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Review Article

Specialised Coating Processes Finding Pharmaceutical Applicability

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Abstract

The manuscript aims at furnishing comprehensive information pertaining specialised coating technology/ processes. Solid dosage forms and solid particulates (SDFSP) are the major contributing group in the solid pharmaceuticals (SoPs). SDFSP exhibit peculiar physico-chemical properties and interaction behaviour which create problems/ issues during their handling, processing, storage, and use. Modifying and/or engineering surface attributes of SDFSP are advocated as powerful tool to modify their interaction behaviour and realise their worthy applications and functionalities. In this regard coating their surfaces with coating material (CM) is novel approach. Said approach involves wet and dry process for realising deposition of CM onto the surface of SDFSP substrates. Both the processes modify and/or alter innate properties of SDFSP substrates either physically or chemically. Basing on involved wet or dry process the coating method is either dry coating method (DCM) or wet coating method (WCM). Accordingly nowadays there available number of specialised devices, that bases on diverse technologies. Amongst them some involves state-of-art process/ technology like Supercell coating technology (SCT), Chemical vapour deposition (CVD), Atomic/molecular layer deposition (AMLD), Electrostatic deposition, Thermo-mechanical process, Resonant acoustic technology, Fluidised-bed process, Supercritical fluid (SCF) technology, and others. These foundational for commercially availability of specialised equipments like Magnetically Assisted Impaction Coater (MAIC), Resodyn acoustic mixer, Hybridizer®, Theta-composer®. Mechanofusion®, and others. Working and working principle, applicability, benefits, pros and limitations of specialised coating processes and technologies are herein discussed and presented. Contained information hoped to be beneficent for pharmaceutical professionals and technocrats and professionals of allied field.

Keywords: Coating, composite product, modification, specialised, surface.

INTRODUCTION

SDFSP are the most popular one, as drug delivery systems/ carriers [1, 2]. In most of pharmaceutical processes/ operations that deals SoPs, the SDFSP exhibit peculiar physico-chemical properties and interaction behaviour [2, 3]. These issues create problems during their processing, storage, use, and handling [3, 4]. Scientific finding is that said issues are contributed from the surface and surface attributes of the SDFSP, in most instances [2]. Thus handling of said issues is most inevitable [1, 3].

Modifying and/or characterising surface energy/ attributes of SDFSP are doubtlessly powerful tool to modify and/or characterise their interaction behaviour [1, 3, 4]. In this area, pharmaceutical technocrats and researchers are working extensively [1, 3]. They are mostly engaged in modifying SDFSP's interaction behaviour and/or finding their worthy applications and functionalities; for taking assorted advantage [1, 3, 5]. In this regards, they are exploiting numerous elegant strategies/ engineering methods to modify SDFSP's surface and/or surface attributes [1-3]. Among the available diverse strategies/ methods, these technocrats and researchers are considering coating as powerful, elegant, and efficient tool/ methodology [1, 3].

In pharmaceutical field, modification of surface and/or surface attributes of SDFSP thru coating their surfaces with an appropriate additive is extensively exploited, nowadays [1-3]. This strategy is nowadays becoming vital and used extensively for active(s) that are difficult to formulate [1, 3]. Herein coating is used for modifying/ altering innate properties of the SDFSP either physically or chemically [1-3].

Most of techniques/ process for surface modifications/ alterations of SoPs are frequently for functional and/or protective (non-functional) purposes [1, 3, 4]. These purposes includes changes in visual attributes, improved appearance, enhanced mechanical properties, masking of obnoxious odour and taste, stabilisation and improved stability, and defined drug release profile in the biological system [1-3].

Surface modification/ engineering process for SoPs thru coating are of diverse type and origin; refer Figure-1 [1, 3, 6, 7]. Wide diversity of the coating process/ methodologies is inherited with complex processing steps and with complexity of diverse origin and type [1, 3, 8]. Discussing all of them, a vast area and versatile field, is an immense task and out of scope of this manuscript [4, 9].

Content of manuscript is discussion and outline on recent development of specialised coating process/ techniques along with their applicability for SDFSP [1-3]. Presented information will increase visibility of specialised coating processes. This will resulting better understanding of

involved technology and interpreting of physico-chemical principles that influences these process side-by-sides finding their novel industrial applications. It is hoped that the contained information will inspire others to exploit this area.

PROCESS BASIS OF COATING

Coating process for SoPs involve either wet coating process or dry coating process [1, 3, 4, 6, 7, 9]. Both the processes are of diverse type and origin [1, 3, 9], refer Figure-2, and are associated with complex processing steps [1, 3, 9]. These steps are inherited with complexity of diverse type and origin [2, 3]. Generalising them in broader term is an impracticable act [1, 2].

However, a generalised concept of the process basis is: coating involves application of coating composition to a moving bed of the substrate and concurrently fixing of CM(s) onto the surface of the substrate [1-3, 6, 7]. Thus, the process and equipment must have proviso for [1-3, 6, 7]:

1. Application & distribution of CM(s): This for even distribution of coating formulation (containing CM) over the whole of available surface of substrate [1-3].
2. Rotation of substrate: This step for continuous mixing of substrate load and for interacting coating formulation with substrate surfaces [3, 6]. Thus achieving an evenly coated product [1, 2, 7].
3. Congealing or fixing of CM(s) on the substrate surfaces: This for firm affixing of the applied film of coating [1, 2].
4. Removal of the generated effluents and the carrier used for carrying the CM(s), if any: This for facilitating formation of uniform film and purifying the product [3, 6, 7].

WET COATING METHOD

The process basis of wet method usually comprises sequential steps of droplet formation, wetting, spreading, evaporation, and drying [1, 4, 9]. Herein typically, CM(s) in the form of suspension or solution is applied onto the fluidised substrate [3, 6, 7]. The result is, individual substrates are wrapped by the applied liquid, as film [3, 6, 7, 9]. When evaporation of liquid from the liquid film is effected a new solid layer formed [7, 9]. Thus is resulting in coating of substrates, at individual level [1, 4].

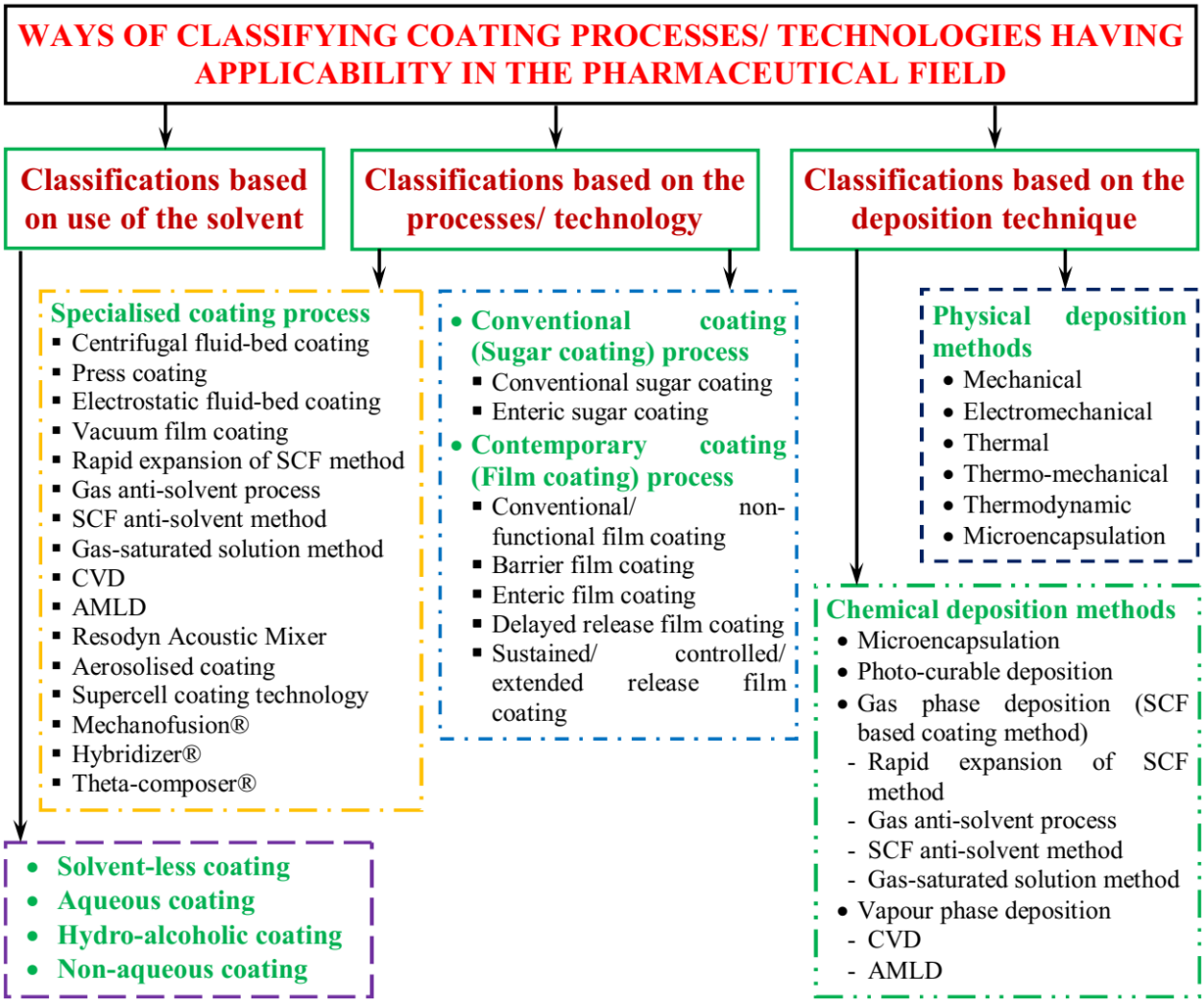

Figure 1: Classifications of coating process and methods [1, 3, 9]

However there may slight variations in process depending on nature of substrate, apparatus, processing conditions, and CM(s) used [4, 9]. Available WCMs are pan coating, fluidised bed coating, wet-chemistry based techniques (coacervation, urea/formaldehyde deposition, interfacial polymerisation, and many others) [1, 5-7, 9].

Wet method forms primarily a barrier-film between substrate core and surrounding environment [1, 4, 9]. The

purpose is to overcome incompatibilities; control/ extend/ sustain/ delay release [1, 4]; improve aesthetic property and/or stability/ shelf-life; and many more [4, 9]. Improvement of aesthetic property is by taste/ odour/ colour masking while improvement of stability is by protecting product from atmospheric oxygen, light, water vapour [1, 9].

WCMs have become less preferable due to reasons as follows [1, 4, 6, 7, 9]:

a. Can cause reduced stability [7],

b. May cause particle agglomeration [7],

c. Might leave residual organic solvents [1], and

d. As can cause environmental concerns [9]. This is arousing from unwanted waste streams and possible emissions of volatile organic solvents [1].

DRY COATING METHOD

The process of DCM directly attaches CM(s) onto relatively larger substrates [1, 3]. Herein the particles of CM(s) are brought into close contact with the substrates by the thermo-mechanical energy or by involvement of electrical or chemical interactions [3, 4]. By said interactions the deposition or coating is accomplished [3]. Basing of deposition process the DCMs can be classifying as follows [1]:

a. Mechanical deposition processes,

b. Thermo-mechanical deposition processes,

c. Electricals or electrostatic deposition processes,

d. Chemical deposition processes.

i. Gas-phase deposition processes. and

ii. Vapour-phase deposition processes.

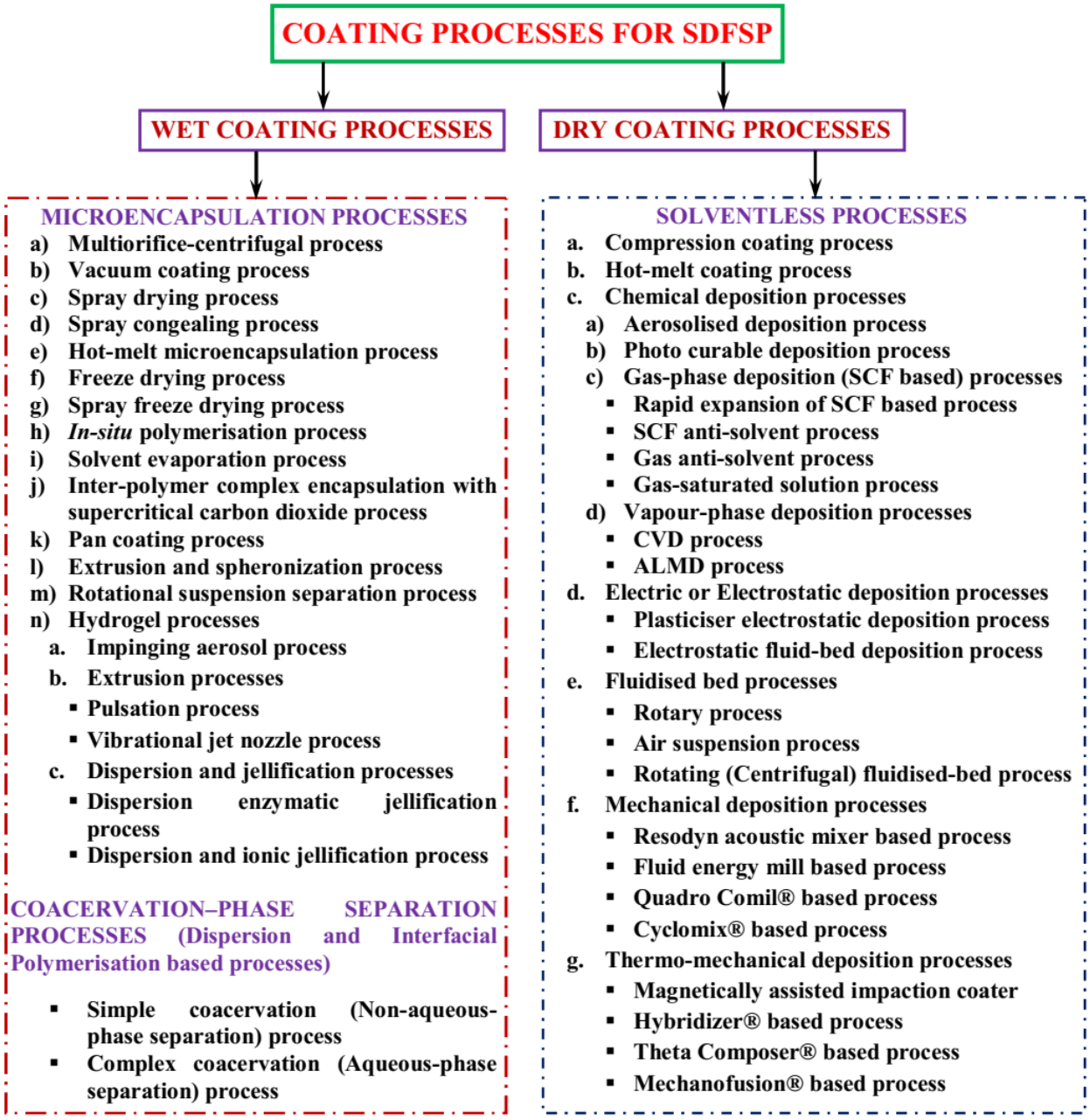

Figure 2: Classifications of wet and dry coating process/ methods [1, 3, 9].

Apart from forming a barrier-film, as in wet coating, the DCMs make improvement or modification of diverse surface properties [4, 10]. Amongst them properties of pharmaceutical importance are dispersibility, hydrophobic & hydrophilic properties, wettability, solubility, particle shape, flowability [4, 8, 10], sphericity, electrostatic, solid phase reactivity, electric, magnetic, sinterability, optical, colour, flavour, odour, taste, and many others [1, 3, 8].

Comparing WCMs the process does not require any binder(s), solvent(s), or even water [1, 3, 4]. Further the process does not produce any organic gas or aqueous or liquid waste streams [3, 4]. Thus the process is cost effective and environmentally benign and considered promising alternate to WCMs [1, 3, 4]. These methodologies steadfastly established themselves as viable methods to realise composite SoPs, from past few years [1, 3, 8].

Mechanical Deposition Processes

It is a simplest way of DCM wherein the CMs are applied directly onto substrates by compression/ compaction [3]. The process is suitable mostly for tablets [2]. It involves compaction of CM(s) around a preformed substrate cores using specialised equipment, designed specifically for this purpose [11].

Thermo-Mechanical Deposition Processes

These are the thermo-mechanical energy based processes [1, 2], Said processes of DCM for modifying particle surface attributes considered as a potentially cheaper, simpler, safer, faster, and environment-friendly approach comparing other DCMs and WCMs [2, 3].

In these processes use of thermal energy and/or impaction force or application of high shearing stress realises coating [3, 11]. Applied strong impaction/ mechanical force accompanying with generated heat is realising layering and embedding of CM particles onto the surface of substrates [3, 12, 13]. In some instances, deformation of the CM(s) along with their embedding onto the surface of substrates realises coating [1, 3]. Said deformation and/or embedding results increase in the contact area of CM(s) and substrate [1, 2]. Thus cause attraction between them to become even larger and realises much stronger coating [1, 3, 4]. By this the process produces engineered SoPs with complete different functionality and surface attributes [1, 4]. Resulted value-added composite SoPs have tailored properties, and confer them with 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].

Electrical or Electrostatic Deposition Processes

Electrostatic deposition process is a novel technology for coating of powders, tablets, capsules, and living cells [11, 14]. The involved technology results electrostatic deposition of charged particles of CM(s) onto charged substrate surfaces [3]. This in turn dramatically enhances uniformity of film coating [15, 16]. An optimised electrostatic deposition process can produce coated substrate with excellent coating uniformity, continuous film coat with smooth surfaces, and drug release significantly similar to that of substrate cores [14, 15]. Thus said process is an excellent alternate to WCMs [9].

Advantages: Electrostatic deposition process finds follow advantages [1, 15, 16]:

a) The method is efficient for applying electrically conductive CM(s) onto electrically conductive substrates [1].
b) The process makes accomplishable complete & uniform coating even of edges and corners [17].

Chemical Deposition Processes

Gas-phase deposition processes: Important gas-phase deposition methods are SCFs based technology/ methods and, and aerosol flow reactor based methods [1-3]. However, gas-phase deposition strategies are relatively expensive, complex, and challenging scale up also issues [1-3].

Vapour-phase deposition processes: Methods based on this processes are CVDs, physical vapour depositions, plasma-enhanced CVDs, and sputtering [1, 4]. Said vapour-phase strategies involve generation of vacuum and typically call for huge capital investments & large overhead costs, in the process equipment [3, 4].

SPECIALISED COATING METHODS/PROCESSES

Compression Coating

Compression coating technique is a DCM suits for tablet substrates [18, 19]. It is well suited for components that are incompatible with organic solvents and/or are thermal and moisture labile, but calls for functional or non-functional coating [11. 17]. This coating process results moisture-proof coated tablets [14], in addition can conveniently separate incompatible ingredients [17].

The process involves compaction of CM(s) around a preformed tablet core using specialised tableting equipment, designed specifically for this purpose [11]. The resultant products are characterised by either two component system (tablet-within-a-tablet) or three component systems (tablet-within-a-tablet-within-a-tablet) [17, 18].

As a simplest way the materials for coating are applied directly onto substrate cores by compression [17]. However, off-centre positioning of substrate cores, in this method, results non-uniform coating [17]. Said problem is overcome by Ozeki *et al* [19] with a design namely "one-step dry-coated tablet manufacturing method" [17, 19]. This method consists of set of centre punches (lower and upper centre punch), and a set of outer punches (lower and upper outer punch) that makes dry-coated tablets in single run. Therefore prefabrication of tablet cores is unnecessary [17, 19].

Aerosolised Coating

A DCM patented by Aston Particle Technologies that involves aerosolised principle for realising coating of particulate substrates [1, 2]. It is a one-step process [3]. Herein realisation of coating is based on co-aerosolization of particles under ambient temperature [2, 3]. In aerosolised state the clouds of individual particles results [1, 3]. In this state occurring is intimate contact of individual particle clouds [1, 2]. This facilitates attachment of CM particles (as fine particles) onto coarse substrate particle surfaces without causing unwanted physico-chemical modification to substrate particles [2, 3].

Involved co-aerosolization interaction of CM particles and substrate particle can confer designed functionalities and attributes to particles, even of highly sensitive active(s) [2, 3]. The state-of-the-art of this technology is, here coating happens through particle-particle interaction in aerosolised state as opposing to solid-solid interactions involved in other DCM involving high-thermal/ shear stresses [1, 2]. No exposure to solvent/ thermal and mechanical attrition during processing is the inherited significant advantage of this state-of-the-art technology over that of other DCM [1, 2]. By precise control of processing parameters the process can realise reproducible product performance using useable commercial grade excipients [2, 3].

Mechanism/ principle: The principle underlying aerosolization based DCM is penning from particle size difference between the CM particles and substrate [2, 3]. Underlying science of said technology calls for a high G-force chamber [1, 2]. Said chamber is having curtain of nitrogen gas [1]. The gas curtain fluidises the powder at chamber wall [3]. This is to disperse any agglomerates of CM particles and/or substrate particles [1, 2]. Principle/ mechanism of coating inherited by this technology can be presented in three primary steps/stages, that occur simultaneously [2, 3], refer Figure-3.

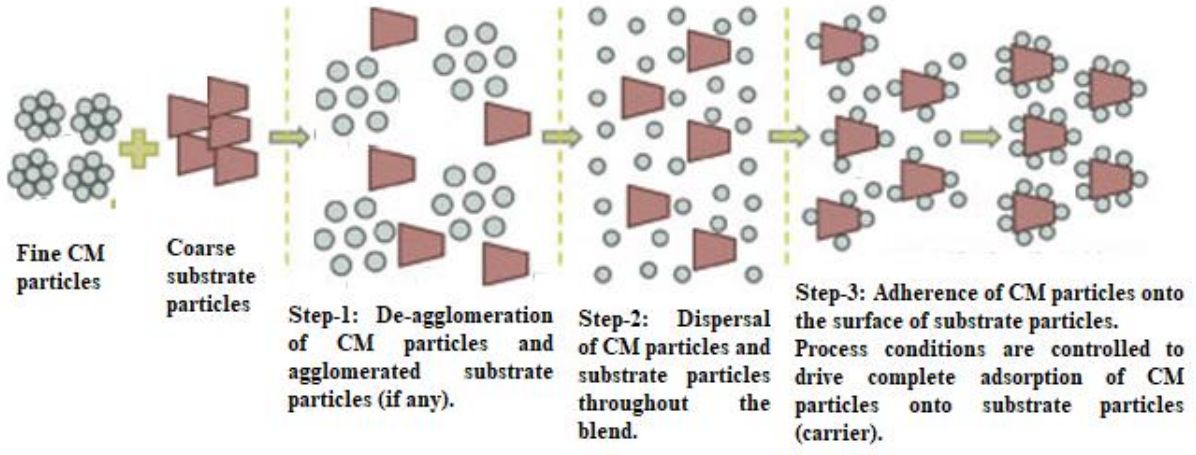

Figure 3: Mechanism and stages of aerosolised coating [1-3].

Stage-1: Dispersal of all agglomerates. Herein the application of high G-force disperses agglomerated particles of both substrates (as coarse particles) and CM (as fine particles) [1, 2]. High G-force is generated by revolving the processing chamber at high speed and counter balancing it by injection of nitrogen gas, into the processing chamber [2, 3].

Stage-2: Dispersal is of the CM particles around substrate particles [2, 3].

Stage-3: Attachment/ fixing/ adhesion of CM particles onto the surface substrate particle [3]. By this reaching a uniform spatial distribution is of CM particles [1, 2].

Electrostatic Coating

The process involves applying strong electrostatic charge onto the substrate for making their surface electrically conductive [16, 17]. This step is followed by spraying step [1, 3]. In spraying step charged substrate surfaces is sprayed with CM particles comprising oppositely charged conductive ions [1, 17]. Spraying of CM particles is done using electrostatic spray gun and is continued till adequate deposition of CM particles is achieved [14, 20]. Following CM particle deposition step there is curing step [2, 3]. Curing step of film formation step results coalesces together of the lodged CM particles to form continuous film of coating over substrate surfaces [14, 21].

Thus the coating assembly comprises of [14, 15]:

a. an electrically earthen container assembly/ coating pan [3],

b. charging gun [1], and

c. heating source [2].

Principle: The basic principle of electrostatic coating involves spraying the fine CM particles, in dry sate, onto electrically charged substrate surface [14, 16]. This is followed by curing is accomplished thru heating of substrate in an oven for until applied CM particle mixture fuses into film [11, 15]. Accordingly, the process consists of follow three steps [1, 14, 15]:

- creation of electrostatic field thus achieving substrate surface electrically charged and conductive [1],
- deposition of the coating particle [2], and
- curing and film formation [3].

Charging mechanisms for CM particles: Available are there two types of charging (spraying) units for spraying the dry CM particles, namely Corona charging and Tribocharging [3, 15, 17].

Plasticiser electrostatic coating

This DCM is featured with combined usage of heat, plasticiser, and electrostatic field [1, 3]. Involved basic concept is coating process can be promoting by spraying suitable of liquid plasticiser of suitable quantity [3, 14]. Suitable liquid plasticiser is one that which when added in adequate amount is capable of reducing glass transition temperature (*Tg*) of polymeric CM(s) and increasing electrical conductivity of substrate [15, 21, 22]. A separate electrostatic spray gun is also normally needed to apply liquid plasticiser(s) [14, 15]. Herein processing time shortens [1, 2]. This is due to postulate; incorporation of plasticiser promotes adhesion of CM particles, encourages film formation, and lowers curing temperature [15, 23].

The technique of said DCM comprises of follow steps [1, 3]:

- Placing of pre-heated solid substrates in the chamber of rotating coating pan [3]. Said pan must be electrically earthen [1].
- Spraying/ charging plasticiser and powdered CMs onto the solid substrate surface [1]. The exposed surfaces should be in moving state in coating pan [3].
- Separate electrostatic spray gun is used for charging/ spraying powdered CMs and liquid plasticiser [1].
- Charging is carried out for a preset time period [3].

Electrostatic fluid-bed coating

Fluidised-bed coating process assisted with electrostatic field is termed electrostatic fluid-bed coating [16, 20, 24]. Herein the powder blend comprising CM particles and substrate particles kept in fluidised-bed processor [1, 20]. The powders

are fluidised by passing dry air through porous base plate [3, 23]. Then the fluidised powder particles are subjected for electrostatic field [24]. Electrostatic field is applied ether by placing an electrode beneath surface of fluidising powder or thru charge transfer from pre-ionised fluidising air [1, 16]. Combined effect of fluidisation and repulsive effect of charged powder particles results upward motion of particles [22, 23]. This forms cloud of charged particles above the bed [24]. Generated cloud, herein, is much alike that obtainable from conventional electrostatic gun [22, 24]. Through the said cloud heated or unheated charged particles make several passes [16, 20]. Figure-4 presents the equipment and the process [3].

Advantages and limitations: Said process never dips particles into powder bed [16]. Further, in general, said process results thin coat to that results from conventional fluidised-bed coating processes [16, 20]. The process is unsuitable for elongated substrates or other objects passing vertically or axially across through powder-bed and through powder cloud [16]. As these gets deposited as layer [16, 22].

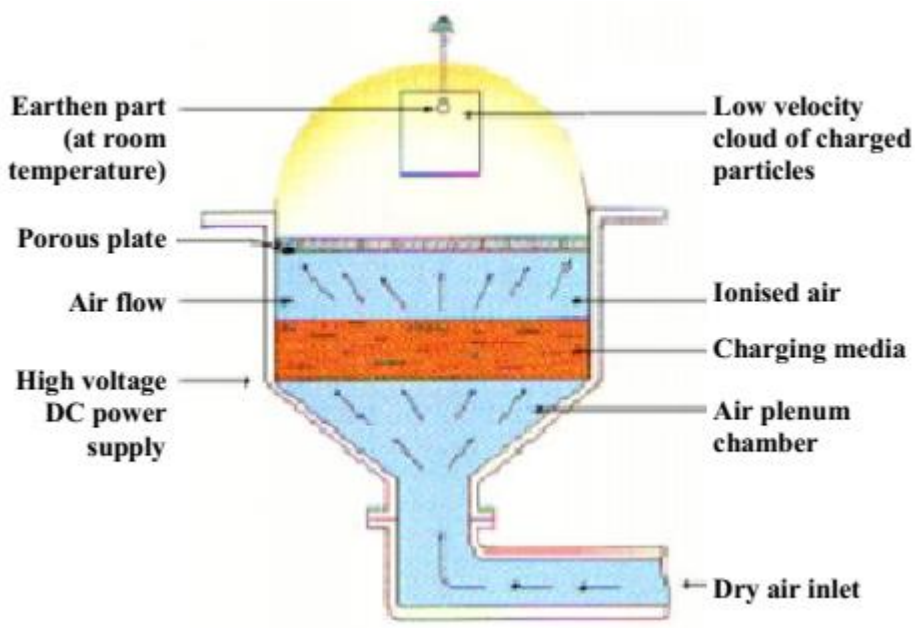

Figure 4: Electrostatic fluidised-bed coating process and equipment [1-3, 16]

Vacuum Film Coating

A WCM is suitable for tablet substrate and is effectively suits organic solvent based coating formulations. Design approach of process and equipment provides high degree of environment safety [14, 17]. It's a novel coating technique that uses specially designed baffled-jacketed-pan for heating and cooling that can be sealed to create vacuum [17]. Upon placing substrate in pan, displacement of the air is done by nitrogen until desired vacuum level is achieved [17]. Spraying of coating formulation is done using airless spraying nozzle [17]. Vacuum system removes vapours of evaporated solvents [17].

Supercell Coating Technology

It is a novel WCM, based on Wurster type fluid-bed processor, to realise tablet coating [11, 17]. The equipment is presented with Figure-5.

Reasoning of technology: Systems of conventional coating processes/ methods are unsuitable for coating of friable or extremely hygroscopic tablets and fail to consistently coat flat and other odd shaped tablets [11]. Further, loading tablets in large rotating pan along with venting for hot-air drying in the conventional coaters, and semi-perfect and inconsistent condition is the standard practice for tablet's coating following conventional tablet coating process/ method that often delivers non-homogenous product an outcome of inaccurate deposition of CM(s) [11, 17]. In addition, said issues outcomes imperfect and inconsistent results for instances grounding off of tablets, filling in of intagliation by CM, uneven thickness of coating on tablet's corners/ edges/ faces [11, 17]. These facts limit the use of conventional coating systems to conventional coatings and not to modified release coatings [11, 17]. As solutions to discussed issues SCT had been devised [17].

Technology basis: In general, Wurster type fluid-bed processors find applicability to coat tablets [11]. But associated attrition generally restricts its usability to all tablets excluding hardest one [11, 17]. However upon embedding these processors with unique air distribution plate design of SCT, the tablets move very rapidly and predictably across spray zone, thus receives small amount of coating per pass, and thereby achieve coating accuracy of higher degree [11, 17]. The substrates receive coating spray from same direction to that of drying gas/air. This makes the process more efficient [11, 17].

Process features: SCT based process achieves very fast drying, results sufficiently high deposition accuracy suiting to layer active onto substrates, and realises application of uniform layer of taste masking barrier coating followed by modified release coatings, consecutively, within a single continuous batch [11, 17]. The process time of SCT process is short, that ranges from seconds to minutes as opposed to hours, thus is gentler for tablets [11]. Said process accurately lodges controlled amount of CM(s) on tablet surface; even on highly oblong, flat, friable or extremely hygroscopic one [11, 17].

Twinning problem inherited to this process can be prevented by slow running of the process [11]. Said process enables coating of tablets having weight ranging from 30 to 120 grams and have linearly scale-up to production batch capacities [11].

Unique and salient features of SCT: Unique and salient features of SCT are as follows [11, 17].

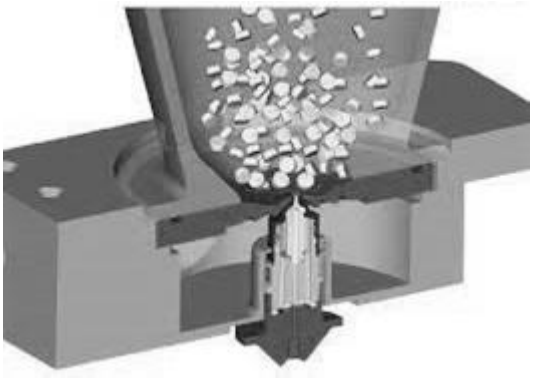

Figure 5: Figure of equipment designed with SCT [11, 17]

a. Enhancing technology [11],

b. High accuracy of coating (demonstrated RSD is less than 1%) [17],

c. Short processing time [11],

d. Continuous coating [17],

e. Suitable for hygroscopic and moisture sensitive materials as is a low humidity process [11, 17],

f. Suitable for friable tablets [17],

g. Multi-layer coating [11],

h. Flexible modular design [17],

i. Production capacity of six cells coater is 200Ktph for tablets weighing 120 mg [11, 17],

j. Minimum R&D batch size ~30 grams [17],

k. No scale-up to parameters [11], and

l. Difficult-to-coat shapes [17].

Photo Curable Coating

Photo curable coating or photo-curing had find applicability for coating of pharmaceuticals [1-3]. It's a chemical approach proposed to coat substrates rapidly at/or below room temperature with an extremely rapid rate [1, 3]. The process involves rapid conversion of specifically formulated liquid, solventless compositions, into solid films by way of photo-curing [1, 6]. The curing step involves irradiation of product with ultraviolet or visible light [3, 7]. Comparing visible light, ultraviolet light is more energetic therefore is more efficient in rupturing chemical bonds [1, 7]. Thus in most cases, curing reactions are performing with ultraviolet light [1, 3]. Contrary the use of visible light bears many attractive features [3, 7]. These include safety and ease of handling, thus receiving attentions [6, 7]. The curing is mediated by free-radical mechanism and/or ionic mechanism [3]. Ionic one is anionic or cationic; the cationic mediation is mostly [1, 3].

Mechanisms: Radiant energy of the light initiates polymerisation reaction [1]. Said reaction mediates through generation of free radical through either anionic or cationic mechanism [3]. Involved mechanism depends on the functional groups of monomers or pre-polymers and initiators or catalyst used [3]. Generated free radical results chemical reaction of functionalised liquid monomers or pre-polymers [2]. Result is leading to polymerisation of liquid monomers or pre-polymers, thus their transition into solid film [1, 3].

Presence of moisture & oxygen slows down and/or reduces the extent of curing in some acrylate functionalised silicone systems [1]. Said complication is out coming from the quenching of excited states and the scavenging of free radicals from initiator and growing polymer network [3]. Said complication is overcoming usually by purging the photo-curable systems with nitrogen [1, 3].

Said system generally consists of four major components [1, 3], as follow:

a) Pre-polymers or monomers [1].

b) Photo initiators or catalysts [3].

c) Ultraviolet/visible light source for curing [1].

d) Pore-forming agents or pore-formers [3].

Pre-polymer or monomer: These undergoes photochemical polymerisation process resulting film coat [2]. These available in liquid state thus can be easily spread on solid substrates [3]. Specially functionalised liquid pre-polymers or monomers having stability to ultraviolet light exposure during the entire coating process are suitable [1, 3]. However, these should be polymerising during ultraviolet light curing process while keeping up acceptable film firmness, integrity, and stability [2, 3].

Photo-initiators or catalysts: These initiate the reaction that outcomes formation of solid coating [1, 3]. These upon absorption of radiation energy generate a free radical pair that gets added to the double bounds of the unsaturated reaction partners [1, 3]. The photo-initiators are either mono-molecular type or bi-molecular combinations [2]. They cause photochemical generation of a radical pair involving mono-molecular reaction or bi-molecular reaction, respectively [1, 3]. Comparing bi-molecular combinations the mono-molecular photo-initiators are more effective [1, 3].

Ultraviolet/Vis light source: Example is 80 W/cm medium-pressure mercury lamps [1, 3].

Pore-formers: Silicon polymer upon curing with ultraviolet light results a film that is complete and almost perfect barrier for drug diffusion [1, 3]. Herein drug release depends on presence of defects and/or pores or weak points in coating [1, 3]. Pore-formers are incorporated in formulation for conferring porosity to the resulted polymeric film [1]. This confers the coatings with functional and non-functional attributes [1, 3].

By changing pore-formers, proper choice of material and desired number of coating layers with wished thickness reasonable is having functional and non-functional attributes like delayed, sustained, immediate release profile [1, 3]. However, for a variety of pore-formers the efficiency & uniformity of coating dependent on follow factors [1].

a) Ratio of the liquid pre-polymer volume to solid pore-former weight [1].

b) Pore-former's particle size [1].

c) Concentration is of the photo-initiator [1].

d) Light intensity [1].

e) Exposure time is of light [1].

Amongst these, ratio of liquid pre-polymer volume to solid pore-formers weight is most significant parameter [1, 3].

Mechanofusion®

Of available DCMs, the Mechanofusion® has arguably grabbed most attention in the pharmaceutical field for coating of the particulate substrates [25-27]. The methodology brings forth a chemical-mechanical-reaction among two or

more powder materials [10, 28]. Thus produce composite material having differing properties [10, 28, 29].

Involved methodology, in Mechanofusion®, merges CM particles on substrate particles by inputting high mechanical energy through mechano-chemical reaction [1, 3, 4, 10, 30]. Said reaction takes place in contact area of the CM particles and substrate particles [1, 3, 4]. During processing the material comprises of CM particles and substrate particles gets subjected to compression and simultaneous stress of intense shear, in Mechanofusion® reactor [1, 3]. Thus resulting controlled particle shape [16, 25].

Available devices: Device for Mechanofusion® is available in two versions [3]. Its early version is designed with a four bladed propeller processor, refer Figure-6(a); while later one is lab-scale version with rounded processor; refer Figure-6(b) [1, 3]. The earlier design comprises higher void spaces thus allows higher powder load [1]. The coating performance of both design modules is significantly equivalent [3].

The design approach of early version, refer Figure-6(a), comprises of follow components [1, 3]:

a. an outer processing vessel is rotating,

b. an inner piece is a round stationary processor,

c. a scraper is stationary,

d. a powder-inlet channel, and

e. a powder-outlet channel.

The outer vessel is driven by a motor [3]. It rotates at a controlled speed set between 200 – 10,000 rpm [1, 3]. The round stationary processor, the inner piece, acts as press head or arm head [3]. Stationary scraper is for overcoming any caking and agglomeration [1, 3]. The device can be jacketed [3]. Jacketing is for cooling or heating of the processing chamber wall [1]. This is if process-induced heat is a concern [3].

The later version simplified design of early version with some deviations [3]. One deviation is, herein the scraper and the processor is replaced by an exchangeable processor module [1, 3]; refer Figure-6(b). The second deviation is the vessel is stationary while the processor rotates at a speed up to 6000 rpm [1, 3].

Processing: Processing of coating involve placing of an aliquot quantity of CM particles and substrate particles into the processing vessel [1, 16, 25]. When device is turned ON, the powders are pushed outwardly towards vessel wall [10, 27-29]. During processing the gap between processing vessel and processing module is monitored/ controlled [1, 3].

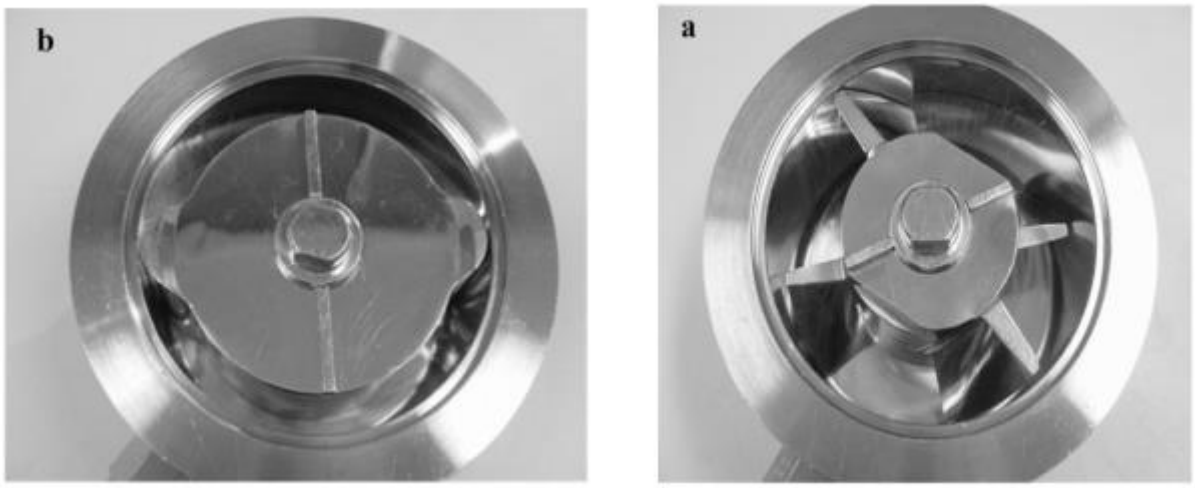

Figure 6: Mechanofusion® with the exchangeable processor [3, 16]

Herein during processing, while powder particles are passing through the gap they are subjecting for intense forces of compression and shearing [1, 27, 28]. Intense shearing force may chemically & physically alter properties of materials which are associated with size reduction to some extent [3, 10, 29]. Joint action of compression & shearing forces acting on the powder particles build-up localised temperature [1, 3, 27]. The generated heat is sufficient to fuse the CM particles onto the surface of substrate particles [10, 28, 29].

The size of gap between the processing vessel and processing module plays crucial role [27, 28]. This controls thickness of the coating [10, 29]. Also the gap between the scraper and the processing vessel wall requires controlling, in earlier design only [16, 25].

Hybridizer®

The novelty in design of Hybridizer® machine suits it for particulate substrate coating following DCM [25, 26]. The machine is batch operated one [1, 3, 16]. It embeds/ coats the CM particles onto substrate particles within very short time span of 1-5 minutes [3, 16]. Design approach of Hybridizer® machine [16, 25, 26], refer Figure-7, is similar to that of Mechanofusion® that basically comprises of components as follows [3]:

a) a processing vessel with six bladed rotor assembly,

b) a stator,

c) a re-circulation unit/ device,

d) an unit for powder-inlet, and

e) an unit for powder-outlet..

The re-circulation unit/ device are for powder re-circulation during processing [2]. It is made up of ceramic or stainless steel and moves the powder particles continuously in & out of the processing chamber and against the rotor blades [16]. The processing vessel is jacketed [2]. Jacketing is for heating/ cooling the vessel [1]. This is to control local temperature [1, 3].

Processing: The processing of coating with Hybridizer® machine is basically of two steps [1, 3]. First is pre-mixing step that involves feeding of CM particles and substrate particles into a high shear mixer, like Ordered Mixture dizer [1, 3]. Herein CM particles and substrate particles are mixed and dispersed to have an ordered mix [1, 3].

Second is hybridization step [1, 3]. Herein the ordered powder mixture of CM particles and substrate particles placed in processing portion of machine [1, 3]. In this stage powder blend subjected to high shear impaction and dispersion [1, 3].

As the machine is turned ON, the rotating blade assembly rotates at very high speed set at any speed up to 16,000 rpm [1, 3]. High rotational speed of rotating blade assembly disperses CM particles and substrate particles and impart them thermo-mechanical energy [1, 16]. Imparted mechanical energy induces the powder particles to undergo numerous collisions [16]. In the other hand imparted high impaction forces builds-up temperature [1]. Said collisions result breaking-up of fine agglomerates and embedding/ filming of the CM particles onto the surface of substrate particles [1, 3]. Said embedding/ filming realises coating whilst built-up temperature aids embedding/ filming [1, 16].

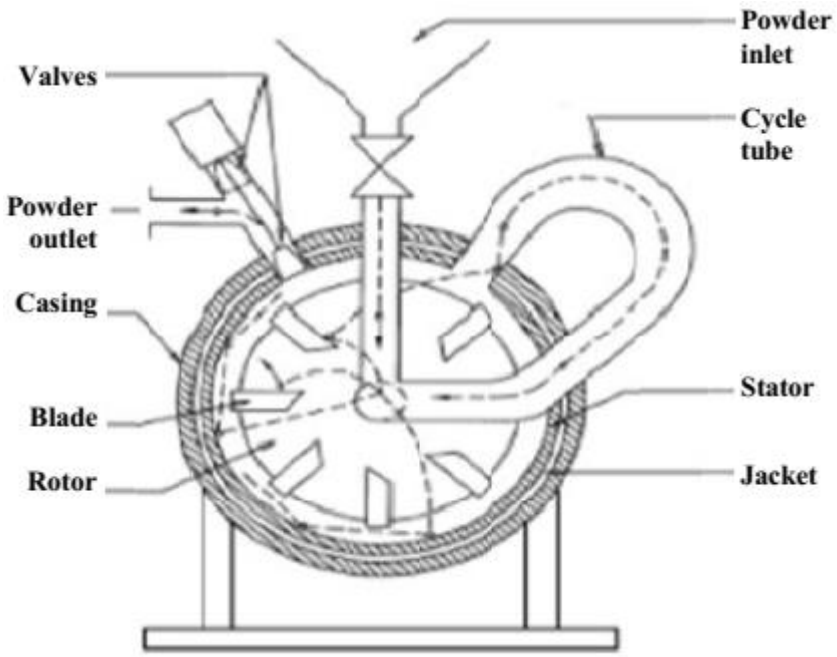

Figure 7: Figure presenting design of Hybridizer® [3, 16]

Theta-composer®

Theta-composer®, refer Figure-8 for its design, is novel equipment suits for particulate substrate coating following DCM [25]. The basic design, refer Figure-8(d), of it comprises of follow components [1, 3]:

i. an outer elliptical-vessel, and

ii. a inner elliptical rotor.

Device and principle: The inner rotor rotate very fast inside the slowly rotating outer vessel and rotates in opposite direction to that of outer vessel, refer Figure-8(a), 8(b), 8(c) & 8(d) [16, 25, 26]. The rotational speed of outer vessel lies between 30-40 rpm while that of inner rotor between 900-1200 rpm [3]. Outer vessel rotates clockwise whilst inner rotor rotates anticlockwise [16]. Said peculiar rotation of vessel and rotor result cyclic changes in clearance width from larger-to-smallest-to-larger, refer Figure-8(a), 8(b) & 8(c) [1, 3]. Said cycling of clearance width is resulting cycling of lifting-mixing-impaction-lifting states [16]. As a result during processing powder particles are lifted up within the device with mixing in one stage [26], refer Figure-8(c). Then these are subjected for strong compaction forces & shear stress in other stage [1, 3], refer Figure-8(b), Coating is realised when powders pass thru a very narrow clearance, a stage while the clearance is narrowest between the vessel wall and the rotor [1, 3], refer Figure-8(b). Concurrent applications of compaction force and strong shear stress consequences firm coating & formation of composite particles [1, 3].

Operation and processing: During processing the powder mix comprising CM particles and substrate particles are fed into the vessel [1, 3]. Then the device is turned ON. Due to discussed peculiar rotation of inner rotor and outer vessel, there occur cyclic changes in clearance width [1, 3, 16]. Thus in coating stage, while clearance is narrowest, the powder blend is forced through said narrowest clearance [1, 3, 16], refer Figure-8(b).

In this phase CM particles and substrate particles are subjected for shearing and compressive stresses [16, 25]; refer Figure-8(b). The inner rotor and vessel continues to move [3]. Thus the clearance gradually becomes wider and reaches to widest level [1, 3], refer Figure-8(c). The phase while the clearance is maximum, there occurs bulk mixing of CM particles and substrate particles [16, 25]; refer Figure-8(c).

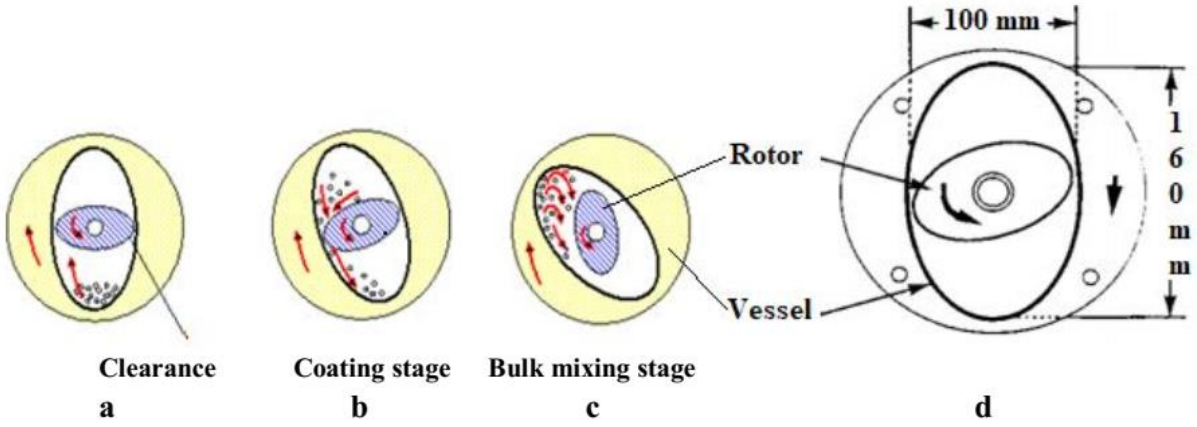

Figure 8: Figure presenting design of Theta-composer®, and stages of processing [3, 16]

During the initial phase of processing through blending CM particles and substrate particles is to be done [3, 16]. This is performed with a condition comprising of vessel speed at low and rotor speed at high [3, 25]. Then the vessel speed is gradually increased [3, 16]. During this phase, simultaneous application of compression forces and strong shearing accelerates precise blending & composite fabrication [3, 25].

The critical revolution speed (N_c) of the particles can found from the inner diameter of the vessel (D) and acceleration due to gravity (g) using mathematical relation [1, 3, 31], as follows.

$$N_c = \frac{60}{\pi}\sqrt{\frac{g}{2D}}$$

It is pertinent to inform that speed of outer vessel must be much smaller than the N_c [31]. Otherwise powders particles will remain adhere to vessel wall [1, 3]. This is due to the higher centrifugal force [1, 3, 25].

Resodyn Acoustic Mixer

It is a sophisticated bench top mixer finds suitability for particulate substrate coating following DCM [32, 33]. Sophistication herein is, the mixing operation is based on resonant acoustic technology [32-36]. Employment of said technology creates a low frequency, high intensity shear field [34, 35]. This is resulting intense vibration that helps in thorough & uniform blending of powdery material within very short time span [35. 36]. Primary parameter herein promoting mixing is acceleration [32, 33].

Principle: Use of acoustic energy in the form of intense vibrations is the state-of-art of this technology for realising coating of particulate substrates [32, 33]. Said vibration creates high shearing zones within mixing vessel of the device [33, 34], refer Figure-9. Said state along with imparted high energy creates a virtually fluidised state for powder particles, wherein the particles collide with each other [34-36].

Processing: During processing the powder blend of CM and substrate is fed into the vessel of the device [32, 33]. As the device is turned ON a virtually fluidised state is reached [34]. In said fluidisation state submicron sized CM particles collide with substrate particles [34, 35]. Intense vibration of process disperses CM particles and fixes and/or adhere them to surface of substrate particles [35, 36]. Thus realises creation of uniform coating layer [32, 34]. Thereby dry-coated substrate particles are resulted [32, 35].

The frequency of vibration is generally between 50-65 Hz [32, 33]. External digital control system is to monitor & control intensity of vibration & processing time [33, 35].

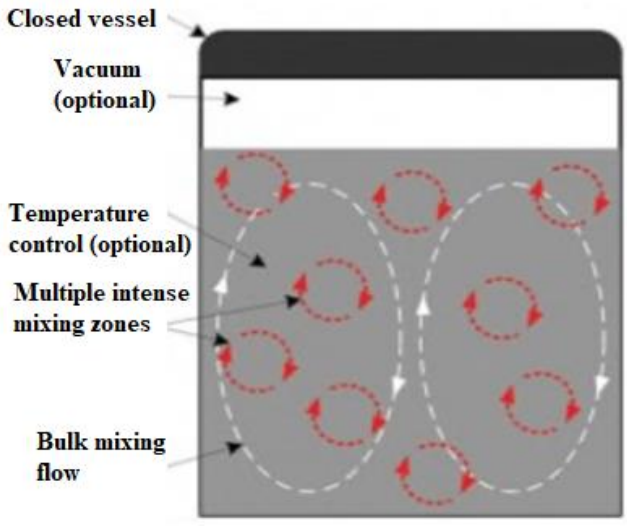

Figure 9: Figure device design and operation of Resodyn Acoustic Mixer [16, 32]

Magnetically Assisted Impaction Coater

The design and operational mechanism of MAIC makes it amenable for coating of particulate substrates following DCM [1, 3]. This coater results thermo-mechanical coating of substrate particles using mechanical impaction by oscillating magnetic beads [1, 16]. Thus these coaters are warranted for handling materials calling soft coating processes/ methods [1, 16]. Involved soft coating technology makes the coater suitable for thermolabile, relatively soft, and easily deformable product [11, 17, 25]. Further the device realises coating with a minimal deformation of particle shape & size, and degradation of components [11, 17].

In these devices, magnetic beads are placed in processing vessel along with powder of CM and substrate [1, 3]. Oscillating magnetic field is generated surrounding the processing vessel to agitate magnetic particles [1, 3]. Agitating magnetic particles causes collisions between magnetic particles & CM/ substrate particles, CM particles & substrate particles, and CM/ substrate particles & vessel wall [1, 3]. Thereby peening of CM particles onto substrate surface realises coating [1, 16, 25].

A batch process has ability to coat substrates as fine as 0.25 microns [3]. For continuous operation the device has mechanism to separate coated substrates from magnetic elements [1]. Some instances warrant coating of the magnetic particles, appropriately, to overcome shedding of contaminants [1, 3]. Major concern of this coater is its poor scale-up potentiality [2].

Vapour Phase Coating

The methodology is up-roused as a novel DCM for SDFSP [1, 3, 37, 38]. Herein vapour phase deposition is the under lined principle for realising coating, in most cases of powders [3, 39, 40]. The methodology enables synthesising polymeric coating films for having composite products having coating uniformity to a satisfactory level [3, 39, 41]. Resulted SDFSP composite is of orchestrated topography, surface, and functionalities [41].

Principle basis: The coating is realised herein by process of 'electro-dispersion' [16]. Electro-dispersion process involves dispersal of a powder or liquid through application of electrostatic field [16]. The process of electro-dispersion involves dispersal of dispersed phase and maintenance of dynamic equilibrium [3]. In dispersal phase intense electric field is used to disperse a part of static-bed of substrate into a stable cloud of fast moving particles [2, 3]. In maintenance phase a dynamic equilibrium is maintained between the static phase and the dispersed phase [1, 16]. Herein this stage electro-deposition effected [1, 3].

The substrate herein is either a powder or a liquid [1]. The process enables in producing uniform, durable, and slow dissolving coatings [2, 3]. Realised coatings are of controlled thickness and on individual substrate level [1, 3]. The cloud densities of dispersed phase particles are dependent on diverse factors [2, 3]. This includes field strength and nature of substrates [3, 16]. In addition to realise dispersion the applied electric field makes proviso for two beneficial effects [1, 3]. One is it ensures that only uncoated particles are coated [16]. Other is prevents agglomeration of coated substrates, as they posses similar charges thus repel each other [2, 3].

Processing: Herein coating is realised by generating a vapour of desired CM and allowing generated vapour to permeate the dispersed particles [16]. Basing on synthesis/generation mechanisms follow are major methods having applicability to SDFSP [1, 16].

a. CVD [1].

i. Plasma enhanced CVD.

ii. Initiated CVD.

b. AMLD [41, 42].

Both CVD and AMLD involve vapour phase deposition reactions [40, 41]. Involved reaction is similar in both of the process since these utilises gaseous reagents for realising a film coat [42, 43]. CVD is a single step process while AMLD is a two step one [43, 44].

AMLD: Herein there is split-up of reactions into two surfaces half, thus coating involves two step reactions [16, 41], refer Figure-10. This intends, substrate surface is exposed to one reagent only at a time thus is cyclically reacting with each reagent [16, 41, 42]. By splitting the reaction into surfaces half, the substrate surface is reacting cyclically with each reagent, until complete substrate surface is gets coated by a new atomic/ molecular-layer [16, 42].

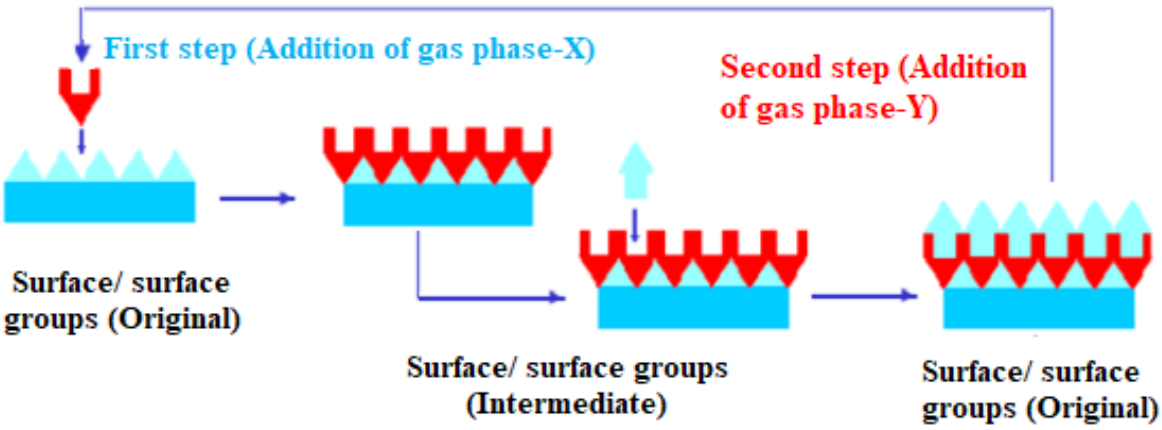

Figure 10: Figure is schematic presentation on steps of AMLD process [3, 16].

For elucidation as the process starts, suppose reactant X is reacting with surface functional groups present on substrate surface [3, 16]. Now reactant X replaces the original surface functional groups [3, 16]. Thus new (intermediate) surface functional groups are in place of original one [3, 16]. When this transformed (intermediate) surface exposes to reactant Y, the reactant Y reacts with new/intermediate functional groups [3, 16]. As a result the new/ intermediate surface

functional groups are transformed to original one [3, 16]. Means the intermediate surface gets transformed into original surface having original surface functional groups [3]. By this way a monolayer of film-coat results with one complete cycle of X and Y [3]. At this stage the reaction gets stopped as reaction is self-limiting [16, 42]. However the process can be repeating cyclically until wished film thickness is realised [16, 41].

The AMLD process realises a monolayer-film with a film thickness of an order of 1 angstrom (0.1 nano-meters) [16, 42]. In other words the process can attain effective thin coating having thickness of few atomic layers only [42]. Presently the process is relatively expensive one that often necessitating toxic precursors [42].

Rotating (Centrifugal) Fluidised-Bed Coating

It is a novel WCM based on rotating fluidisation principle finds applicability in instances requiring soft coatings [16]. The coater is suitable for particulate substrates [16]. Herein developed coater comprises of follow components [16], refer Figure-11:

a. a hollow cylindrical chamber [16],

b. an air-distributor assembly [16],

c. a concentric cylindrical metal filter [16],

d. a binary-fluid spray nozzle [16], and

e. a pulse-jet air-nozzle [16].

The hollow cylindrical chamber is stationary and horizontally positioned [16]. Air-distributor assembly is porous cylinder placed horizontally inside the chamber [16]. Said air-distributor rotates along its horizontal axis within the chamber [16]. The concentric cylindrical metal filter is a sintered mesh of stainless steel [16]. Said metal filter is stationary [16]. It is placed concentrically inside the air-distributor assembly [16]. This for retaining any elutriated fine powdery particles [16]. The metal filter is mounted with binary-fluid spray nozzle for spraying CM formulation onto the substrate bed [16]. Inside the metal filter there a pulse-jet air-nozzle [16]. This is to clean metal filter surface, a provision for preventing clogging of metal filter [16]. An air-knocker is there as outside installation of chamber [16]. This is for preventing adhesion of powders onto front cover chamber and mesh of air-distributor chamber [16]. The substrate bed is fluidised by the radial flow of gas through the porous wall of the distributor [16].

Processing: The mixture of CM particles and substrate particles are fed inside air-distributor [16]. High rotational speed of air-distributor rotates the substrate bed [16]. The resultant centrifugal force forces powders outwardly from distributor towards the chamber wall [16]. As air flows radially inwards through the air-distributor this pushes outwardly moving powders inward [16]. Radial airflow imparts powder buoyancy and drag force [16]. Resultant force acting on powders is balance of centrifugal force and radial airflow [16]. By this way the rotating substrate bed is fluidised by radial flow of air [16].

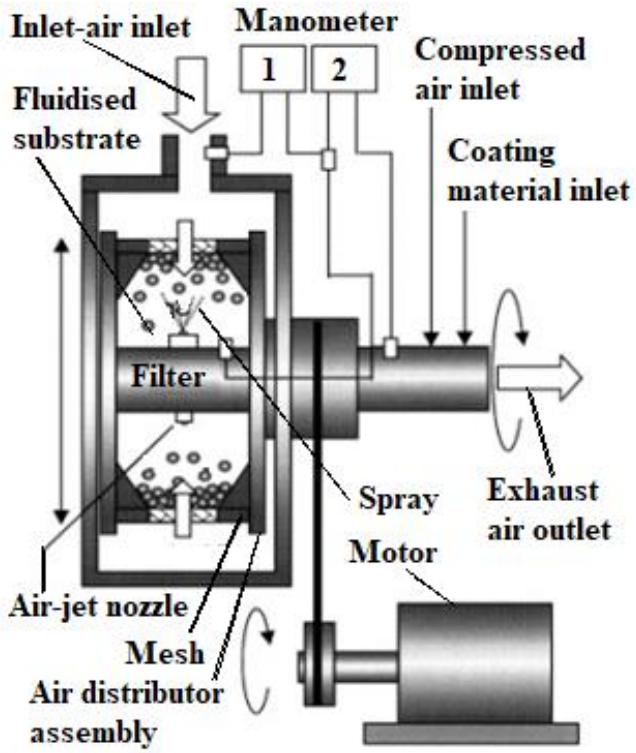

Figure 11: Figure of Rotating (Centrifugal) fluidised-bed coater [16]

Moreover, high rotating speed calls for higher amount of air flow to fluidise the particles [16]. Further higher amount of air flow is needed for having motion of bubbles, when operating substrate bed above minimum fluidisation conditions [16].

Due to high rotational speed generating is very high centrifugal force and shear force, within the fluidised air–powder system [16]. This is leading to the break-up of the agglomerates of the CM particles [16]. The process results strong mixing thus is achieving good coating [16]. Further the process has ability of being operating in a continuous mode [16].

Gas Phase Coating

These are SCF based DCMs suiting coating of particulate substrate [3]. SCFs possess several beneficent attributes of

both liquids & gases [3, 44-46]. An attribute of importance in coating is near the critical point of SCF a minor change in temperature and/or pressure causes significant change in their density & rapid change in solvent power of them [44-46]. Said peculiar attributes of SCFs are the basis for using the as carrier for CM formulation while realising coating [3, 46]. Even though the involved concept in said coating method is designating the process as WCM, but it is considered as DCM, by most of researchers [1, 3].

Materials most widely used as SCF are Nitrous oxide (N_2O), Supercritical carbon dioxide (CO_2), and Alkanes (C_2 - C_4) [1, 3, 16]. For the pharmaceutical purposes, CO_2 is considered as an ideal SCF, due to follow assorted advantages [16].

- Low critical pressure (72 bar) and temperature (31.1 °C) values [1, 16],
- Cost-effective [1, 16],
- Readily available [16],
- Highly pure [1, 16],
- Nontoxic [1], and
- Non-flammable [16].

Process basis: Formulation of CM in prepared with SCF as solvent/ medium [3, 44]. Near the critical point of SCF minor changes in storage pressure and/or temperature is made for having rapid change in solvent power of SCF thereby realising precipitation of CM(s) [1, 45]. This approach is of limited applicability, as realising minor change in pressure and/or temperature is impracticable [1, 3]. Prominent approach is the rapid expansion of SCF vis-à-vis rapid super saturation [1, 3]. Rapid expansion of SCF outcomes the rapid change in density & solvent power of SCF [2, 3]. This transforms into rapid crystallisation rates that result in precipitation of CM(s) [1, 16]. Alternate approach is rapid reduction in solvent power of SCF for CM(s) using an inert gas [1, 3]. This approach realises coating without any substantial change in pressure/ temperature [3, 16]. The process involves interacting SCF-CM solution with an inert gas [1, 16]. Rapid mixing of SCF with inert gas decreases its solvent power [2, 3]. Thus is causing CM(s) to precipitate [1, 3]. Herein requisite is CM should be insoluble in the inert gas like nitrogen or helium [3, 16].

SCF based particle coating methods that find wider applicability in pharmaceutical field are follows [1, 16]:

a. Rapid expansion of SCF method [47].
b. SCF anti-solvent method [47].
c. Gas anti-solvent process [48].
d. Gas-saturated solution method [47, 49, 50].

Rapid expansion of SCF method

Rapid expansion of the SCF vis-à-vis rapid super saturation is the underlying principle for realising particle coating [3, 44-47].

Requirement and imitations: Most important requirement is substrate to be insoluble is the SCF [1, 16]. Poor solubility of most CM in SCFs is the major limitation [3, 16]. Processing calls for high-pressure processing equipments necessitating necessary investment [1, 16]. For realising successful coating, ideally SCF should dissolve CM only while leaving substrate completely un-dissolved [3, 16].

Processing: Processing involved solubilising the CM(s) in SCF under high pressure; in a vessel [1, 16]. Then is realising dispersion of active(s), by dispersing the active(s) in CM-SCF solution [3, 16]. The resultant dispersion is maintained at high pressure [3, 16]. This then released thru narrow nozzle, at atmospheric pressure [1, 3]. As a result the SCF expands rapidly, thereby its solvent power reduces [1, 16]. Sudden pressure drop causes desolvation of CM(s) [3]. Thus CM gets precipitated onto dispersed substrate particles in medium of SCF [1, 3]. Thereby CM forms a layer of coat on the dispersed substrate particles [3, 16].

CMs finds applicability in said process is fatty alcohols, fatty acids, and lipids [1]. Amongst these preferred one is lipids like mono-, di-, & tri-glycerides of fatty acids [3]. However combination of fatty alcohols/ acids with other lipids can be used [1, 16].

Most of CMs, including polymers, possesses very low solubility in SCFs (<1 % w/w) [1, 3]. Exception is polymers having low cohesive force densities & polymer fractions having low molecular weight [3, 16]. In such instances co-solvents (methanol and/or acetone) are used [2, 3]. Said co-solvents increase the solubility of CM(s) in SCF(s) [1, 16]. Further, in some cases non-solvents can be using [1, 3]. Herein non-solvent increases CM's solubility in SCF while these don't dissolve CM(s) at atmospheric pressure [3, 16].

SCF anti-solvent method

The process designed for handling CMs and substrate which are soluble in volatile organic solvent whilst are insoluble in SCF and solution of SCF & organic solvent [2, 3]. The SCF be miscible with organic solvent [1, 3]. In literatures its synonym is '*Aerosol solvent extraction systems*' [2, 3]. '*Solution-enhanced dispersion by supercritical fluids*' is its reported variation [3, 46, 47].

Process basis: Herein SCF is used as an anti-solvent to process the SCF-insoluble CMs and substrates, from a pre-mixed solution of CM(s) and substrate in organic solvent, by pouring SCF into said organic solution [1, 16]. Addition of SCF causes increase in its concentration in organic solution and expansion of resulted solution [3, 16]. CM(s) and substrates start precipitating as the resulted solution becomes supersaturated with CM(s) and substrates [1, 3].

Processing: Processing involves continuous adding the solution of CM and substrate in volatile organic solvent to continuous stream of SCF (anti-solvent for CM and substrate) [1, 16]. Organic solution rapidly mixes with SCF and dissolves in it [1, 3]. Thus forms homogeneous fluid mixture at high-pressure [3, 16]. Since CM and substrate are considerably insoluble in SCF, and SCF and organic solvent are miscible, thus causing is precipitation of CM and substrate in high pressure vessel [1, 16]. The mixture of SCF-organic solvent is passed thru a micro-filter into a low pressure vessel [3, 16]. Herein said mixture gets expanded thus separation of SCF from volatile organic solvent [1, 3].

The process is suits for thermolabile material and materials having little solubility in SCF of choice [2, 3]. Said method able to coat submicron particles but fails to coat water soluble materials [1, 16]. A batch process is fails to handle large quantities of material [1, 3].

Gas anti-solvent process

Herein rapid reduction in SCF's solvent power is resulted by its interaction with an inert gas, without any substantial changes in pressure [1, 3]. The process basis is interacting solution of CM and substrate in SCF with an inert gas that is non-solvent for CM and substrate [3, 48]. The inert gas may be kept at pressure par to that of said solution [1, 16]. Rapid mixing is of inert gas with SCF solution decreases solvent power of SCF and causes CM and substrate to precipitate [1, 3]. Said precipitation realises coating of CM on the substrate surface

[3, 16]. Design of said process is for handling CM and substrate that are insoluble in inert gas but soluble in SCF [1, 16].

During processing solution of CM and substrate in SCF is maintained at high pressure, in a vessel [3, 16]. Then the inert anti-solvent gas is poured into the vessel [1, 3]. Result is rapid mixing is of inert gas with SCF [16]. This causes extraction of SCF from the solution realising super saturation to an extent that precipitation of CM and substrate occurs [1, 16].

Gas-saturated solution method

Herein mixing of substrate particles and polymeric CM(s) in SCF is performed, at high pressure [3. 47, 49]. SCF penetrates polymeric CM causing swelling of CM [49, 50]. Then resultant mix is heated above the *Tg* of polymeric CM to liquefy polymer [3, 16]. Thereafter pressure is released [1, 3]. Upon releasing pressure the CM gets deposited onto substrate particles [2, 3]. Here in this process it's not a requirement that the substrate particles and the CM(s) soluble in SCF of choice [1, 16].

CONCLUSION

Surface and surface attributes of SDFSP can be modifying by either WCM or DCM. Most of WCMs and DCMs realising surface modification alter innate properties of the SDFSP either physically or chemically. In most instances, the WCMs are suitable for the CM that are solid or liquid, where as DCMs are suitable for solid CMs. The WCMs are unsuitable for fine and ultrafine particles; as they exhibit cohesivity of highest degree. Residual organic solvents and environmental issues are major concerns with WCMs. Thus become less preferable, arousing from unwanted waste streams and possible emissions of volatile organic solvents. Herein DCMs are novel alternative.

Mechanical compaction based DCMs results composite product with new functionality and/or attributes, are unsuitable for elastic CM(s) and elastic SDFSP substrate. In case of plastic CM(s) and plastic SDFSP substrate possible mechanical interlocking is possibly realising composite product.

Operations of equipments used in DCMs are mostly a one-step straightforward process. Some of them have ability to be designed for continuous processing. Herein, particle size of CM(s) and substrate is crucial for realising and reproducing coating uniformity. A general recommendation is diameter of CM(s) be less than 1 percent to that of the SDFSP substrate.

Most of DCMs bears with minimal concern for process deviation associated with the skills of operators. Further, majority of DCM based coating processes have apparent potentiality for scaled-up. Manufacturing process based on DCMs upon optimisation and validation will become robust one.

Specialised WCMs and DCMs bears with involvement of technologies that calls for use of high pressures, high shear, elevated temperatures, and/or solvents. Further, for finding pharmaceutical applicability of WCMs and DCMs their scalability for larger manufacturing scale batch calls more robust investigation.

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