic precursors but can realise effective fine coating with fineness of a few atomic layers only [70].

Fluidised-bed CVD process: The state-of-art technology combines CVD and fluid-bed process for realising coating [69]. CVD on fluidised powder bed is an efficient technique to functionalise & to deposit CoM on individual powder particles [69]. Herein one process-step aims to deposit CoM on substrate by itself while other process-step aims to suspend CMPs in deposition zone [69]. The suspending-step is resulted most often by upwardly flowing fluidising-gas through powder-bed [69].

FLUID-BED PROCESSOR BASED PROCESSES

The fluid-bed processor based processes offers an alternative to pan-coating process [16]. These processes bear potential pros being able to effect most effectual drying of any product comparing any other existing coating process [16]. Thus are particularly popular coating processes for multi-particulates, like pellet coating and microencapsulation [16]. Their use is uncommon for coating of tablets, on large scale, as associated high process attrition causes tablets to chip, break, and abrade out [16].

Fluid-bed processor based processes having applicability in coating are [16]:

1. Top-spray process,

2. Bottom-spray (Wurster) process,

3. Tangential-spray (Rotary) process,

4. Rotating (centrifugal) fluidised-bed process, and
5. Huttlin Kugel coater based process.

The coating liquid is continuously applied from a spray nozzle located at top of chamber (in top-spray process), bottom of chamber (in Wurster process), or tangentially (in Rotary process) onto the fluidised substrate-bed [16]. Selection of particular process is often decided by nature & intended functionality to be realising from coating, refer Table-3, for example [16]:

a) Films produced by top-spray process are not of uniform thickness [16]. Thus preferred in instances where critical control of drug release rate is not desirous, like taste masking and barrier films [16]. However, suit in hot-melt coating processes [16].

b) Wurster process is for conferring sustained/ controlled/ extended/ enteric/ delayed release property to wide variety of multi-particulates and pellets [16]. The process also suits for drug layering of drug with dose in low-to-medium range [16].

c) Rotary process has applicability in modified-release (controlled/ sustained/ extended/ enteric/ delayed release) and film-coating of wide ranged multi-particulate products [16]. The process ideally suits for drug layering having dose in medium-to-high range [16]. It is useful also in extrusion & spheronizing process to get pellets with modified-release attributes [16].

Rotating (Centrifugal) fluidised-bed process: Wet method based soft coating process employs rotating fluidisation principle [16]. It finds applicability for delicate and soft particulate substrates [16]. High rotational speed mediated centrifugal force and inwardly directed radial-air-flow fluidises the rotating substrate-bed [16]. In fluidised state a binary-fluid sprayer sprays coating fluid onto the substrate-bed to realise coating [16]. Excellent mixing is add on pro of the process thus achieves good coating in addition to operating in a continuous mode [16].

Table 3: Advantages, disadvantages and application of fluid-bed processor in coating [16].

Processing method	Disadvantages	Advantages	Applications
Top-spray	Limited applications.	Simple setup. Large batch size. Easy access to nozzle.	For aesthetic and enteric coating. Not recommended for tablet coating or sustained release products.
Bottom-spray	Tedious setup. Impossible to access nozzle during process. Tallest fluid-bed machine for particle coating.	Moderate batch size. Uniform and reproducible film characteristics. Wider application range.	Sustained release, enteric coating, aesthetic, layering. Not recommended for tablet coating.
Tangential-spray	Mechanical stress on product.	Simple setup. Nozzle access during process. High spray rate. Shorter machine.	Very suitable for sustained release, enteric coating, layering. Not recommended for tablets and friable products.

CONCLUSION

Modifying surface and surface attributes of solid-orals and FiUlFiPs thru coating can be realising by wet- and dry-coating process. In major instances, wet-processes suits for CoM that is liquid or solid, whilst dry-processes suits for solid CoM. The wet-processes unfit for FiUlFiPs. Residual VOS and handling of environmental issues along with unwanted waste streams are major concern of VOS based wet-processes. In this regard dry-processes are novel alternatives.

Dry-processes are one-step straightforward processes. These bear minimal concern to process deviation arousing from operator-skills. In addition some of these can be designed for continuous operation. Most of dry-process has high degree of scale-up potentiality. Further these can realise composite product having new/ novel functionality and/or surface attributes.

However, in dry-process particle size of CoM and substrate plays crucially for realising & reproducing the coating uniformity. Mechanical compaction based dry-processes unfit for elastic CoM and substrates. Mechanical interlocking of CoM and substrates that are plastic is possibly realising composite product.

Involved technologies of specialised wet- and dry-processes make use of ambient conditions like high pressures, high shear, elevated temperatures, and/or solvents. Gas-phase and vapour-phase deposition processes involve vacuum and/or pressure generation. These processes typically require immense capital investment & huge overhead costs, in process equipments. Strategies like plasma-enhanced CVD, AMLD, SCF based process are complex, relatively expensive, and challenging scale-up.

Among the wet-methods aqueous film-coating process be considering first option for realising coating of the solid-orals, regardless conventional (immediate) release and modified-release applications.

It is hoped that dry-processes upon optimisation & validation will become robust, thus may have high degree of potentiality suiting to manufacturing line-up. Finally, for finding pharmaceutical applicability wet and dry process their scalability potential for larger and pilot manufacturing-scale batch calls extreme robust investigation.

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