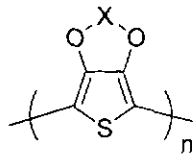
We claim

1. Aqueous formulation of water dispersible polymers of 3,4-alkylenedioxythiophene of the formula IV:



Formula IV

wherein X represents $-CH_2CH_2-$ or $CH_2C(RR')CH_2-$, wherein R represents a $-CH_2-O-(CH_2)_A-B$, wherein A represents 0 to 10 and B represents a hydrogen or a C_1-C_5 linear or branched alkyl or aryl group optionally substituted by one or more groups selected from amines, carboxylic acids, alcohols, ethers, sulfonic acids, thiols or amides; R' represents R as defined above or hydrogen or C_1-C_3 linear or branched alkyl group or aryl group optionally substituted by one or more groups selected from aryl, propargyl or azide and n is the number of recurring or repeating polymer units, the formulation comprising a dispersion of nano particles of the polymers of 3,4-alkylenedioxythiophene in water.

2. The formulation as claimed in claim 1, which comprises polymers of 3,4-alkylenedioxythiophene in the particle sizes of about 20 to 350 nm.

3. A process for the preparation of aqueous formulation of water dispersible polymers of 3,4-alkylenedioxythiophene of the formulae IV:

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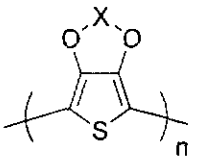

Formula IV

wherein X represents $-CH_2CH_2-$ or $CH_2C(RR')CH_2-$, wherein R represents a $-CH_2-O-(CH_2)_A-B$, wherein A represents 0 to 10 and B represents a hydrogen or a C_1-C_5 linear or branched alkyl or aryl group optionally substituted by one or more groups selected from amines, carboxylic acids, alcohols, ethers, sulfonic acids, thiols or amides; R' represents R as defined above or hydrogen or C_1-C_3 linear or branched alkyl group or aryl group optionally substituted by one or more groups selected from aryl, propargyl or azide and n is the number of recurring or repeating polymer units, which process comprises shearing mixing the water dispersible polymers of the 3,4-alkylenedioxythiophene of the formula IV in water at a pressure of 100 to 5000 atmospheres to form a dispersion of nano particles of the polymers followed by separating the dispersion by filtration.

4. The process as claimed in claim 3, wherein the water dispersible polymers of 3,4-alkylenedioxythiophene are shear mixed in water in powder form.

5. The process as claimed in claim 3 or 4, wherein the dispersion comprises nano particles of the polymers in the particle sizes of about 20 to 350 nm.

6. The process as claimed in anyone of claims 3 to 5, wherein the shear mixing of the polymers is carried out in the presence of an oxidizing agent

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7. The process as claimed in claim 6, wherein the oxidizing agent is selected from sodium peroxydisulphate, hydrogen peroxide, horse radish peroxidase or ferric salt or combination thereof and is preferably sodium peroxydisulphate.

8. The process as claimed in anyone of claims 3 to 5, wherein the shear mixing of the polymers is carried out in the presence of a polymeric or monomeric anionic, cationic or neutral surfactant.

9. The process as claimed in claim 8, wherein the polymeric anionic surfactant is a polyelectrolyte selected from polyanionic polystyrene sulfonate (PSS) sodium salt or polyacrylic acid sodium salt and is preferably PSS sodium salt.

10. The process as claimed in claim 8, wherein the monomeric anionic surfactant is selected from sodium dodecyl sulfonate, sodium dodecyl benzene sulfonate or sodium lauryl sulfonate and is preferably sodium dodecyl sulfonate.

11. The process as claimed in claim 8, wherein the polymeric cataionic surfactant is selected from polyethylene amines or polyoxymethylene amines and is preferably polyethylene amines.

12. The process as claimed in claim 8, wherein the polymeric neutral surfactant is selected from block copolymers of polystyrene-polyethylene oxide or polyethylene glycol esters and is preferably block copolymers of polystyrene-polyethylene oxide.

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13. The process as claimed in claim 8, wherein the monomeric cataionic surfactant is selected from dodecyl ammonium bromide, cetyltrimethyl ammonium bromide or hexadecyl trimethyl ammonium bromide and is preferably dodecyl ammonium bromide.

14. The process as claimed in claim 8, wherein the monomeric neutral surfactant is selected from otoxynol or ethoxylated aliphatic alcohols and is preferably otoxynol.

15. The process as claimed in any one of claims 3 to 5, wherein the shear mixing of the polymers is carried out in the presence of a water soluble viscosity modifier polymer.

16. The process as claimed in claim 15, wherein the viscosity modifier polymer is selected from polyethyleneoxide, polyvinylpyrrolidone, polypropyleneoxide, polyethylene glycol, polypropylene glycol or polyvinyl alcohol and is preferably polyethyleneoxide.

17. The process as claimed in any one of claims 3 to 5, wherein the shear mixing of the polymers is carried out in the presence of a water soluble organic solvent.

18. The process as claimed in claim 17, wherein the organic solvent is selected from dimethyl sulfoxide, N-methylpyrrolidone, dimethylformamide, ethylene glycol or sorbitol and is preferably dimethyl sulfoxide.

19. The process as claimed in anyone of claims 3 to 18, wherein the shear mixing of polymers is carried out by mechanical agitation, sonication or homogenization.

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20. The process as claimed in claim 19, wherein the shear mixing of the polymers is carried out by homogenization in a high pressure homogenizer.

Dated this 11th day of October 2010.

Indian Institute of Technology, Bombay
By their Agent & Attorney

(Jose M A)
of Khaitan & Co
Reg No IN/PA-44

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FIELD OF THE INVENTION

This invention relates to aqueous formulation of polymers of 3,4-alkylenedioxythiophene and process for the preparation thereof.

The term polymers as used in the specification in relation to 3, 4-alkylenedioxythiophene in the context of the invention includes oligomers and copolymers thereof.

BACKGROUND OF THE INVENTION

Polymers of 3,4-alkylenedioxythiophene exhibit excellent chemical and thermal stability in their reduced and oxidized forms. They also exhibit high conductivity and are transparent in their conducting form. Because of the above properties, polymers of 3,4-alkylene dioxythiophene are used for various applications in diverse fields. For instance, they are used in display devices, photovoltaics, electrochromic devices, chemical and biological sensors, antistatic, transparent or conducting coatings, conducting paints or adhesives or as hole transparent layer in thin film devices like LEDs [Electrochemistry of Poly(3,4-alkylenedioxythiophene) derivatives, Groenendaal,L.; Zotti,Gianni; Aubert,Pierre Henri; Waybright,Shane M.; Reynolds,John R; Advanced Materials, 15,11,2003, pp 855-879].

Polymers of 3,4-alkylenedioxythiophenes are prepared by polymerizing the 3,4-alkylenedioxythiophene monomers oxidatively using oxidizing agents like ferric salt such as ferric chloride or tosylate or sodium peroxydisulphate or reductively using Grignard Metathesis Polymerization or Palladium(II) compounds catalyzed coupling reaction [Spray Coatable

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Electrochromic Dioxythiophene Polymers with High Coloration Efficiencies, Reeves,B.D.; Grenier,C.R.G.; Argun,A.A.; Cirpan,A.; McCarley,T.D.; Reynolds,J.R.; Macromolecules, 37, 20, pp 7559-7569; Single Step Reductive Polymerization of Functional 3,4-Propylenedioxythiophenes via Direct C-H Arylation Catalyzed by Palladium Acetate, Anshu Kumar, Anil Kumar, Polymer Chemistry, 2010, 1, 286-288]. In case ferric salt is used in the oxidative polymerisation, the polymers will contain iron impurity and this may not be acceptable in some applications, in which case the iron impurity will have to be removed by ion exchange treatment.

Reductive polymerization generally gives polymers with improved material properties and hence is the preferred method for polymerization. However, Grignard Metathesis reductive polymerization requires extremely dry solvents like tetrahydrofuran and drastic reaction conditions. Therefore, it is uneconomical and cumbersome to carry out. Palladium (II) compounds catalysed coupling polymerisation is carried out in organic solvents under normal conditions. Further the palladium (II) compounds catalysed coupling polymerisation gives polymers with functional groups which play a very important role in tailoring or adapting the properties of the polymers to suit various applications. Therefore, within the reductive polymerisation, palladium (II) compounds catalysed coupling is preferred as it is versatile, easy and convenient to carry out and economical.

Organic soluble polymers of 3,4-alkylenedioxythiophenes of the formulae I and II:

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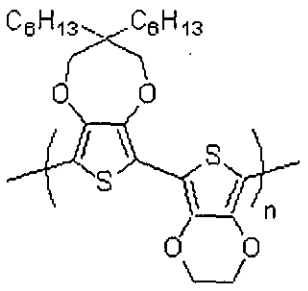
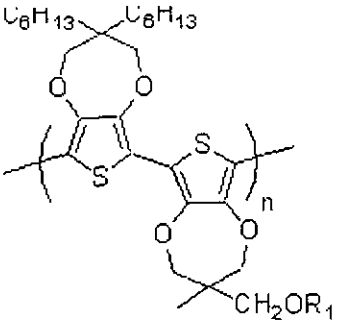


Formula I



Formula II

wherein R_1 is H, CH_2CH_2CN, CH_2COOEt, $C_6H_{12}Br$ or $C_6H_{12}N_3$ and n is the number of repeating or recurring units of the polymer are prepared by palladium (II) compounds catalysed polymerization. [Single Step Reductive Polymerization of Functional 3,4-Propylenedioxythiophenes via Direct C-H Arylation Catalyzed by Palladium Acetate, Anshu Kumar, Anil Kumar, Polymer Chemistry, 2010, 1, 286-288].

Many of the important applications or uses of the polymers of 3,4-alkylenedioxythiophene are in their conducting form. In order to make effective use of the polymers for variouos applications it is, therefore, essential that the polymers are dispersible in solvents in their conducting state. The conducting forms of the polymers of 3,4-alkylenedioxythiophene are generally insoluble in non-polar organic solvents. In order to make formulations of conducting forms of the above polymers, highly polar organic solvents are required. As a result, the choice of the solvents is limited and the potential use or versatility of use of the polymers is limited. Use of organic solvents for dissolution of the polymers also increases the cost. Further the formulations are monomer specific in that each formulation is formulated starting with a specific monomer. The monomers are few and therefore the number of polymers that can be made are also limited thereby limiting the number of applications of the polymers.

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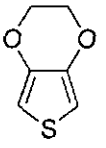
Aqueous dispersions of the polymers of 3,4-ethylenedioxythiophene of the formula III

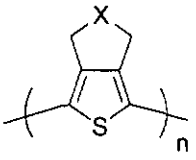


Formula III

are prepared by in situ oxidative polymerization of the monomer in the presence of anionic surfactant. A commonly used oxidising agent is a combination of sodium peroxydisulphate and ferric salt like ferric chloride. A commonly used anionic surfactant is electrolyte like polyanionic polystyrene sulfonate (PSS) sodium salt. Such dispersions are available under the trade name "CLEVIOS" (www.clevios.com). Oxidative polymerisation has the disadvantage as stated earlier. Use of surfactant like PSS sodium salt in the polymerisation reaction gives rise to acid formulation which may not be acceptable in some applications of the polymeric formulations.

DETAILED DESCRIPITON OF THE INVENTION

According to the invention there is provided an aqueous formulation of water dispersible polymers of 3,4-alkylenedioxythiophene of the formula IV:



Formula IV

wherein X represents $-CH_2CH_2-$ or $CH_2C(RR')CH_2-$, wherein R represents a $-CH_2-O-(CH_2)_A-B$, wherein A represents 0 to 10 and B represents a hydrogen or a C_1-C_5 linear or branched alkyl

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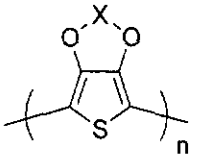
or aryl group optionally substituted by one or more groups selected from amines, carboxylic acids, alcohols, ethers, sulfonic acids, thiols or amides; R' represents R as defined above or hydrogen or C_1-C_3 linear or branched alkyl group or aryl group optionally substituted by one or more groups selected from aryl, propargyl or azide and n is the number of recurring or repeating polymer units, the formulation comprising a dispersion of nano particles of the polymers of 3,4-alkylenedioxythiophene in water.

According to the invention there is also provided a process for the preparation of aqueous formulation of water dispersible polymers of 3,4-alkylenedioxythiophene of the formulae IV:



Formula IV

wherein X represents $-CH_2CH_2-$ or $CH_2C(RR')CH_2-$, wherein R represents a $-CH_2-O-(CH_2)_A-B$, wherein A represents 0 to 10 and B represents a hydrogen or a C_1-C_5 linear or branched alkyl or aryl group optionally substituted by one or more groups selected from amines, carboxylic acids, alcohols, ethers, sulfonic acids, thiols or amides; R' represents R as defined above or hydrogen or C_1-C_3 linear or branched alkyl group or aryl group optionally substituted by one or more groups selected from aryl, propargyl or azide and n is the number of recurring or repeating polymer units, which process comprises shearing mixing the water dispersible polymers of the 3,4-alkylenedioxythiophene of the formula IV in water at a pressure of 100 to 5000 atmospheres to form a dispersion of nano particles of the polymers followed by separating the dispersion by filtration.

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The polymers used for making the formulation of the invention are new and are prepared by the process described in our Patent Application No _____ filed on _____

Preferably the dispersion of polymers of 3, 4-alkylenedioxythiophenes comprises the polymers in the particle sizes of about 20 to 350 nm. Preferably, the polymers of formula IV are shear mixed in water in powder form.

According to an embodiment of the invention, the shear mixing of the polymers of the formula IV is carried out in the presence of an oxidising agent in order to improve the conductivity of the formulation. The oxidizing agent is selected from sodium peroxydisulphate, hydrogen peroxide, horse radish peroxidase or ferric salt such as ferric chloride or tosylate or combination thereof and is preferably sodium peroxydisulphate. In case the oxidation is carried out in the presence of ferric salt, the dispersion after filtration is, if required, subjected to an exchange treatment to remove iron particles in the formulation. Ferric chloride is a preferred ferric salt.

According to another embodiment of the invention, the shear mixing of the polymers of the formula IV is carried out in the presence of a surfactant so to improve the thermal stability of the formulation. The surfactant is selected from a polymeric or monomeric anionic, cationic or neutral surfactant. The polymeric anionic surfactant is preferably a polyelectrolyte selected from polyanionic polystyrene sulfonate (PSS) sodium salt or polyacrylic acid sodium salt and is preferably PSS sodium salt. The monomeric anionic surfactant is selected from sodium dodecyl sulfonate, sodium dodecyl benzene sulfonate or sodium lauryl sulfonate and is preferably sodium dodecyl sulfonate. The polymeric cataionic surfactant is selected from polyethylene amines or poloxymethylene amines and is preferably polyethylene amines. The polymeric neutral

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surfactant is selected from block copolymers of polystyrene-polyethylene oxide or polyethylene glycol esters and is preferably polystyrene-polyethylene oxide. The monomeric cataionic surfactant is selected from dodecyl ammonium bromide, cetyltrimethyl ammonium bromide or hexadecyl trimethyl ammonium bromide and is preferably dodecyl ammonium bromide. The monomeric neutral surfactant is selected from otoxynol (Triton x 100) or ethoxylated aliphatic alcohols and is preferably otoxynol. The surfactant treatment is not carried out with an acid forming surfactant if the application area of the formulation does not permit acid formation in the reaction or alternatively the acid may be neutralized by treatment with a base selected from triethyl amine or sodium hydroxide.

According to an embodiment of the invention, the shear mixing of the polymers of the formula IV is carried out in the presence of a water soluble viscosity modifier polymer so as to modify the viscosity of the formulation. The water soluble viscosity modifier polymer is selected from polyethyleneoxide, polyvinylpyrrolidone, polypropyleneoxide, polyethylene glycol, polypropylene glycol or polyvinyl alcohol and is preferably polyethyleneoxide.

According to an embodiment of the invention, the shear mixing of the polymers of the formula IV is carried out in the presence of a water soluble organic solvent so as to improve the conductivity of the formulation. The water soluble organic solvent is selected from dimethyl sulfoxide, N-methylpyrrolidone, dimethylformamide, ethylene glycol or sorbitol and is preferably dimethyl sulfoxide.

Preferably the shear mixing of the polymers is carried out by mechanical agitation, sonication or homogenization. Preferably, the shear mixing of the polymers is carried out by homogenization

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in a high pressure homogenizer. The particles size distribution of the formulation is controlled or modified by controlling the pressure and time for shearing of the polymers of the formula IV.

According to the invention the aqueous formulation is prepared with aqueous dispersible polymers directly by shear mixing. A large number of polymers with multiple functional groups and a large number of monomers are available for use in the invention. The properties / characteristics of the formulation like conductivity, stability, viscosity or particle size can be varied and tailor made by treatment with oxidizing agents, surfactants, viscosity modifier polymers or water soluble organic solvents or with modifications in the shear mixing conditions like pressure to suit different requirements of use and applications. The formulation also can be made with or without iron generating ferric salt or acid generating PSS sodium salt to suit respective applications. Therefore, both the formulation and process of the invention are versatile and economical. The formulation is also easy to handle and use besides having a wide spectrum of applicability and use. The process is also simple and easy and convenient to carry out and requires reduced time. The formulation of the invention may be used for various applications in diverse fields. For example, the formulation may be used in display devices, photovoltaics, electrochromic devices, chemical and biological sensors, antistatic, transparent or conducting coatings, conducting paints or adhesives or as hole transparent layer in thin film devices like LEDs.

The following experimental examples are illustrative of the invention but not limitative of the scope thereof:

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Example 1

2g powder of copolymers of ProDOT-Sultone{[Sulfuric acid mono-[3-(3-methyl-3,4-dihydro-2H-thieno(3,4-b)(1,4)dioxepin-3-ylmethoxy)-propyl] ester} and 3,4-ethylenedioxythiophene (EDOT) was initially mixed in 300 ml of ultra pure water in a high pressure homogenizer at a pressure of 200 atmospheres and subsequently shear mixed in the high pressure homogenizer by increasing the pressure up to 700 atmospheres to form a blue color dispersion which was filtered through a 450 nm polyvinyl acetate membrane to obtain the filtrate as a dark blue color dispersion with conductivity of 0.01 S/cm, viscosity 2cP, dispersion stability in terms of Zeta potential of 35 and particle sizes of abut 300 nm.

Example 2

2g powder of homopolymer ProDOT-OH [3-Methyl-3,4-dihydro-2H-thieno(3,4-b)(1,4)dioxepin-3-yl)-methanol] was initially mixed in 300 ml of ultra pure water in a high pressure homogenizer at a pressure of 200 atmospheres and subsequently shear mixed and filtered as described in Example 1 to obtain the filtrate as a dark blue color dispersion with conductivity of 0.01 S/cm, viscosity of 2cP, dispersion stability in terms of Zeta potential of 35 and particle sizes of about 300 nm.

Example 3

2g powder of copolymers of 3,4-Propylenedioxythiophene (ProDOT) and ProDOT-OH was initially mixed in 300 ml of ultra pure water in a high pressure homogenizer at a pressure of 200 atmosphere and subsequently shear mixed and filtered as described in Example 1 to obtain as filtrate a dark blue color dispersion with conductivity of 0.07 S/cm, viscosity of 3cP, dispersion stability in terms of Zeta potential of 45 and particle sizes of about 300 nm.

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Example 4

2g powder of copolymers of ProDOT-Me_2 (dimethyl substituted 3,4-propylene dioxyethiophene) and ProDOT-OH was initially mixed in 300 ml of ultra pure water in a high pressure homogenizer at a pressure of 200 atmospheres and subsequently shear mixed and filtered as described in Example 1 to obtain as filtrate a dark blue color dispersion with conductivity of 0.01 S/cm, viscosity of 4cP, dispersion stability in terms of Zeta potential of 26 and particle sizes of about 350 nm..

Example 5

2g powder of copolymers of EDOT, ProDOT-Me_2 and ProDOT-OH was initially mixed in 300 ml of ultra pure water in a high pressure homogenizer at a pressure of 200 atmospheres and subsequently shear mixed and filtered as described in Example 1 to obtain as filtrate a dark blue color dispersion with conductivity of 0.001 S/cm, viscosity of 3cP, dispersion stability in terms of Zeta potential of 34 and particle sizes of about 250 nm..

Example 6

2g powder of copolymers of propargyl functionalized ProDOT-OH and ProDOT-OH was intially mixed in 300 ml of ultra pure water in a high pressure homogenizer at a pressure of 200 atmospheres and subsequently shear mixed and filtered as described in Example 1 to obtain as filtrate a dark blue color dispersion with conductivity of 0.07 S/cm, viscosity of 5cP, dispersion stability in terms of Zeta potential of 42 and particle sizes of about 200 nm..

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Example 7

2 g powder of copolymers of ethyl azide functionalized ProDOT-OH and ProDOT-OH was initially mixed in 300 ml of ultra pure water in a high pressure homogenizer at a pressure of 200 atmospheres and subsequently shear mixed and filtered as described in Example 1 to obtain as filtrate a dark blue color dispersion with conductivity of 0.009 S/cm, viscosity of 3cP, dispersion stability in terms of Zeta potential of 25 and particle sizes of about 200 nm.

Example 8

The aqueous dispersions of Examples 1 to 7 were prepared by mixing and shear mixing the respective copolymers and homopolymer in the presence of sodium peroxydisulphate (one equivalent of the repeat unit of the polymer). The conductivity of the dispersions increased to 100, 120, 500, 100, 200 and 1500 S/cm, respectively.

Example 9

The aqueous dispersions of Examples 1 to 7 were prepared by mixing and shear mixing the respective copolymers and homopolymer in the presence of sodium peroxydisulphate (one equivalent of the repeat unit of the polymer) and dimethulsulfoxide (5ml). The conductivity of the dispersions increased to 200, 820, 500, 1200, 2000 and 2500 S/cm, respectively.

Example 10

The aqueous dispersions of Example 9 were prepared by mixing and shear mixing the respective copolymers and homopolymer in the presence of water soluble polyethylene oxide polymer (1 wt%). The viscosity of the dispersions was modified and decreased to 60, 45, 70, 200, 300, 200 and 500 cP, respectively.

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Example 11

The aqueous dispersions of Example 9 were prepared by mixing and shear mixing the respective copolymers and homopolymer in the presence of polyanionic polystyrene sulfonate (1 wt%). The viscosity of the dispersions increased to 10, 25, 20, 20, 80, 30 and 50 cP, respectively.

Example 12

The aqueous dispersions of Examples 1 to 7 were prepared by mixing and shear mixing the respective copolymers and homopolymer by increasing the pressure upto 1500 atmospheres. The particle sizes of the dispersions reduced to about 20 nm.

Example 13

The aqueous dispersions of Example 9 were prepared by mixing and shear mixing the respective copolymers and homopolymer in the presence of polyethylene amine (1wt%). The viscosity of the dispersions was modified and increased to 25, 15, 50, 10, 20, 30 and 60 cP, respectively.

Example 14

The aqueous dispersions of Example 9 were prepared by mixing and shear mixing the respective copolymers and homopolymer bin the presence of otoxynol (1 wt%). The viscosity of the dispersions was modified and increased to 3, 5, 10, 5, 8, 3 and 5 cP, respectively.

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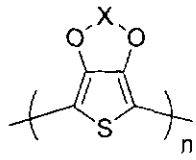
We claim

1. Aqueous formulation of water dispersible polymers of 3,4-alkylenedioxythiophene of the formula IV:



Formula IV

wherein X represents $-CH_2CH_2-$ or $CH_2C(RR')CH_2-$, wherein R represents a $-CH_2-O-(CH_2)_A-B$, wherein A represents 0 to 10 and B represents a hydrogen or a C_1-C_5 linear or branched alkyl or aryl group optionally substituted by one or more groups selected from amines, carboxylic acids, alcohols, ethers, sulfonic acids, thiols or amides; R' represents R as defined above or hydrogen or C_1-C_3 linear or branched alkyl group or aryl group optionally substituted by one or more groups selected from aryl, propargyl or azide and n is the number of recurring or repeating polymer units, the formulation comprising a dispersion of nano particles of the polymers of 3,4-alkylenedioxythiophene in water.

2. The formulation as claimed in claim 1, which comprises polymers of 3,4-alkylenedioxythiophene in the particle sizes of about 20 to 350 nm.

3. A process for the preparation of aqueous formulation of water dispersible polymers of 3,4-alkylenedioxythiophene of the formulae IV:

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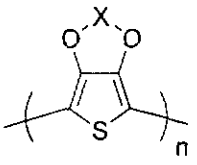

Formula IV

wherein X represents $-CH_2CH_2-$ or $CH_2C(RR')CH_2-$, wherein R represents a $-CH_2-O-(CH_2)_A-B$, wherein A represents 0 to 10 and B represents a hydrogen or a C_1-C_5 linear or branched alkyl or aryl group optionally substituted by one or more groups selected from amines, carboxylic acids, alcohols, ethers, sulfonic acids, thiols or amides; R' represents R as defined above or hydrogen or C_1-C_3 linear or branched alkyl group or aryl group optionally substituted by one or more groups selected from aryl, propargyl or azide and n is the number of recurring or repeating polymer units, which process comprises shearing mixing the water dispersible polymers of the 3,4-alkylenedioxythiophene of the formula IV in water at a pressure of 100 to 5000 atmospheres to form a dispersion of nano particles of the polymers followed by separating the dispersion by filtration.

4. The process as claimed in claim 3, wherein the water dispersible polymers of 3,4-alkylenedioxythiophene are shear mixed in water in powder form.

5. The process as claimed in claim 3 or 4, wherein the dispersion comprises nano particles of the polymers in the particle sizes of about 20 to 350 nm.

6. The process as claimed in anyone of claims 3 to 5, wherein the shear mixing of the polymers is carried out in the presence of an oxidizing agent

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7. The process as claimed in claim 6, wherein the oxidizing agent is selected from sodium peroxydisulphate, hydrogen peroxide, horse radish peroxidase or ferric salt or combination thereof and is preferably sodium peroxydisulphate.

8. The process as claimed in anyone of claims 3 to 5, wherein the shear mixing of the polymers is carried out in the presence of a polymeric or monomeric anionic, cationic or neutral surfactant.

9. The process as claimed in claim 8, wherein the polymeric anionic surfactant is a polyelectrolyte selected from polyanionic polystyrene sulfonate (PSS) sodium salt or polyacrylic acid sodium salt and is preferably PSS sodium salt.

10. The process as claimed in claim 8, wherein the monomeric anionic surfactant is selected from sodium dodecyl sulfonate, sodium dodecyl benzene sulfonate or sodium lauryl sulfonate and is preferably sodium dodecyl sulfonate.

11. The process as claimed in claim 8, wherein the polymeric cataionic surfactant is selected from polyethylene amines or polyoxymethylene amines and is preferably polyethylene amines.

12. The process as claimed in claim 8, wherein the polymeric neutral surfactant is selected from block copolymers of polystyrene-polyethylene oxide or polyethylene glycol esters and is preferably block copolymers of polystyrene-polyethylene oxide.

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13. The process as claimed in claim 8, wherein the monomeric cataionic surfactant is selected from dodecyl ammonium bromide, cetyltrimethyl ammonium bromide or hexadecyl trimethyl ammonium bromide and is preferably dodecyl ammonium bromide.

14. The process as claimed in claim 8, wherein the monomeric neutral surfactant is selected from otoxynol or ethoxylated aliphatic alcohols and is preferably otoxynol.

15. The process as claimed in any one of claims 3 to 5, wherein the shear mixing of the polymers is carried out in the presence of a water soluble viscosity modifier polymer.

16. The process as claimed in claim 15, wherein the viscosity modifier polymer is selected from polyethyleneoxide, polyvinylpyrrolidone, polypropyleneoxide, polyethylene glycol, polypropylene glycol or polyvinyl alcohol and is preferably polyethyleneoxide.

17. The process as claimed in any one of claims 3 to 5, wherein the shear mixing of the polymers is carried out in the presence of a water soluble organic solvent.

18. The process as claimed in claim 17, wherein the organic solvent is selected from dimethyl sulfoxide, N-methylpyrrolidone, dimethylformamide, ethylene glycol or sorbitol and is preferably dimethyl sulfoxide.

19. The process as claimed in anyone of claims 3 to 18, wherein the shear mixing of polymers is carried out by mechanical agitation, sonication or homogenization.

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20. The process as claimed in claim 19, wherein the shear mixing of the polymers is carried out by homogenization in a high pressure homogenizer.

Dated this 11th day of October 2010.

Indian Institute of Technology, Bombay
By their Agent & Attorney

(Jose M A)
of Khaitan & Co
Reg No IN/PA-44

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