



(51) International Patent Classification:

C08L 71/02 (2006.01) *C08J 3/22* (2006.01)
C09B 67/00 (2006.01)

(21) International Application Number:

PCT/SG2017/050160

(22) International Filing Date:

28 March 2017 (28.03.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

CN201610182565.5 28 March 2016 (28.03.2016) CN

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,

BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- of inventorship (Rule 4.17(iv))

Published:

- with international search report (Art. 21(3))

(54) Title: A LIQUID COLOUR CONCENTRATE

(57) Abstract: The present invention mainly relates to a liquid colour concentrate for plastic substrates, and a method and system of manufacturing thereof. The liquid colour concentrate comprises (a) a carrier comprising a polyether having an average molecular weight of about 300 to about 400,000; (b) a colourant; and (c) one or more additives selected from a group consisting of dispersants, defoamers and functional additives, wherein the carrier is in an amount of about 30% to about 80% by weight of the liquid colour concentrate, the colourant is in an amount of about 10% to about 40% by weight of the liquid colour concentrate and the one or more additives is in an amount of about 0.2% to about 10% by weight of the liquid colour concentrate. (Fig. 3)



A LIQUID COLOUR CONCENTRATE

Technical field

The present invention generally relates to the chemical industry, in particular, a liquid colour concentrate suitable for plastic substrates and will be described in this context. The present invention also relates to a method and system of making the same.

Background

The following discussion of the background to the invention is intended to facilitate an understanding of the present invention only. It should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to was published, known or part of the common general knowledge of the person skilled in the art in any jurisdiction as at the priority date of the invention.

Since its first use, plastics has grown to be widely used in many industries and has gradually penetrated into every corner of society, from industrial production to basic necessities of life. According to statistics, worldwide plastics production reached 288 million tons in 2012, an increase in 3% from 280 million tons in 2011. In addition, worldwide plastics production in 2011 increased by 265 million tons, thereby representing an increase of 6% from 2010. Table 1 shows the quantity of plastics produced worldwide and in selected countries from 2010 – 2012.

With the rapid growth of the plastics industry, factors such as product quality, manufacturing conditions, efficiency and environmental protection, have affected the manufacturing quality and manufacturing process. In particular, production costs have increased, manufacturing equipment have become obsolete through prolonged use and production technology has lowered. In instances where high-end products are needed, the requirements for colour and performance is relatively high. However, commercially available powdered colourants and colour concentrates are currently unable to achieve the desired quality for colour and performance. As such, efforts have been made to replace plastics with other materials, thereby leading to the decline of the plastics industry.

Table 1: Plastics Production Worldwide and in Selected Countries from 2010 - 2012

	2010		2011		2012		
	Quantity (billion)	Proportion (%)	Quantity (billion)	Proportion (%)	Quantity (billion)	Proportion (%)	Increase (%)
Global Production	2.65	100	2.80	100	2.88	100	3
Asia	1.15	44	1.23	44	1.28	45	4
Japan	0.12	5	0.11	4	0.11	4	0
China	0.62	24	0.64	23	0.69	25	8
Others	0.41	15	0.48	17	0.48	16	0
Europe	0.65	25	0.67	24	0.67	23	0
EU-25, Norway, Switzerland	0.57	22	0.59	21	0.59	20	0
Others	0.08	3	0.08	3	0.08	3	0
North American Free Trade Area (NAFTA)	0.54	21	0.56	20	0.57	20	2
Latin America	0.13	5	0.14	5	0.14	5	0
South Africa, Middle East	0.17	7	0.20	7	0.21	7	5

In addition, the supply chain of the plastics industry is not well adapted to meet changes in market demand, and constraints in resources, energy, environment and other factors.

Thus, there is a need to develop the plastics industry, such that the above
5 shortcomings may be overcome or ameliorated.

Currently, the plastics industry primarily comprises of powdered colourants and colour concentrates (or masterbatches). Powdered colourants are commonly referred to as toners, and comprise of two main types: organic and inorganic toners. The particle size of powdered colourants is usually relatively small. For instance,
10 titanium dioxide (TiO_2) is an example of an inorganic toner (pigment) that has a particle size of about $0.7\text{-}2.5\mu\text{m}$. The particle size of the toner is usually determined by the process used to manufacture the toner. Each toner particle is usually lightweight and has a particle size of less than $10\mu\text{m}$. Consequently, dust particles can easily form during the injection molding process, thereby raising concerns that
15 the exposure of these toners may be harmful to the environment and humans, and possibly lead to cross-contamination with other toners. From the outset, use of powdered colourants in the plastics industry has had various challenges, such as high chances of contamination, instability of the coloured plastic product, occurrence of colour specks, non-homogeneity and difficulty in storage. Furthermore, on
20 exposure to the atmosphere, the toners are susceptible to oxidation or absorption of moisture from the environment. Consequently, the quality and shelf life of the coloured plastic product can be adversely affected, and maintenance of the manufacturing equipment can be problematic, thereby affecting the advancement of the plastics industry.

25 Powdered colourants also suffer from another serious drawback. In particular, the manufacture of powdered colourants is complex. As illustrated in Figure 1, the process of manufacturing a coloured plastic product using powdered colourants typically comprises the following steps: (1) accurately measure out the quantity of the plastic raw materials according to the quantity required (Step 1); (2) accurately
30 measure out the quantity of the coloured pigment according to the colour requirements of the coloured plastic product (Step 2); (3) mix the carefully measured

out quantities of plastic raw materials and coloured pigment homogeneously with a stirrer/blender (Step 3); (4) package the homogeneously mixed coloured plastic product (Step 4); (5) transport the packages containing the coloured plastic raw material to an injection molding machine (Step 5); (6) add the coloured plastic raw material to the hopper of the injection molding machine (Step 6); (7) start production of the coloured plastic product after setting the parameters of the injection molding machine according to the product requirements (Step 7).

Colour concentrates (or masterbatches) were developed in the 1960s and are concentrated mixtures of colourants (for instance, pigments) and/or additives encapsulated during a heat process into a carrier resin (or binder) which is then cooled and cut into a granular shape. The dimensions of colour concentrates is usually 2 mm x 3-4 mm, the particle size is relatively bigger and does not form dust particles easily. Consequently, colour concentrates are not as harmful to humans and the environment, thereby circumventing the limitations of powdered colourants (or toners). As colour concentrates are already premixed compositions, their use leads to uniform colouration, and specks of colours are not easily formed. As the carrier resin separates the colourants (for instance, pigments), air and moisture, the quality of the colourants can be sustained for long periods of time without changing, thereby increasing the storage shelf life and stability of colour concentrates. As such, colour concentrates are more commonly used than powdered colourants in the plastics industry.

Although colour concentrates overcomes some of the problems associated with the use of powdered colourants and has various advantages over powdered colourants, such as the use of colour concentrates is safer, colour concentrates are not as widely applicable as powdered colourants. In other words, there is a limited scope of use. This is because selection of the colour concentrate must take into account chemical compatibility with the plastic raw material. As such, one type of carrier resin of the colour concentrate may be compatible with only predominantly one type of plastic raw material. Consequently, non-uniform colouration and formation of colour specks may occur if there is incompatibility between the carrier resin and plastic raw material. Notwithstanding, the manufacture of colour concentrates is more complicated: the colourants (for instance, pigments) have to be selected in

accordance with the desired colour; after verification of the colour, encapsulation with a carrier resin will be carried out according to a specific formulation, followed by cutting into a granular shape. After comparing with a sample of the desired colour, if there is a difference in the colours, it would be necessary to re-synthesize the colour concentrate, thereby leading to the use of more time, energy and materials. Consequently, the production costs are increased. As the production costs are relatively high and there is limited scope of use, there are limitations to the development of the plastics industry because of the persistence of problems such as non-homogenous colouring, differences in colouration and difficulties in achieving full automation of the colouring process.

As illustrated in Figure 2, the process of manufacturing a coloured plastic product using colour concentrates typically comprises the following steps: (1) accurately measure out the quantity of the plastic raw materials according to the quantity required (Step 1'); (2) accurately measure out the quantity of the masterbatch according to the colour requirements of the coloured plastic product (Step 2'); (3) mix the carefully measured out quantities of plastic raw materials and masterbatch homogeneously with a stirrer/blender (Step 3'); (4) package the homogeneously mixed coloured plastic starting material (Step 4'); (5) transport the packages containing the coloured plastic starting material to an injection molding machine (Step 5'); (6) add the coloured plastic starting material to the hopper of the injection molding machine (Step 6'); (7) start production of the coloured plastic product after setting the parameters of the injection molding machine according to the product requirements (Step 7').

Typically, the production of powdered colourants and colour concentrates will lead to a pre- loss of about 5%. If the manufacturing process is disrupted during production, it would not be possible to use the raw materials and colouring agent (powdered colourants or colour concentrates) again. If, during the production process there are any anomalies or cancellation of the order, it would not be possible to continue using the coloured plastic intermediate from step 3 or step 3'. Consequently, the loss in profits would be significant, and there would be wastage a second time. This is a key reason why powdered colourants and colour concentrates cannot be used in the plastics industry in the long run.

In light of the above, there exists a need to develop a liquid colour concentrate that can ameliorate or overcome the above disadvantages.

The present invention seeks to provide a liquid colour concentrate that addresses the aforementioned need at least in part. The present invention also seeks to provide
5 a method of making the same.

List of Patent Prior Art Documents

Patent Document 1: China Patent Application Publication No. 101421348 (Claims, Examples, etc)

10 Patent Document 2: China Patent Application Publication No. 102504599A (Claims, Examples, etc)

Patent Document 3: China Patent Application Publication No. 102702658A (Claims, Examples, etc)

15 Patent Document 4: China Design Patent Application Publication No. 303320330S (Claims, Examples, etc)

Patent Document 5: China Patent Application Publication No. 203994338U (Claims, Examples, etc)

Patent Document 6: China Patent Application Publication No. 104924490A (Claims, Examples, etc)

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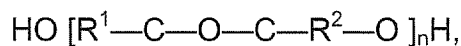
Summary of Invention

In an aspect of the present invention, there is provided a liquid colour concentrate, comprising: (a) a carrier comprising a polyether having an average molecular weight of about 300 to about 400,000; (b) a colourant; and (c) one or more additives
25 selected from a group consisting of dispersants, defoamers and functional additives, wherein the carrier is in an amount of about 30% to about 80% by weight of the liquid colour concentrate, the colourant is in an amount of about 10% to about 40% by weight of the liquid colour concentrate and the one or more additives is in an amount of about 0.2% to about 10% by weight of the liquid colour concentrate.

30

Preferably, the polyether is a copolymer, homopolymer or a mixture thereof.

Preferably, the structure of the polyether is:



- 5 wherein $1 \leq n \leq 1000$,
 wherein $\text{R}^1 = \text{R}^2$ when the polyether is a homopolymer, wherein $\text{R}^1 \neq \text{R}^2$ when
 the polyether is a copolymer, and
 wherein R^1 and R^2 are independently an alkyl group comprising of 1 to 50
 carbons.

10

Preferably, the polyether has a molecular weight of about 300 to about 1000.

Preferably, the polyether has a molecular weight of about 300 to about 500.

- 15 Preferably, the polyether has a viscosity of about 2000 cP to about 5000 cP.

Preferably, the colourant comprises one or more organic powdered colourant, one or
 more inorganic powdered colourant or a combination thereof.

- 20 Preferably, the functional additives comprises one or more levelling agents, anti-
 oxidants, light stabilizers, antistatic agents, steel agents, nucleating agents or
 brighteners.

- Preferably, the liquid colour concentrate is capable of forming a homogenous mixture
 25 with a plastic resin comprising acrylonitrile - butadiene, acrylonitrile - butadiene -
 styrene, polymethyl methacrylate, polyethylene terephthalate, polycarbonate ester,
 polyethylene terephthalate-1,4-cyclohexanedimethanol, polybutylene terephthalate,
 thermoplastic elastomer, polypropylene, high density polyethylene or low density
 polyethylene.

30

Preferably, the liquid colour concentrate is in an amount of about 0.2% to about 0.8%
 by weight of the plastic resin.

Preferably, the liquid colour concentrate has a viscosity of about 6000 cP to about 13,000 cP, and a particle size of about 0.2 μm to about 8.0 μm .

5 In another aspect of the present invention, there is provided a method of preparing a liquid colour concentrate, the method comprising blending two or more of a liquid colour concentrate according to an aspect of the present invention.

10 In another aspect of the present invention, there is provided a coloured plastic product comprising at least one liquid colour concentrate according to an aspect of the present invention and a plastic resin.

Preferably, the plastic resin comprises one or more of acrylonitrile - butadiene, acrylonitrile - butadiene - styrene, polymethyl methacrylate, polyethylene terephthalate, polycarbonate ester, polyethylene terephthalate-1,4-
15 cyclohexanedimethanol, polybutylene terephthalate, thermoplastic elastomer, polypropylene, high density polyethylene or low density polyethylene.

In another aspect of the present invention, there is provided a method of manufacturing a liquid colour concentrate, the method comprising: (a) mixing a
20 carrier comprising a polyether having an average molecular weight of about 300 to about 400,000, with one or more additives selected from a group consisting of dispersants, defoamers and functional additives to form a first mixture; (b) adding a colourant to the first mixture to form a second mixture; and (c) milling the second mixture to obtain a liquid colour concentrate, wherein the carrier is in an amount of
25 about 30% to about 80% by weight of the liquid colour concentrate, the colourant is in an amount of about 10% to about 40% by weight of the liquid colour concentrate and the one or more additives is in an amount of about 0.2% to about 10% by weight of the liquid colour concentrate.

30 Preferably, the polyether is a copolymer, homopolymer or a mixture thereof.

Preferably, the polyether has an average molecular weight of about 300 to about 1000.

Preferably, the polyether has an average molecular weight of about 300 to about 500.

Preferably, step (a) further comprises stirring the carrier homogeneously.

5

Preferably, the first mixture is stirred for about 15 minutes.

Preferably, step (b) further comprises stirring the second mixture for about 20 to 30 minutes.

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Preferably, stirring of the second mixture occurs at a speed of about 300 revolutions/min to about 500 revolutions/min.

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Preferably, stirring of the second mixture further comprises stirring the second mixture at a speed of about 1000 revolutions/min to about 1500 revolutions/min at a temperature of about 40°C to about 50°C.

Preferably, step (c) comprising milling the second mixture with a processing mill, wherein the processing mill is a bead mill.

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Preferably, the diameter of the beads of the bead mill is about 0.3 mm to about 2.4 mm.

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Preferably, step (c) further comprises cooling the second mixture during the milling of the second mixture to obtain the liquid colour concentrate.

Preferably, the milling occurs at a temperature of about 50°C to about 80°C.

Preferably, the milling occurs at a temperature of about 60°C.

30

Preferably, the method further comprising separating the second mixture.

In another aspect of the present invention, there is provided a system for manufacturing a coloured plastic product, the system comprising: (a) a production

system comprising a colour oil gauge and a mixer, the colour oil gauge operable to connect to a mixer; and (b) an injection molding machine comprising a hopper; wherein the mixer is operable to receive and mix a liquid colour concentrate according to an aspect of the present invention and a plastic resin to form a mixture for transfer to the hopper to produce the coloured plastic product.

In another aspect of the present invention, there is provided a method of manufacturing a coloured plastic product, the method comprising: (a) providing an automated production system comprising a colour oil gauge connected to a mixer; (b) passing a liquid colour concentrate according to an aspect of the present invention and a plastic resin through the automated production system to form a mixture; (c) stirring the mixture homogeneously using mixer; (d) transferring the mixture to a hopper of an injection molding machine to produce the coloured plastic product.

Preferably, step (b) further comprises transferring the liquid colour concentrate and the plastic resin to the apparatus capable of stirring via conduits to form the mixture.

Brief Description of Figures

The present invention will now be described, by way of example only, with reference to the accompanying figures, in which:

Fig. 1 illustrates a prior art manufacturing process of a coloured plastic product using powdered colourants;

Fig. 2 illustrates a prior art manufacturing process of a coloured plastic product using colour concentrates;

Fig. 3 illustrates a method of manufacturing a coloured plastic product using a liquid colour concentrate in accordance with an embodiment of the present invention.

Definitions

The following words and terms used herein shall have the meaning indicated:

As used herein, the term "colourant" refers to any conventional inorganic or organic pigment, organic dyestuff or carbon black. The colourant used in the liquid colour concentrate of the present invention can comprise a pigment, a dye, a combination of pigments, a combination of dyes, a combination of pigments and dye, a combination of pigment and dyes, or a combination of pigments and dyes.

As used herein, the term "pigment" is used interchangeably with the term "toner".

As used herein, the term "polyether" is used interchangeably with the term "organic polyether".

As used herein, the term "VNC" or "volatile non-aqueous constituent" means substances other than water which are released into the environment from a liquid colour concentrate composition under conditions to which such composition is normally exposed. The term encompasses both organic (for instance, volatile organic compounds or "VOCs") and inorganic substances, and decomposition or other reaction products of precursor materials in the composition.

As used herein, the units "cP" has been used for viscosity. A person skilled in the art would know how to convert values with the units "cP" to the pascal-second (Pa·s), or (N·s)/m², or kg/(m·s). The viscosity of a substance (includes liquids) in the present invention was measured at a temperature of 25°C using a Stormer-IV viscometer.

Unless otherwise indicated, all percentages and proportions given herein are by weight, i.e. weight percentage, based on the total weight of liquid colour concentrate.

Unless specified otherwise, the terms "comprising", "comprise", and grammatical variants thereof, are intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, unrecited elements. The terms "including", "include", and grammatical variants thereof are construed similarly.

As used herein, the term "about" may refer to +/- 5% of the stated value, more preferably +/- 4% of the stated value, more preferably +/- 3% of the stated value, more preferably +/- 2% of the stated value, even more preferably +/- 1% of the stated value, and even more preferably +/- 0.5% of the stated value.

Throughout this disclosure, certain embodiments may be disclosed in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as a limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. Ranges are not limited to integers, and can include decimal measurements where applicable. This applies regardless of the breadth of the range.

Detailed Description

Provided herein is a liquid colour concentrate for plastic substrates. Exemplary, non-limiting embodiments of the liquid colour concentrate will now be disclosed. Advantageously, the liquid colour concentrate of the present invention is synthesized from powder to liquid form, is more environmentally friendly, does not result in dust, does not lead to pollution, and has excellent dispersion properties. Consequently, there is minimization of formation of colour specks and non-uniform colouration, an increase in surface smoothness of the coloured substrate, reduction in the amount of colourant used per unit area and minimization of the impact of the liquid colour concentrate on the plastic substrate itself.

In an aspect, there is provided a liquid colour concentrate comprising a carrier comprising a polyether having an average molecular weight of about 300 to about 400,000; a colourant; and one or more additives selected from a group consisting of dispersants, defoamers and functional additives, wherein the carrier is in an amount of about 30% to about 80% by weight of the liquid colour concentrate, the colourant is in an amount of about 10% to about 40% by weight of the liquid colour concentrate and the one or more additives is in an amount of about 0.2% to about 10% by weight of the liquid colour concentrate. As such, the liquid colour concentrate of the present invention comprises a colourant encapsulated in a carrier, preferably a liquid, thereby forming a polymer composite that is an environmentally friendly colourant.

Furthermore, the liquid colour concentrate is water-soluble and biodegradable, thereby making it easier to clean up and environmentally friendly. In particular, the liquid colour concentrate is an environmentally friendly colourant because of the low amount of VNC, especially VOC, present in the one or more additives.

5 Advantageously, manufacture of the liquid colour concentrate does not lead to pollution or production of hazardous waste, and is substantially free of undesired discharge. Consequently, the liquid colour concentrate is environmentally friendly and substantially harmless to the environment. Furthermore, zero or almost zero VOC are produced when the liquid colour concentrate of the present invention is
10 used to manufacture a coloured plastic product using the manufacturing process of the present invention.

The supply chain of liquid colour concentrates is not well adapted to the challenge of colour matching, as will be outlined below. For existing liquid colour concentrates
15 currently in the market, it is not possible to easily combine a liquid colour concentrate with a different liquid colour concentrate to obtain the desired colour. Typically, a combination of colourants is prepared and then used to manufacture a liquid colour concentrate of a specific desired colour. In particular, two or more toners in desired proportions may be used to arrive at the specific desired colour in accordance to a
20 specific formulation. As illustrated in Figure 2, the process of manufacturing a coloured plastic product using liquid colour concentrates typically comprises steps 1' to 7'. Thereafter, the coloured plastic product is transported to the client and the colour will be verified and accepted by the client if the colour is satisfactory. If the colour is not satisfactory, it would be necessary to re-adjust the specific formulation
25 until the colour of the coloured plastic product matches the desired colour. If the colour is satisfactory, the specific formulation is brought back to the company so that the formulation engineer can use the formulation to arrive at an entire batch of liquid colour concentrate having the desired colour (step 8'). In step 9', the entire batch of liquid colour concentrate is transported to the client. In step 10', the client will verify
30 and accept the entire batch of liquid colour concentrate if the colour is satisfactory. If the client is not satisfied, it would be necessary to send the entire batch of liquid colour concentrate back to the company and repeat steps (8') to (10') until the client is satisfied (step 11'). During this entire process, the costs of transport, labour and raw materials contribute to the manufacturing costs. Furthermore, a significant

amount of time is required. As such, if a particular colour were required for a specific use or application, it would be necessary to prepare the custom-coloured liquid colour concentrate using the specific combination of colourants. This makes the manufacturing process more tedious as a specific colour would have to be prepared for a specific use, thereby potentially incurring significant production costs. In particular, during the manufacturing process, the colourants and carriers used would have to be changed in order to obtain the specific desired colour of liquid colour concentrate.

In contrast and more advantageously, the liquid colour concentrate of the present invention is more well adapted to the challenge of colour matching and allows a user to easily mix two or more different liquid colour concentrates (or colour oils) to obtain the desired colour i.e. the technique of "oil-adjusting-oil" is achieved. This is primarily achieved by the choice of carrier. In particular, the carrier used for the liquid colour concentrate of the present invention has the following characteristics: (1) strong dispersibility, and can be directly used as a dispersant in the plastics industry, thereby achieving high compatibility with various toners and good compatibility with most of the existing toners; (2) high versatility, wide scope of applicability; and (3) good stability. Consequently, it is possible to mix two or more different liquid colour concentrates of the present invention in any proportion, thereby achieving the technique of "oil-adjusting oil". Furthermore, as the carrier used for the liquid colour concentrate of the present invention can be applied to a larger number of plastic resins compared to existing carriers, the production costs and manufacturing time may be reduced. This is because, for instance, the same carrier can be used to manufacture various different liquid colour concentrates, and accordingly, different coloured plastic products, without having to change the carrier.

Due to the technique of "oil-adjusting-oil", after achieving the desired colour of liquid colour concentrate, the resultant liquid colour concentrate may be transferred into an injection molding machine with a plastic resin at the required temperature to make the colour sample and matched to the desired colour. Once the client verifies the colour sample, it can be brought back to the company and an entire batch of liquid colour concentrate can be achieved on the spot by for instance, mixing the two or more liquid colour concentrates homogeneously. Thereafter, the entire batch of liquid

colour concentrate can be transported to the client and the colour will be verified and accepted by the client if the colour is satisfactory. If the colour is not satisfactory, it is possible to use one or more liquid colour concentrates to modify the colour on-site because of the carrier having the properties as described above. Furthermore, if the colour is not satisfactory, missing colours can be added into the batch of liquid colour concentrate on-site until the colour is satisfactory. As such, there is no need to send the entire batch of liquid colour concentrate back. Consequently, the present invention is convenient and keeps manufacturing costs low, cuts down on transportation costs, and leads to a savings in time, labour and money. Furthermore, manufacturers would not need to tie up their capacity producing small lots of custom-coloured liquid colour concentrates because the "oil-adjusting-oil" technique allows a user to easily mix two or more different liquid colour concentrates to obtain the desired colour. Importantly, the supply chain of liquid colour concentrates is significantly improved i.e. well suited to meet challenges in colour matching.

In various embodiments, the carrier is a polyether, which is a colourless transparent liquid having good miscibility with a plastic resin and has no effect on the transparency and gloss of the plastic resin. In various embodiments, the carrier is substantially free of a polyester. In various embodiments, the structure of the polyether is $\text{HO}[\text{R}^1-\text{C}-\text{O}-\text{C}-\text{R}^2-\text{O}]_n\text{H}$, wherein $1 \leq n \leq 1000$, wherein $\text{R}^1 = \text{R}^2$ when the organic polyether is a homopolymer, wherein $\text{R}^1 \neq \text{R}^2$ when the organic polyether is a copolymer, and wherein R^1 and R^2 are independently an alkyl group comprising of 1 to 50 carbons, preferably 5 to 15 carbons.

In a preferred embodiment, the polyether is a polyether polyol. The polyether polyol may be DS-206 polyether polyol. As the polyether polyol has at least two hydroxyl groups that can undergo esterification, it can be advantageously directly used as a plasticizer in the plastics industry. Furthermore, the polyether polyols can function as good lubricants and can be widely used in the plastics industry as an internal lubricant. For instance, when used as an internal lubricant for screws, the insides of the screw can be made smooth, thereby facilitating smooth running of the manufacturing process. In addition, when used as an external lubricant for molds, the mold can be made glossier, thereby resulting in the production of coloured plastic products that have a better gloss and brighter colour.

In various embodiments, the polyether is a copolymer, homopolymer or a mixture thereof having an average molecular weight of about 300 to about 400,000, about 300 to about 100,000, about 300 to about 10,000, preferably about 300 to about 4000, more preferably about 300 to about 1000, or about 300 to about 500, most preferably about 322. In general, a polyether polyol having a longer aliphatic chain would be more hydrophobic than a polyether polyol having a shorter aliphatic chain. Advantageously, low molecular weight polyether polyols that have a shorter aliphatic chain (for instance, average molecular weight of about 300 to about 1000) can be easily cleaned off using water and will not cause environmental pollution because of its higher hydrophilicity.

In various embodiments, the polyether is in an amount of about 25% to about 85% by weight, about 30% to about 80% by weight, about 35% to about 85% by weight, about 40% to about 85% by weight, about 45% to about 85% by weight, about 45% to about 80% by weight, about 45% to about 75% by weight, about 45% to about 65% by weight, about 65% to about 85% by weight, about 65% to about 80% by weight, preferably about 35% to about 75% by weight, most preferably about 40% to about 65% by weight of the liquid colour concentrate.

Advantageously, the carrier of the liquid colour concentrate is a polymer with relatively good fluidity, thereby resulting in a more homogeneous liquid colour concentrate. The average molecular weight of the carrier has an effect on the viscosity of the carrier. In general, the greater the molecular weight of the polyether polyol, the higher the viscosity of the carrier. In various embodiments, the carrier has a viscosity of about 2000 cP to about 5000 cP, about 2000 cP to about 4500 cP, about 2000 cP to about 4000 cP, about 2000 cP to about 3500 cP, about 3000 cP to about 5000 cP, about 3000 cP to about 4500 cP, or about 3500 cP to about 4500 cP. In a preferred embodiment, the carrier has a viscosity of about 2000 cP to about 5000 cP, preferably about 4000 cP, when the average molecular weight of the carrier is about 300 to about 1000. Consequently, it is easier to combine the polymer with a plastic resin, thereby leading to the production of coloured plastic products that do not have specks of colour and have bright, homogeneous colouring. In addition, the liquid carrier advantageously avoids or minimizes interaction of the colourant with air

and water, thereby leading to prolonged quality of the coloured plastic product as the stability of the liquid colour concentrate may be increased, making it easier for storage. As such, the gloss, shade and other properties of the liquid colour concentrate does not change even during a long period of storing. In other words, the storage shelf-life is increased.

The amount of colourant present relative to the amount of carrier is important because of the relative cost of the colourant and the need for the colour to consistently and precisely mix and disperse into the carrier and then to consistently and precisely dilute into the plastic resin and other compound ingredients during "letdown" of the concentrate in mixing equipment prior to formation of the coloured plastic product. The ideal proportion of the colourant will need to be determined according to the oil absorption ability of the colourant. In various embodiments, the different chemical structure of the colourant will lead to a different degree (or extent) of integration between the colourant and the carrier, which affects the consistency of the colour of the liquid colour concentrate. Due to the different degree of integration between the colourant and the carrier, a different proportion of colourant would be required to achieve consistency. In various embodiments, the colourant is in an amount of about 10% to about 70% by weight, about 10% to about 60% by weight, about 20% to about 70% by weight, about 30% to about 60% by weight, about 30% to about 50% by weight, about 35% to about 70% by weight, about 35% to about 55% by weight, about 20% to about 35% by weight, about 20% to about 55% by weight, about 18% to about 40% by weight, preferably about 15% to about 40% by weight, most preferably about 18% to about 35% by weight of the liquid colour concentrate. The oil absorption ability (ml/100g) of the colourant may be for instance, ≤ 50 when toluidine red RN is used, ≤ 40 when phthalocyanine blue B is used, ≤ 40 when phthalocyanine green G7 is used, ≤ 45 when benzidine yellow G is used, ≤ 23 when titanium dioxide is used or ≤ 60 when cabot 430 carbon black is used.

In various embodiments, the colourant is an environmentally friendly colourant, preferably approved by regulatory boards such as the Food and Drug Administration (FDA), EN 71-3:2013, Restriction of Hazardous Substances (RoHS), Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). Consequently, manufacture of the liquid colour concentrate does not lead to pollution or production

of hazardous waste, and is substantially free of undesired discharge. The colourant may be one or more selected from the group consisting of inorganic or organic pigment, organic dyestuff or carbon black. Suitable inorganic pigments can be selected from the group consisting of an oxide, e.g. iron oxide (brown, red, black),
5 chrome oxide (green) or titanium oxide (white), carbon, e.g. rust-black, chromate, e.g. lead chromate-yellow, molybdate-orange, a complex of colourful inorganic pigments, e.g. chrome titanium yellow, chrome iron brown, cobalt blue, nickel titanium yellow, zinc iron brown or bismuth vanadate yellow or a sulphide, e.g. cadmium sulphide (yellow, orange, red), cerium sulphide (yellow, orange, red),
10 ultramarine (violet, blue) or zinc sulphide (white), and a mixture thereof. Suitable organic pigments can be selected from the group consisting of azo pigments, such as lacquered azo pigments (yellow, red), disazo pigments (yellow, orange, red), disazo condensation pigments (yellow, red), benzimide azo pigments (yellow, orange), metal complex pigments (yellow), isoindoline pigments (yellow),
15 isoindolinon pigments (yellow) and polycyclical pigments, e.g. quinacridone (violet, blue), quinophthalone (yellow), diketo-pyrrolo-pyrrol (orange, red, violet), disoxazine pigments (violet), indanthron (blue), perylene (red, violet) or phthalocyanine (blue, green) and a mixture thereof. Suitable dyestuff can be selected from the group consisting of anthraquinone, quinophthalone, pyrazolone, perinone, monoazo dyes
20 and fluorescent dyes, e.g. perylene, naphthalimide, cumin derivatives, thioindigo or thioxanthene benzanthrone and a mixture thereof. In a preferred embodiment, the colourant may be one or more selected from the group consisting of an oxide, e.g. titanium oxide (white), carbon, e.g. rust-black, chromate, e.g. lead chromate-yellow, or a sulphide, e.g. cadmium sulphide (yellow, orange, red), azo pigments, such as
25 lacquered azo pigments (yellow, red), disazo pigments (yellow, orange, red), disazo condensation pigments (yellow, red), benzimide azo pigments (yellow, orange), chromamines, or phthalocyanine (blue, green) and a mixture thereof.

In various embodiments, the liquid colour concentrates of the present invention can
30 lead to good quality coloured plastic products with enhanced performance. This may be achieved by the use of additives which can improve processing or performance of the liquid colour concentrate. Generally, minor amounts of additives can provide improvement of performance of the liquid colour concentrate either in the liquid colour concentrate or the coloured plastic product. In various embodiments, the one

or more additives is in an amount of about 0.2% to about 10% by weight, about 0.2% to about 5% by weight, about 0.2% to about 1% by weight, about 0.2% to about 0.5% by weight, preferably about 0.3% to about 7% by weight, more preferably about 0.5% to about 5% by weight, most preferably about 0.5% by weight of the liquid colour concentrate.

In various embodiments, the functional additives is one or more selected from the group consisting of levelling agents, anti-oxidants, light stabilizers, antistatic agents, steel agents, nucleating agents and brighteners. The number of functional additives can be selected based on the desired requirements.

For instance, in some translucent products, in order to achieve a long shelf life and maintain the colour, a suitable amount of antioxidant can be added to prevent oxidation due to the environment, which can cause yellowing, discolouration, aging, thereby increasing the shelf life.

Alternatively, there may be a need to undergo long term exposure to UV radiation, thereby causing the coloured plastic product to deteriorate and reduce the stability of the plastic resin and colourant. As such, a suitable amount of UV stabilizers can be added to increase the shelf life of the coloured plastic product when exposed to UV radiation.

The average molecular weight of the carrier, such as a polyether polyol, has an effect on the viscosity of the liquid colour concentrate. In general, the greater the average molecular weight of the carrier, the higher the viscosity of the carrier, which results in a higher viscosity of the liquid colour concentrate. In various embodiments, the liquid colour concentrate of the present invention has a viscosity of about 2000 cP to about 13,000 cP, about 2000 cP to about 10,000 cP, about 2000 cP to about 6000 cP, about 2000 cP to about 5000 cP, about 3000 cP to about 5000 cP, about 3000 cP to about 4500 cP, about 3500 cP to about 4500 cP, or about 6000 cP to about 13,000 cP. In various embodiments, the liquid colour concentrate has a particle size of about 0.2 μm to about 8.0 μm , about 0.2 μm to about 1.0 μm , about 0.2 μm to about 8.0 μm , about 1.0 μm to about 8.0 μm , about 0.2 μm to about 2.0 μm , about 2.0 μm to about 8.0 μm , about 0.5 μm to about 5.0 μm , about 0.5 μm to

about 8.0 μm , about 2.5 μm to about 5.0 μm or about 4.0 μm to about 6.0 μm . The viscosity and particle size of a liquid colour concentrate having these properties exhibit good fluidity, can mix well with a plastic resin, thereby leading to a homogeneously coloured plastic product with no colour specks. As such, the problems faced by traditional liquid colour concentrates i.e. poor dispersity and easy production of colour specks, are overcome by the liquid colour concentrate of the present invention.

In a preferred embodiment, when the average molecular weight of the polyether polyol is about 300 to about 1000, there is no or substantially no effect on the particle size of the liquid colour concentrate. When the average molecular weight of the polyether polyol is about 300 to about 1000, the particle size of the liquid colour concentrate is preferably about 5.0 $\mu\text{m} \pm 3.0 \mu\text{m}$ (in other words, about 2.0 μm to about 8.0 μm) and the viscosity of the liquid colour concentrate is about 7000 to about 10,000 cP, preferably about 9000 to about 10,000 cP. When the average molecular weight of the polyether polyol is more than 1000, due to the increase in molecular weight, the viscosity is also increased and processing of the liquid colour concentrate becomes more difficult. When the average molecular weight of the polyether polyol is more than 1000, the particle size of the liquid colour concentrate is $\geq 10\mu\text{m}$ and the viscosity of the liquid colour concentrate is $\geq 12,000$ cP. Consequently, there will be decreased efficiency of the milling process, thereby leading to a larger particle size. As such, the average molecular weight of the polyether polyol is preferably about 300 to about 1000 so that the resultant viscosity facilitates efficient processing of the liquid colour concentrate and the resultant liquid colour concentrate would exhibit good fluidity.

In view of the foregoing, there is provided a method of preparing a liquid colour concentrate, the method comprising blending two or more of a liquid colour concentrate as described above. This method of preparing a liquid colour concentrate is achieved by the technique of "oil-adjusting-oil" as described above.

In various embodiments, the liquid colour concentrate of the present invention is capable of forming a homogeneous mixture with a plastic resin. Accordingly, there is provided a coloured plastic product comprising at least one liquid colour concentrate

as described above and a plastic resin. Advantageously, the liquid colour concentrate of the present invention has good stability and compatibility, does not affect or change the properties of the plastic resin, and has strong versatility. In various embodiments, the liquid colour concentrate of the present invention has good miscibility with a plastic resin comprising one or more selected from the group consisting of acrylonitrile – butadiene (AB), acrylonitrile - butadiene – styrene (ABS), polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), polycarbonate ester (PC), polyethylene terephthalate-1,4-cyclohexanedimethanol (PETG), polybutylene terephthalate (PBT), thermoplastic elastomer (TPE), polypropylene (PP), high density polyethylene (HDPE) and low density polyethylene (LDPE). Among these, AB, ABS, PC, PETG are preferred, and ABS is most preferred.

In various embodiments, the liquid colour concentrate makes up about 0.2% to about 1% by weight, preferably about 0.2% to about 0.8% by weight, and more preferably about 0.4% to about 0.8% by weight of the plastic resin. According to the desired requirements (e.g. transparent, translucent, opaque), the proportion of the constituents of the liquid colour concentrate can be adjusted and there is no need to add other components to achieve the desired requirements, thereby reducing the manufacturing costs.

Exemplary, non-limiting embodiments of a method of making a liquid colour concentrate and a method of making a coloured plastic product using a liquid colour concentrate of the present invention will now be disclosed. The manufacturing process of the present invention is advantageously automated, more efficient and more cost effective than existing manufacturing processes. Consequently and advantageously, the method of the present invention leads to a savings in money, time and manpower. In particular, the time needed to deliver the desired coloured plastic product to the client is significantly shortened and the overall manufacturing costs (e.g. raw material and manpower usage) is decreased. This is because the liquid colour concentrate of the present invention can be easily co-formulated and used compared to existing commercially available liquid colour concentrates. As described above, the liquid colour concentrate of the present invention may be mixed with one or more different liquid colour concentrates of the present invention to obtain the desired colour i.e. the technique of “oil-adjusting-oil”. Furthermore, the

manufacturing process produces zero or almost zero pollution and zero or almost zero VOC, and can be applied to a relatively wide range of liquid colour concentrates suitable for various applications. In addition, it is simple to clean the components of the automated production system because of the good hydrophilic properties of the carrier. Consequently, the liquid colour concentrate of the present invention and the method of making the same are beneficial and make a significant technical contribution to the plastics industry.

In an aspect, there is provided a method of manufacturing a liquid colour concentrate, the method comprising: (a) mixing a carrier comprising a polyether having an average molecular weight of about 300 to about 400,000, with one or more additives selected from a group consisting of dispersants, defoamers and functional additives to form a first mixture; (b) adding a colourant to the first mixture to form a second mixture; and (c) milling the second mixture to obtain a liquid colour concentrate, wherein the carrier is in an amount of about 30% to about 80% by weight of the liquid colour concentrate, the colourant is in an amount of about 10% to about 40% by weight of the liquid colour concentrate and the one or more additives is in an amount of about 0.2% to about 10% by weight of the liquid colour concentrate.

In various embodiments, the polyether is a copolymer, homopolymer or a mixture thereof.

In various embodiments, the polyether has an average molecular weight of about 300 to about 500.

In various embodiments, step (a) of the method involves adding the carrier portion-wise into an apparatus capable of high-speed stirring (stirrer or mixer), allowing the carrier to react, undergo homogeneous stirring and further reaction. The carrier in the stirrer is stirred at a predetermined speed to achieve homogeneity, which advantageously facilitates efficient and homogeneous mixing when other components, such as one or more additives, are added. In a preferred embodiment, the homogeneity is achieved after a duration of about 10 minutes. After stirring for about 10 minutes, a suitable amount of one or more additives selected from the

group consisting of dispersants, defoamers and functional additives is added into the apparatus capable of high-speed stirring.

The entire mixture is allowed to stir to form the first mixture. In various embodiments, the first mixture is stirred for about 15 minutes or until the first mixture is stirred
5 homogeneously to form an emulsified state that is clear, transparent and homogenous.

In various embodiments, step (b) of the method involves slowly adding the colourant portion-wise after the first mixture has been stirred for about 15 minutes, thereby forming the second mixture. In a preferred embodiment, slow portion-wise addition of
10 the colourant occurs when the first mixture is stirred at a speed of about 300 revolutions/min to about 500 revolutions/min. Portion-wise addition of the colourant is more advantageous than adding the colourant as one batch because portion-wise addition of the colourant avoids agglomeration (or clumping) of the colourant. The second mixture is then stirred for another 20 to 30 minutes.

15 In various embodiments, step (b) of the method further comprises a step of stirring the second mixture at a speed of about 300 revolutions/min to about 500 revolutions/min to obtain a homogeneous mixture, followed by a speed of about 1000 revolutions/min to about 1500 revolutions/min at a temperature of about 40 °C
20 to about 50 °C.

In various embodiments, step (c) of the method further comprises transferring the second mixture to a processing mill and milling the second mixture to obtain a liquid colour concentrate having the desired viscosity and fineness. Advantageously, milling (or grinding) may reduce the particle size of the second mixture to achieve a
25 desired shade with maximum tinting strength. Preferably, the processing mill is a bead mill, wherein the structural properties of the beads can be adapted to obtain a liquid colour concentrate having the desired viscosity and fineness. In a preferred embodiment, the diameter of the beads is about 0.3 mm to about 2.4 mm. For instance, the processing mill may be two EDW-ELE full ceramic pin-type bead mill
30 EDW ELE stick pin horizontal sand mill in series, one of which is capable of coarse grinding and the other is capable of fine grinding, or a EDW-ELE full ceramic pin-type bead mill EDW-ELE stick pin horizontal sand mill combined with a three sticks

machine capable of grinding the second mixture. As the processing mill may comprise a stick pin horizontal sand mill, the processing mill is suitable for materials that require a moderately high viscosity or high fineness. Furthermore, the processing mill may be configured to be an efficient separation system, such that
5 there is no stopping or breakage of beads and the liquid colour concentrate may flow out smoothly with efficient high-energy density output. Accordingly, the method further comprises separating the second mixture so that any undesired material, such as the beads from the bead mill, can be removed. In a preferred embodiment, separation of the second mixture is by centrifugal separation using, for instance,
10 zirconia and ceramic material. In addition, the method of the present invention is efficient and has low production costs.

In various embodiments, the processing mill used for step (c) may comprise multiple cooling systems with strong cooling capabilities to effectively and completely reduce the heat generated during the grinding process, thereby reducing the occurrence of
15 accidents. Accordingly, step (c) further comprises cooling the second mixture during the milling of the second mixture to obtain the liquid colour concentrate. Consequently, the milling may advantageously occur at a temperature of about 50°C to about 80°C, more preferably about 60°C. In another preferred embodiment, the milling may occur at a temperature of less than 60°C. This may advantageously lead
20 to a prolonged lifetime of the processing mill because for instance, overheating of the components of the processing mill may be avoided.

The various steps of the method of manufacture of a liquid colour concentrate as described above leads to a liquid colour concentrate having strong dispersibility. As such, when mixed with a plastic resin, the coloured plastic product has improved
25 colour, gloss and/or saturation. Importantly, the reaction time, stirring speed and reaction temperature of the various steps described above were found to advantageously improve the dispersibility of the resultant liquid colour concentrate.

In an aspect, there is provided a system for manufacturing a coloured plastic
30 product, the system comprising: (a) a production system comprising a colour oil gauge and a mixer, the colour oil gauge operable to connect to a mixer; and (b) an injection molding machine comprising a hopper; wherein the mixer is operable to

receive and mix a liquid colour concentrate as described above and a plastic resin to form a mixture for transfer to the hopper to produce the coloured plastic product.

In an aspect and as illustrated in Figure 3, there is provided a method of manufacturing a coloured plastic product using a liquid colour concentrate, the method comprising providing an automated production system comprising a colour oil gauge connected to an apparatus capable of stirring (stirrer or mixer). At step 1", the raw materials (liquid colour concentrate and plastic resin) are passed through the automated production system to form a mixture.

In various embodiments, the method further comprises installing a colour oil gauge capable of measuring the amount of liquid colour concentrate (or colour oil) to the apparatus capable of stirring. The colour oil gauge allows the quantity of the liquid colour concentrate to be set according to the colour requirements of the coloured plastic product. Thereafter, the injection molding machine can be activated via the on/off switch.

In various embodiments, the method further comprises a production step (step 2"). Upon activation of the injection molding machine, the liquid colour concentrate and plastic resin will enter the apparatus capable of stirring via conduits (e.g. pipes) to form a mixture that will be mixed homogeneously. After the mixture has been mixed homogeneously, the mixture will enter the hopper of the injection molding machine (in other words, transferred to the hopper) and production of the coloured plastic product will start after the parameters of the injection molding machine have been set according to the product requirements. In various embodiments, after the mixture enters the hopper, the mixture feeds into an extruder. An extruder screw pushes the mixture through a heating chamber in which the mixture is then melted. At the end of the extruder, the molten mixture is forced at high pressure into a closed cold mold. The high pressure is needed to be sure the mold is completely filled. Once the mixture cools to a solid, the mold opens and the finished coloured plastic product is ejected. Consequently, the liquid colour concentrate can be applied evenly and homogeneously to the plastic resin in a satisfactory manner (i.e. to the desired quality for colour and performance), thereby leading to a savings in manpower and employment costs and minimizing of wastage of raw materials. More

advantageously, it is easy and convenient to change the colour of the liquid colour concentrate because of the "oil-adjusting-oil" technique. There is no need for too many persons during the manufacturing process, thereby achieving automation as illustrated in Fig. 3.

5

Examples

Non-limiting examples of the present disclosure will be further described, which should not be construed as in any way limiting the scope of the disclosure.

10 The colourants used in the following examples are commercially available from a number of sources well known to those skilled in the art. Commercially available pigments are well known to those skilled in the art and include organic and inorganic colourant chemistries. Commercially available dyes are well known to those skilled in the art and include all organic chemistries. Commercial sources for pigments and
15 dyes include companies such as BASF, LanXess, Ciba-Geigy, Color-Chem International, Sun Chemical and Zhuhai Skyhigh Chemicals.

Example 1: Comparison of Powdered Colourant, Solid Masterbatch and Liquid Masterbatch

20

When assessing the compatibility of the base polymer of a liquid colour concentrate and a plastic resin, the two different polymers typically need to have similar solubility parameters in order to be miscible with each other. However, this is not the case for some colourants because they may contain dyes that are non-polymeric. As such,
25 the molecular dispersion state of dyes is non-polymeric and the state of dispersion of the particles are not affected by the concept of solubility parameters. Therefore, after considering only structural similarity and miscibility and polar adsorption, it is believed that the compatibility of plastic colourants primarily depend on the compatibility in polarity, followed by temperature dependency, pressure, other
30 additives, etc.

Compatibility of the plastic resin with the liquid colour concentrate is not absolute; solubility leads to the colourant being dissolved or dispersed in the gaps of the resin molecules, while insolubility leads to the colourant being expelled to the surface of the plastic substrate. A colourant is typically present in a plastic substrate in one of three forms: (1) dissolved in a macromolecular resin; (2) dispersed in the matrix of the resin; (3) attached to or adsorbed on the surface of the plastic substrate.

1. Powdered colourant, is a powdered form of a non-polymeric dye. Its compatibility with plastic largely depends on temperature and pressure, and it is usually dispersed in the matrix of the resin or adsorbed on the surface of the plastic substrate.
2. Solid masterbatch, typically makes use of a carrier such as: straight-chain fatty acid salts (for example, oxidized polyethylene waxes, polyvinyl acetate, etc). Its compatibility with plastic depends on it having a certain degree of solubility, temperature and pressure, and it is usually dispersed in the matrix of the resin or adsorbed on the surface of the plastic substrate.
3. Liquid colour concentrate, typically makes use of an organic liquid carrier, and has good compatibility with plastic; it can be easily dissolved in the macromolecular structure of the resin due to its miscibility with plastic, temperature and pressure. Compared to other masterbatches, it has a broader scope of applicability, making it applicable to all resins; its use is non-polluting, more environmentally friendly and safe.

Table 2 illustrates the advantages and disadvantages of the 3 generations of colourants.

Table 2: Advantages and Disadvantages of 3 Generations of Colourants

Type of Colourant	Powdered Colourant	Solid Masterbatch	Liquid Masterbatch
State	powdery	granular	liquid
Safety Indication	dangerous	safe	safe
Degree of Pollution	serious	none	none

Product Characteristics	easy production of colour specks, unstable colouration	easy production of colour specks, poor colour predictability, unstable colouration	no colour specks, bright colouration, stable
Time taken for colour change (min)	30	10	10
Gloss/fullness (%)	70-80	75-85	95-100
Surface area of toner dot (%)	4-5	1-2	0
Performance	6	7-8	9-10
Scope of Application	specific resin	specific resin	compatible with all resins
Cost	low usage cost	high	moderate

(Note: The surface area of toner dot (or colour specks) in Table 2 was calculated by using plastic plates having the following dimensions: 65.1 mm x 45.7 mm and determining the proportion (%) of the entire plastic plate that contained toner dots (or colour specks). Using the starting materials as the reference materials, and setting them as 100%, the degree of gloss was determined using a German BYK 4446 gloss meter at 20°; performance of the plastic product was determined using a scale of 0-10, 0 representing a poor performance, while 10 representing the best performance.)

As shown in Table 2, the liquid masterbatch of the present invention is more advantageous than the powdered colourant and solid masterbatch because it is safe, environmentally friendly, possesses stable colouration and exhibits better performance. Furthermore, the liquid masterbatch is advantageously cost effective because of its moderate costs and afore-mentioned advantages.

The liquid masterbatch shown in Table 2, as exemplified by KY-000044M (more details in Example 4), has overcome the problems faced by powdered colourants

and solid masterbatches, and to a certain extent catalyzed the growth of the sluggish plastics industry.

Example 2: Effect of Using Different Carriers

5

When developing a liquid colour concentrate of the present invention, the compatibility of the base polymer of a liquid colour concentrate and a plastic resin was investigated by studying the effect of using carriers having a different molecular weight and hydroxyl value. By varying the ratio of the initial starting material and monomers used, a series of carriers having different average molecular weight and hydroxyl value were synthesized. Table 3 below shows various carriers synthesized in the present invention using alcohol as the starting material.

10

Table 3: Carriers having Different Molecular Weight and Hydroxyl Value

Alcohol/G	Alkanes Monomer/G	Hydroxyl value/G	Molecular Weight	Viscosity (cP)
200	220	2.8	200	2000
200	500	3.2	322	4000
200	750	5.8	500	4400
200	1300	10.5	800	4700
200	1600	14.3	1000	5000
200	2000	20.0	2000	6000
200	2250	25.0	3000	7500
200	3000	31.2	4000	10,000

15

The synthesized carriers having different molecular weight were subsequently mixed with acrylonitrile - styrene resin (ABS-758) in a ratio of 1kg ABS-758: 8g carrier, followed by injection molding into a 65.1mm × 45.7mm × 2.5mm transparent plastic sample. The compatibility of the synthesized carriers with the ABS-758 resin, viscosity, gloss template (or fullness), and performance comparison test experiments were carried out. Using the ABS-758 resin, mixing degree of difficulty, compatibility, and other aspects of the comparative test experiments are shown in Table 4 below.

20

Table 4: Investigation of the Compatibility of Various Carriers with ABS-758 resin

Molecular Weight of the Carrier	200	322	500	800	1000	2000	3000	4000
Solubility (%)	20	19.7	18	17.8	16	15.2	13	10
Colour Fluidity*	10	10	8	6	5	3	1	0
Stability	Separation	Stable	Stable	Stable	Stable	Stable	Stable	Stable
Mixing State of Plastic Resin with Powdered Colourant	Homogeneous	Homogeneous	Homogeneous	Difficult to achieve homogeneity	Difficult to achieve homogeneity	Slightly difficult to achieve homogeneity	Slightly difficult to achieve homogeneity	Slightly difficult to achieve homogeneity
Difficulty of Clean up	Easy	Easy	Easy	Moderate	Difficult	Difficult	Difficult	Difficult
Miscibility with Plastic Resin*	10	10	9	7	5	4	2	0
Compatibility with Plastic Resin	Miscible	Miscible	Miscible	Miscible	Miscible	Miscible	Miscible	Miscible
Gloss (%)	100	100	100	100	100	100	100	100

Note: The best fluidity being 10, 0 being no fluidity; For testing the fluidity, vegetable oil was used as the standard. Under the conditions of the in-house laboratory, the vegetable oil was heated to 25°C and the viscosity of the vegetable oil was measured using a Stormer-IV viscometer and determined to be 41 KU. The viscosity of the various test liquids was determined under the

same conditions. For viscosity values of 41-43 KU, a rating of 10 was given and represents the best fluidity. The fluidity rating decreased by 1 for every increase of 5KU relative to the viscosity of the vegetable oil (i.e. 41 KU). The miscibility of the test liquid with a plastic resin is directly proportional to the fluidity of the liquid colourant. In general, the better the fluidity of the liquid colourant, the better and easier the miscibility of the liquid colourant with the plastic resin. The degree of miscibility with a plastic resin is measured from 1 to 10, wherein a degree of miscibility with plastic resin of 10 represents the best miscibility, 0 representing difficulty in mixing. For testing the miscibility with a plastic resin, the following standard was used: test compound and plastic resin was mixed to give a resin volume, wherein the ratio of the test compound to that of the reference was determined and graded, with 100% being equivalent to a 10 grade and representing the best miscibility, and 0% being equivalent to a 0 grade and representing the worst miscibility.

The results show that the carriers having different molecular weight showed good compatibility with the ABS-758 resin. Furthermore, the molecular weight of the carrier had no effect on the compatibility of the carrier with the resin as evidenced by miscibility of all the carriers tested with the ABS-758 resin. In general, the viscosity of the test liquid increased as the molecular weight of the carrier increased, thereby exhibiting a decrease in the fluidity. For instance, a fluidity of 0 to 3 was obtained using a carrier having a molecular weight between 2000 to 4000. In contrast, good fluidity of 6 to 10 was obtained using a carrier having a molecular weight between 200 to 800 and a viscosity of between 2000 cP to 4700 cP. Furthermore and advantageously, the performance and gloss of the plastic resin was not affected after injection molding was carried out, thereby demonstrating that the carriers used are compatible with the plastic resin. More advantageously, when a carrier having a molecular weight between 200 and 500 was used, homogeneous colouring was observed.

Of all the carriers synthesized, the carrier having a low molecular weight of 322 exhibited a low viscosity and consequently, a good fluidity of 10. Besides exhibiting good fluidity, it also exhibited good miscibility and good compatibility with the plastic resin, which led to a more successfully completed injection molding process.

In view of the above, the carrier having a molecular weight of 322 was determined to be the most preferred carrier.

The ABS-758 resin was replaced by the following resins: polyethylene terephthalate (PET), polycarbonate (PC), acrylonitrile - butadiene (AB), polypropylene (PP), high density polyethylene (HDPE) and low density polyethylene (LDPE), and the experimental procedures outlined above were repeated using each resin with carriers having a different molecular weight. Comparative tests were carried out, and the results obtained were identical to those shown in Table 4. As such, the carriers used in the present invention are versatile because the carriers are not compatible with only one type of plastic resin.

Example 3: Effect of Using Different Polyols as the Carrier

In order to study the suitability of different polyols as the carrier, a comparative study using a polyether polyol, such as DS-206 polyether polyol, and a polyester polyol, such as adipic acid polyester polyol was carried out. The method of the present invention was used to synthesize the liquid colour concentrates using different polyols as the carrier, and the only other component used was a red toner, such as 3307 red toner. The results are illustrated in Table 5.

Table 5: Comparison of Polyols

Type of Polyol	DS-206 Polyether polyol	Adipic Acid Polyester Polyol
Fluidity	Good	Average
Surface State of Liquid Colour Concentrate	Good levelling, no oil slick	Poor levelling, small quantities of oil slick
Stability	Stable	Formation of layers
Environmental friendliness	Friendly	Pollution exists
Difficulty of Cleaning Up*	Easy to Clean up	More difficult to clean up
Additional Information about Polyol	Appearance at 25°C: colourless to light yellow sticky liquid Hydroxyl value (mgKOH/g): 178-197 Acid value (mgKOH/g): ≤0.15 Moisture (%): ≤0.20 K ⁺ Na ⁺ (ppm): ≤8 Colour (APHA): ≤50	

*The Parameter of Difficulty of Cleaning Up in Table 5 refers to: During the manufacturing process of the liquid colour concentrate, there will be remnants of the

polyol in the machinery used, which can be easily cleaned up using a damp cloth (i.e. cloth wet with water) if DS-206 polyether polyol is used. In contrast, if adipic acid polyester polyol is used, acetone or other organic solvents has to be used for cleaning because adipic acid polyester polyol is immiscible with water. Use of an organic solvent is not as environmentally friendly as using water. Furthermore, disposal or treatment of the organic solvent may lead to pollution and increase production costs. As such, the use of a polyether polyol as the carrier of a liquid colour concentrate is more environmentally friendly because water may be used to clean the machinery used during manufacture of the liquid colour concentrate of the present invention. Furthermore, when a polyether polyol is used as the carrier, there was good fluidity, stability and good levelling, with no formation of oil slicks. In contrast, when adipic acid polyester polyol was used as the carrier, the fluidity was average and there was poor levelling and formation of small quantities of oil slicks.

Example 4: Example of Liquid Colour Concentrate of Present Invention

As mentioned previously, the liquid colour concentrate of the present invention allows a user to easily mix two or more different liquid colour concentrates (or colour oils) to obtain the desired colour i.e. the technique of "oil-adjusting-oil" is achieved.

This is primarily achieved by using a polyether polyol as the carrier. To demonstrate this ability, a liquid colour concentrate, fluorescent red KY-000044M, was synthesized using the method of the present invention. The liquid colour concentrate, fluorescent red KY-000044M, is obtained using the technique of "oil-adjusting-oil" by mixing three different liquid colour concentrates, namely KY-403 Red, KY-408B Fluorescent Red and KT-201M White.

Table 6 shows the formulation of fluorescent red KY-000044M, while Tables 7 to 9 show the formulation of the constituent liquid colour concentrates of fluorescent red KY-000044M, namely KY-403 Red, KY-408B Fluorescent Red and KT-201M White.

Table 6: Formulation of fluorescent red KY-000044M

Product Name	Fluorescent Red KY-000044M		
Liquid Colour Serial No.	KY-403 Red	KY-408B Fluorescent Red	KT-201M White
Proportion (%)	63.3	25	11.7

Table 7: Formulation of KY-403 Red

Product Name	KY-403 Red		
Component	DS-206 Polyether polyol	Bright Red Powdered Colourant	Silicone
Proportion (%)	45-65	34-54	0.3-1

5

Table 8: Formulation of KY-408B Fluorescent Red

Product Name	KY-408B Fluorescent Red		
Component	DS-206 Polyether polyol	Fluorescent Red Powdered Colourant	Silicone
Proportion (%)	64.5-79.5	20-35	0.3-0.5

Table 9: Formulation of KT-201M White

Product Name	KT-201M White		
Component	DS-206 Polyether polyol	Titanium Dioxide	Silicone
Proportion (%)	19-34	65-80	0.5-1

- 10 Accordingly, fluorescent red KY-000044M was tested and shown to have no segregation, exhibited uniform colour distribution and no formation of colour specks even after standing for one year. Consequently, these results show that a liquid colour concentrate formed using the technique of "oil-adjusting-oil" shows good stability.

15

Example 5: Comparison of Liquid Colour Concentrate of the Present Invention and Existing Commercially Available Liquid Colour Concentrates

5 Due to the sluggish plastics industry, various companies worldwide have put in efforts to develop new colourants, in particular, liquid colour concentrates. Table 10 shows a comparison of the advantages and disadvantages of the liquid colour concentrate of the present invention and existing commercially available liquid colour concentrates.

10

Table 10: Advantages and Disadvantages of Present Invention and Existing Commercially Available Liquid Colour Concentrates

Type	Liquid Colour Concentrate of the Present Invention	Existing Commercially Available Liquid Colour Concentrates
Scope of Application	specific colour for specific use, easily co-formulated	specific colour for specific use
Physical Stability	stable, no precipitation, no stratification	precipitation forms upon standing for 1-2 months, formation of layers
Stability of Formulation	good stability, uniform colour distribution, no formation of colour specks	cannot be easily co-formulated

As shown in Table 10, existing commercially available liquid colour concentrates cannot be easily co-formulated. Not only does this result in significant amounts of time being lost, the amount of raw materials used increases substantially and the cost of manufacturing also increases. In contrast, the liquid colour concentrate of the present invention can be tailored for a specific use by using a specific colour, and can be easily co-formulated. Consequently, if a client needs a particular combination of colours, the desired colour combination can be readily formulated on-demand by mixing the constituent liquid colour concentrates on the spot, until the client is satisfied with the particular combination of colours. Not only is this a convenient

process, the entire process can lead to a savings in time, efforts and overall reduction in manufacturing costs. Furthermore, the storage stability of the formulation is long and has good stability, uniform colour distribution and does not result in formation of colour specks or layers, as exemplified in Example 4.

5

Example 6: Synthesis of Various Coloured Plastic Substrates

Five different samples were synthesized using the method of manufacture of the present invention, which involves the use of laboratory scale multi-functional stirring
10 mills, dispersion and milling. Table 11 below shows the experimental results obtained when the samples were subjected to various experimental conditions. Injection molding experiments were carried out using a variety of resins, and mainly carried out in an injection molding machine. ABS-758 was injection molded at a temperature of about 230-250 °C, PC was injection molded at a temperature of about
15 280-300 °C, PET was injection molded at a temperature of about 260-280 °C, PP was injection molded at a temperature of about 180-220 °C, PE was injection blow molded at a temperature of about 200 °C. In all the five samples, the colouration was homogeneous and stable, the surface gloss and fullness were high, and the resultant coloured plastic substrates were brightly coloured and did not exhibit any colour
20 specks. As such, the performance of all the coloured plastic substrates was enhanced using the liquid colour concentrate of the present invention.

Table 12 illustrates details of the components used in Table 11. In addition, the performance of one of the samples (i.e. Example 1 of Table 11) was compared with
25 that of a commercially available liquid colour concentrate. Specifically, the performance was measured using the following parameters: colour fluidity, surface state of coloured plastic product, and stability. As illustrated in Table 13, Example 1 of Table 11 exhibited superior qualities over the comparative Example.

30

Table 11: Weight ratio of the components was used

Example	1	2	3	4	5
Component					
DS-206 polyether polyol	32%	80%	79%	68.9%	59%
DF-881 silicone defoamers	1%	0.3%	1%	0.3%	0.5%
Huntsman RTC30 titanium dioxide	66%				
3307 red toner		19.7%			
5102 green powder			20%		
1005 yellow powder				30%	
4003 blue powder					40%
HL-200 thickener				0.8%	0.5%
TH-568 polymer dispersant	1%				
Total	100%	100%	100%	100%	100%
Injection molding experiments	Resultant white colour oil was injection molded with ABS-	Resultant colour oil was injection molded with PC- 2805 resin	Resultant colour oil was injection molded with PET- CB602	Resultant colour oil was injection molded with South Korean SK	Resultant colour oil was injection molded with Maoming Petrochemical PE 5502 resin

	758 resin		resin	Corporation PP R370Y resin	using an injection blow molding machine
Ratio	ABS-758 resin: colour oil = 1000:10	PC-2805 resin: colour oil = 1000:8	PET- CB602 resin: colour oil = 1000:8	South Korean SK Corporation PP R370Y resin: colour oil = 1000:6	Maoming Petrochemical PE 5502 resin: colour oil = 1000: 6
Performance	10	10	10	10	10

Table 12: Details of Components in Table 11

Component Name	International Number	Type	Colour
3307 red toner	P.R. 170	Oxygen anthracene	red
5102 green powder	P.G. 7	Phthalocyanine Green G	green
1005 yellow powder	P.Y.12	Monoazo	yellow
4003 blue powder	P.B.15:1	Copper phthalocyanine	blue
HL-200 thickener		Silica thickener	white
TH-568 polymer dispersant		High molecular weight polymer	light yellow

Table 13: Comparison of Example 1 of Table 11 with a Commercially Available Liquid Colour Concentrate

Performance	White Liquid Colourant	Comparative Example 2
Colour fluidity	Excellent	Good
Colour liquid surface state	Good leveling; no oil slick	Average leveling; oil slick present
Stability	Stable	Serious separation of layers

It will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the invention. It is intended that all such modifications and adaptations come within the scope of the appended claims.

- 5 Further, it is to be appreciated that features from various embodiment(s), may be combined to form one or more additional embodiments.

Claims

1. A liquid colour concentrate, comprising:

(a) a carrier comprising a polyether having an average molecular weight of about 300 to about 400,000;

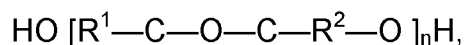
(b) a colourant; and

(c) one or more additives selected from a group consisting of dispersants, defoamers and functional additives,

wherein the carrier is in an amount of about 30% to about 80% by weight of the liquid colour concentrate, the colourant is in an amount of about 10% to about 40% by weight of the liquid colour concentrate and the one or more additives is in an amount of about 0.2% to about 10% by weight of the liquid colour concentrate.

2. The liquid colour concentrate of claim 1, wherein the polyether is a copolymer, homopolymer or a mixture thereof.

3. The liquid colour concentrate of claim 1 or 2, wherein the structure of the polyether is:



wherein $1 \leq n \leq 1000$,

wherein $\text{R}^1 = \text{R}^2$ when the polyether is a homopolymer, wherein $\text{R}^1 \neq \text{R}^2$ when the polyether is a copolymer, and

wherein R^1 and R^2 are independently an alkyl group comprising of 1 to 50 carbons.

4. The liquid colour concentrate according to any one of claims 1 to 3, wherein the polyether has a molecular weight of about 300 to about 1000.

5. The liquid colour concentrate according to claim 4, wherein the polyether has a molecular weight of about 300 to about 500.

6. The liquid colour concentrate according to any one of claims 1 to 5, wherein the polyether has a viscosity of about 2000 cP to about 5000 cP.
7. The liquid colour concentrate according to any one of claims 1 to 6, wherein the
5 colourant comprises one or more organic powdered colourant, one or more inorganic powdered colourant or a combination thereof.
8. The liquid colour concentrate according to any one of claims 1 to 7, wherein the
10 functional additives comprises one or more levelling agents, anti-oxidants, light stabilizers, antistatic agents, steel agents, nucleating agents or brighteners.
9. The liquid colour concentrate according to any one of claims 1 to 8, wherein the liquid colour concentrate is capable of forming a homogenous mixture with a plastic resin comprising acrylonitrile - butadiene, acrylonitrile - butadiene - styrene,
15 polymethyl methacrylate, polyethylene terephthalate, polycarbonate ester, polyethylene terephthalate-1,4-cyclohexanedimethanol, polybutylene terephthalate, thermoplastic elastomer, polypropylene, high density polyethylene or low density polyethylene.
- 20 10. The liquid colour concentrate of claim 9, wherein the liquid colour concentrate is in an amount of about 0.2% to about 0.8% by weight of the plastic resin.
11. The liquid colour concentrate according to any one of claims 1 to 10, wherein the liquid colour concentrate has a viscosity of about 6000 cP to about 13,000 cP, and a
25 particle size of about 0.2 μm to about 8.0 μm .
12. A method of preparing a liquid colour concentrate, the method comprising blending two or more of a liquid colour concentrate of any one of claims 1 to 11.
- 30 13. A coloured plastic product comprising at least one liquid colour concentrate of any one of claims 1 to 11 and a plastic resin.

14. The coloured plastic product of claim 13, wherein the plastic resin comprises one or more of acrylonitrile - butadiene, acrylonitrile - butadiene - styrene, polymethyl methacrylate, polyethylene terephthalate, polycarbonate ester, polyethylene terephthalate-1,4-cyclohexanedimethanol, polybutylene terephthalate, thermoplastic elastomer, polypropylene, high density polyethylene or low density polyethylene.

15. A method of manufacturing a liquid colour concentrate, the method comprising:

(a) mixing a carrier comprising a polyether having an average molecular weight of about 300 to about 400,000, with one or more additives selected from a group consisting of dispersants, defoamers and functional additives to form a first mixture;

(b) adding a colourant to the first mixture to form a second mixture; and

(c) milling the second mixture to obtain a liquid colour concentrate, wherein the carrier is in an amount of about 30% to about 80% by weight of the liquid colour concentrate, the colourant is in an amount of about 10% to about 40% by weight of the liquid colour concentrate and the one or more additives is in an amount of about 0.2% to about 10% by weight of the liquid colour concentrate.

16. The method of claim 15, wherein the polyether is a copolymer, homopolymer or a mixture thereof.

17. The method of claim 15 or 16, wherein the polyether has an average molecular weight of about 300 to about 1000.

18. The method of claim 17, wherein the polyether has an average molecular weight of about 300 to about 500.

19. The method according to any one of claims 15 to 18, wherein step (a) further comprises stirring the carrier homogeneously.

20. The method according to claim 15, wherein the first mixture is stirred for about 15 minutes.

21. The method according to any one of claims 15 to 20, wherein step (b) further comprises stirring the second mixture for about 20 to 30 minutes.

5 22. The method according to claim 21, wherein stirring of the second mixture occurs at a speed of about 300 revolutions/min to about 500 revolutions/min.

23. The method according to claim 21, wherein stirring of the second mixture further comprises stirring the second mixture at a speed of about 1000 revolutions/min to
10 about 1500 revolutions/min at a temperature of about 40°C to about 50°C.

24. The method according to any one of claims 15 to 23, wherein step (c) comprising milling the second mixture with a processing mill, wherein the processing mill is a bead mill.

15 25. The method according to claim 24, wherein the diameter of the beads of the bead mill is about 0.3 mm to about 2.4 mm.

26. The method according to any one of claims 15 to 25, wherein step (c) further comprises cooling the second mixture during the milling of the second mixture to
20 obtain the liquid colour concentrate.

27. The method according to claim 26, wherein the milling occurs at a temperature of about 50°C to about 80°C.

25 28. The method according to claim 27, wherein the milling occurs at a temperature of about 60°C.

29. The method according to any one of claims 15 to 28, the method further comprising separating the second mixture.

30

30. A system for manufacturing a coloured plastic product, the system comprising:

- (a) a production system comprising a colour oil gauge and a mixer, the colour oil gauge operable to connect to a mixer; and
- (b) an injection molding machine comprising a hopper;

5

wherein the mixer is operable to receive and mix a liquid colour concentrate of any one of claims 1 to 11 and a plastic resin to form a mixture for transfer to the hopper to produce the coloured plastic product.

31. A method of manufacturing a coloured plastic product, the method comprising:

10

- (a) providing an automated production system comprising a colour oil gauge connected to a mixer;
- (b) passing a liquid colour concentrate of any one of claims 1 to 11 and a plastic resin through the automated production system to form a mixture;
- (c) stirring the mixture homogeneously using mixer;

15

- (d) transferring the mixture to a hopper of an injection molding machine to produce the coloured plastic product.

32. The method of claim 31, wherein step (b) further comprises transferring the liquid colour concentrate and the plastic resin to the apparatus capable of stirring via conduits to form the mixture.

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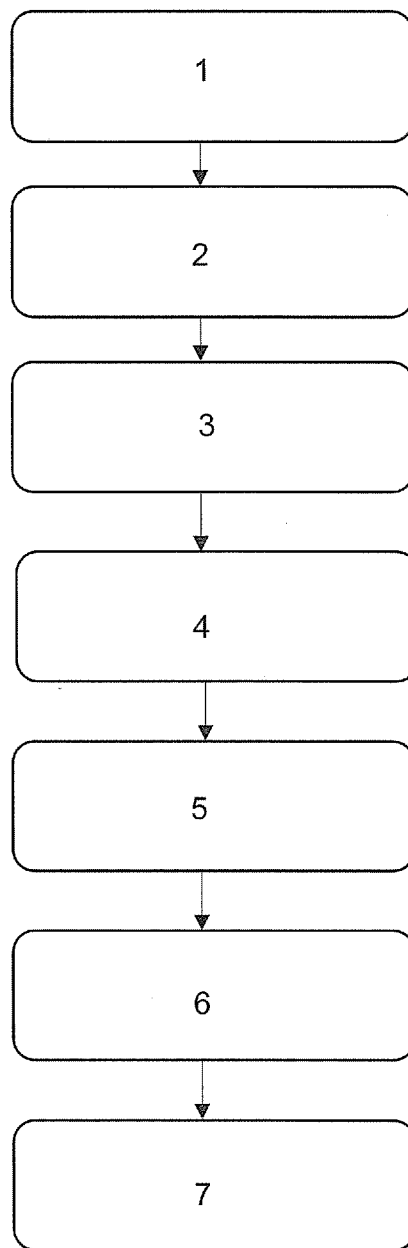


Figure 1

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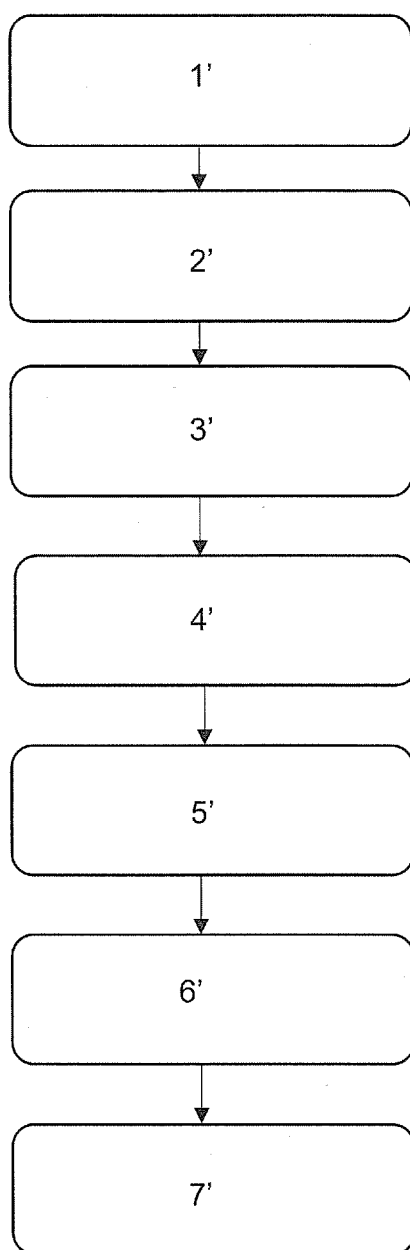


Figure 2

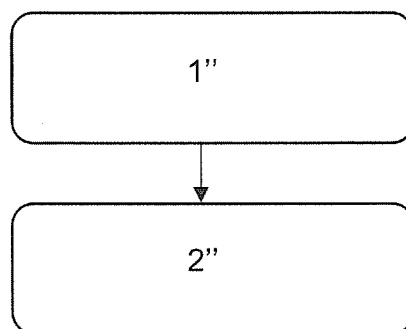


Figure 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2017/050160

A. CLASSIFICATION OF SUBJECT MATTER

C08L 71/02 (2006.01) C09B 67/00 (2006.01) C08J 3/22 (2006.01)

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C09B, C08L, C08J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Databases: REGISTRY, CAPLUS, EPODOC, WPIAP, Scopus and FAMPAT

Keywords: liquid, colourant, concentrate, masterbatch, polyether, polyethylene glycol, 聚醚, 母料, 塑料, 树脂 and related terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4167503 A (CIPRIANI C.) 11 September 1979 examples 2 and 5	1-32
X	US 2010/0204395 A1 (RAJARAMAN H.) 12 August 2010 tables 3-4; examples; and paras [0007], [0009]-[0011], [0014]-[0015], [0017], [0019]-[0021], [0027], [0029]-[0032], [0037], [0038] and [0041]	1-32
A	JP H01-204970 A (KATAOKA K. ET AL.) 17 August 1989 whole document	
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A	WO 2008/045821 A1 (POLYONE CORPORATION) 17 April 2008 whole document	
A	WO 2007/121044 A1 (POLYONE CORPORATION) 25 October 2007 whole document	

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

15/05/2017

(day/month/year)

Date of mailing of the international search report

30/05/2017

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2017/050160

Note: This Annex lists known patent family members relating to the patent documents cited in this International Search Report. This Authority is in no way liable for these particulars which are merely given for the purpose of information.

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