

Method for the Preparation of Fluoropolymer Powdered Materials

The present invention relates to a method for the preparation of Fluoropolymer powdered materials.

Fluoropolymers are long-chain polymers comprising mainly ethylenic linear repeating units in which some or all of the hydrogen atoms are replaced with fluorine. Examples include Poly(tetrafluoroethylene), Perfluoromethyl vinyl ether (MFA), Fluoro ethylene propylene (FEP), Per Fluoro Alkoxy (PFA), Poly(chlorotrifluoroethylene) and Poly(vinylfluoride). They are amongst the most chemically inert of all polymers and are characterised by an unusual resistance to acids, bases and solvents. They have unusually low frictional properties and have the ability to withstand extremes of temperature. Accordingly, fluoropolymers are utilised in a wide variety of applications in which resistance to extreme environments is necessary. Current applications include the formation of tubing and packing materials within chemical plants, semiconductor equipment, automotive parts and structural cladding.

There are several application methods, one of which requires the powdered form of the fluoropolymer. Here the fluoropolymer is typically applied to a surface by electrostatic spraying of the powder. Uses include the coating of household cookware to increase non-stick properties and abrasion resistance, and the coating of automotive parts to increase resistance to environmental weathering.

At present, two methods are used to produce the powdered form of a fluoropolymer. Spray drying methods comprise the pumping of an aqueous dispersion of the fluoropolymer feed into an atomising system, generally located at the top of a drying chamber. The liquid is atomised into a stream of heated gas to evaporate the water and produce a dry powder. This method has several limitations. The requirement that the aqueous dispersion is pumped into the atomising system limits the use of this process to pumpable materials, and the spray dried agglomerates are tightly bound to each other and resist subsequent

disagglomeration. In addition, only non-fibrillatable materials can be processed, as atomisation may result in the fibrillation of the fluoropolymer, resulting in an intractable 'marshmallow' material which is difficult to handle.

An alternative method involves the coagulation of the particles within an aqueous dispersion. Coagulation is facilitated by the use of high mechanical shear, the addition of acids or the addition of gelling agents and subsequent treatment with a water immiscible organic liquid. The coagulated particles can be separated from the residual liquid by filtration and subsequently dried, typically using tray, belt or flash dryers. The coagulated granules are usually case hardened for ease of handling. However, the formation of agglomerates results in a particle size that is too large for use in conventional powder spray application techniques. Milling, traditionally used to adjust the particle size distribution, can cause fibrillation of the particles, to produce an intractable material which is difficult to handle. The case hardened material also produces a tight agglomerate which resists subsequent disagglomeration.

It is an object of the present invention to provide a method for the preparation of fluoropolymer powdered materials in which the fluoropolymer particles do not tightly agglomerate, and in which the powdered material may be produced from a liquid suspension of the solid fluoropolymer particles, which under normal circumstances would not be pumpable because of its fibrillatable nature.

According to the present invention there is provided a method for the preparation of fluoropolymer powdered materials, the method comprising freezing a suspension of the solid fluoropolymer particles in a liquid carrier and subsequently separating out the fluoropolymer particles by means of sublimation of the frozen carrier to produce a dry powder.

The method is particularly suitable for the processing of the following polymers Poly(tetrafluoroethylene), Perfluoromethyl vinyl ether (MFA), Fluoro ethylene propylene (FEP), Per Fluoro Alkoxy (PFA).

Preferably, the fluoropolymer powdered materials have a particle size that is sufficiently small to allow application by conventional powder spray application techniques. The agglomerates (with a primary particle size of about $0.2\mu\text{m}$) produced may have an average diameter of from 1 to $100\mu\text{m}$, more preferably from 20 to $30\mu\text{m}$.

Preferably, the suspension of the solid fluoropolymer particles in a liquid carrier is frozen in a freezer at a temperature below 0°C . More preferably, the suspension is frozen at a temperature in the range -60°C to -20°C . Typically, freezing might be completed in 6 hrs to 24 hrs.

Preferably, the suspension of the solid fluoropolymer particles in a liquid carrier is poured, scooped or otherwise transferred into a tray prior to freezing. Preferably, the tray containing the suspension of the solid fluoropolymer particles is then placed into the freezer and frozen within the tray.

Preferably, the liquid carrier is water based with or without surfactant and with or without bridging solvents (organic solvent used to aid the dispersion/solvating of additional resins). If bridging solvents are used, they should be at concentrations low enough and have high enough melting points so that freezing is not inhibited.

Preferably, the sublimation is carried out using sub-atmospheric pressure or a vacuum. The use of a reduced pressure causes sublimation of the carrier from a frozen state directly to a gaseous state, avoiding the solid to liquid and liquid to gas transition. Preferably, the reduced pressure is created by means of a vacuum pump. Preferably, the reduced pressure is in the range 0.01atm to 0.99atm, more

preferably 0.04atm to 0.08atm Typically, sublimation might be completed in 12 hrs to 48 hrs.

For some fluoropolymers, the method is carried out at a temperature which is in practice below the glass transition temperature of the fluoropolymer. The glass transition temperature, T_g , of a polymer is the temperature at which it changes from a glassy form to a rubbery form. The measured value of T_g will depend on the molecular weight of the polymer, its thermal history and age, and on the rate of heating and cooling. Typical values are PTFE about 130°C, PFA about 75°C, FEP about -208°C, PVDF about -45°C.

The temperature is controlled to assist the sublimation process and avoid melting of the carrier liquid. It is a beneficial coincidence that these controls also maintain temperatures below the T_g values for some of the materials listed. Thus, the method may be carried out at ambient temperature. Alternatively, the method may be carried out at a temperature above ambient temperature, in order to reduce the time taken to complete the process.

The fluoropolymer particles may be modified prior to freezing, after sublimation has occurred or at any point during the process of the present invention. Such modifications may include the addition of fillers, milling or irradiation of the fluoropolymer. The addition of fillers would be carried out before drying to improve blend stability; milling would be carried out after drying.

Irradiation of the fluoropolymer would be carried out after milling to assist in particle size control.

The addition of fillers at the liquid stage allows the filler particles to disperse efficiently between the fluoropolymers particles thus imparting desirable properties to the finished powder coating. Post milling or irradiation of the freeze-dried

fluoropolymers materials can also enhance their suitability as powder coating materials.

Fillers comprise those substances which enhance or modify the specific physical characteristics of the fluoropolymer. For example, fillers may alter the colour, adhesion characteristics, hardness or corrosion resistance of the fluoropolymer. Examples of fillers include temperature stable pigments, binders, glass beads, bronze powder and tungsten. Other specific fillers include silicon carbide, polyphenylene sulphide (PPS), zinc phosphate, poly amide imide (PAI), Poly ether imide (PEI), polyetheretherketone (PEEK) and other engineering polymers.

The method may additionally comprise the milling of the fluoropolymer particles. Milling adjusts the particle size distribution of the fluoropolymer, for example reducing the mean particle size to produce a finer powder. Typically the milling would be carried out conventionally in a pin or jet mill.

The method may additionally comprise irradiation of the fluoropolymer particles, typically as a powder but alternatively in the suspension. Irradiation adjusts the melt characteristics of the fluoropolymer, for example to lower the melting temperatures/glass transition temperatures and increase the melt flow rate.

The method of the present invention does not result in the tight agglomeration of the particles, but instead produces a fine powder, which is suitable for use in conventional powder spray application techniques or for redispersion in aqueous or organic media. The friable powder can be broken down easily for particle size modification.

The method of the invention may be carried out at a temperature below the glass transition temperature of the fluoropolymer, in contrast to the known processes involving spray drying and coagulation, which require temperatures well in excess of 100°C. The use of ambient temperature allows greater energy efficiency, while

the use of temperatures that are above ambient temperature, but below the glass transition temperature, can be used to increase the speed with which the sublimation proceeds. Temperatures above ambient can also be used to assist secondary drying, to drive off any remaining liquid carrier traces.

The method of the invention can be used to prepare fluoropolymer powdered materials from fluoropolymers that are either fibrillatable or non-fibrillatable. Fibrillatable materials are those which form fibers when exposed to a shear force. The known methods, which involve spray drying and coagulation, both expose the solid fluoropolymer particles to shear forces, which can result in the production of an intractable material. The present invention does not involve shear forces at any stage and is therefore suitable for use with fibrillatable fluoropolymers.

The method of the invention may be used to prepare a fluoropolymer powdered material from a pumpable or non-pumpable suspension of the solid fluoropolymer particles in a liquid carrier. The suspension may be non-pumpable because of high viscosity or shear sensitivity and examples include high molecular weight PTFE or unstabilised PFA, MFA and FEP dispersions. The method does not involve any steps where the suspension must be pumped. Instead, the suspension may be poured or scooped into the tray for freezing, and the solid, frozen block may be transferred into the vacuum chamber.

The invention may be carried into practice in varying ways and some embodiments will now be described by way of example.

General Description

In a typical process, a fluoropolymer (modified or unmodified) with a particle size of about 0.2 μm is formed into a dispersion in water by mixing, optionally with a surfactant and/or bridging solvent, depending on the nature of the polymer. The dispersion is poured into trays, typically to a depth of 1 to 1.5cm. The loaded trays are then frozen to a temperature between -60 and -20°C. When frozen the trays are

loaded into a vacuum chamber and the pressure reduced to between 0.01 and 0.99 atmospheres, more typically 0.04-0.08atm. Under these conditions sublimation of the liquid carrier takes place. Additional heating can be applied to assist the sublimation process while avoiding melting the frozen carrier material, and to assist secondary drying.

Subsequent process steps might include milling, irradiating and compaction to modify powder properties and tailor to specific requirements.

Specific dispersions made and treated as described are set out below.

Fluoropolymers

PFA dispersion in water with a solids content of 23-27 wt. % and melt flow rate of 7.2g/10min measured at 372°C.

FEP dispersion in water with a solids content of 23-27 wt. % and melt flow rate of 6.5g/10min measured at 372°C.

MFA dispersion in water with a solids content of 28-32 wt.% and melt flow rate of 5.4g/10min measured at 372°C.

PTFE dispersion in water with a solids content of 30 – 60wt% and melt flow rate of 1-10g/mins measured at 372°C.

Other Components

Other components that can be included in the dispersions mentioned, include:

Silicon Carbide, average particle size 3 microns available from CARBOREX.

Poly phenylene sulphide (PPS) available from RYTON

Red 120 Iron oxide pigment available from BAYFEROX

PK 6075 Ochre pigment available from FERRO

34E23 Black mineral pigment available from JOHNSON

Claims

1. A method for the preparation of fluoropolymer powdered materials which comprises freezing a suspension of solid fluoropolymer particles in a liquid carrier and sublimating the frozen carrier to leave a dry powder.
2. A method as claimed in Claim 1, in which sublimation is achieved by means of a sub-atmospheric pressure.
3. A method as claimed in Claim 2, in which the reduced pressure is in the range 0.01 to 0.99atm.
4. A method as claimed in any proceeding Claim, in which the liquid carrier is water.
5. A method as claimed in any proceeding Claim, in which sublimation is carried out at a temperature below the glass transition temperature of the fluoropolymer.
6. A method as claimed in Claim 5, in which sublimation is carried out at ambient temperature.
7. A method as claimed in Claim 5, in which sublimation is carried out at a temperature between ambient temperature and the glass transition temperature of the fluoropolymer.
8. A method as claimed in any proceeding Claim, in which the suspension of the solid fluoropolymer particles in a liquid carrier is frozen at a temperature in the range -60°C to -20°C.

9. A method as claimed in any preceding Claim, in which the suspension of the solid fluoropolymer particles in a liquid carrier is frozen in trays.
10. A method as claimed in any preceding Claim, additionally comprising modification of the fluoropolymer or the solid fluoropolymer particles.
11. A method as claimed in Claim 10, in which the fluoropolymer is modified by the addition of one or more fillers.
12. A method as claimed in Claim 11, in which the filler comprises pigments and/or binders.
13. A method as claimed in Claim 10, in which the solid fluoropolymer particles are modified by milling and/or irradiation.
14. A method as claimed in any preceding Claim, in which the fluoropolymer is either fibrillatable and/or non-pumpable.