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(54) Title: CRYSTAL FORMS OF TETRA-HYDRO-N, N-DIMETHYL-2, 2-DIPHENYL-3-FURANMETHANAMINE HYDROCHLORIDE, PROCESSES FOR MAKING SUCH FORMS, AND THEIR PHARMACEUTICAL COMPOSITIONS

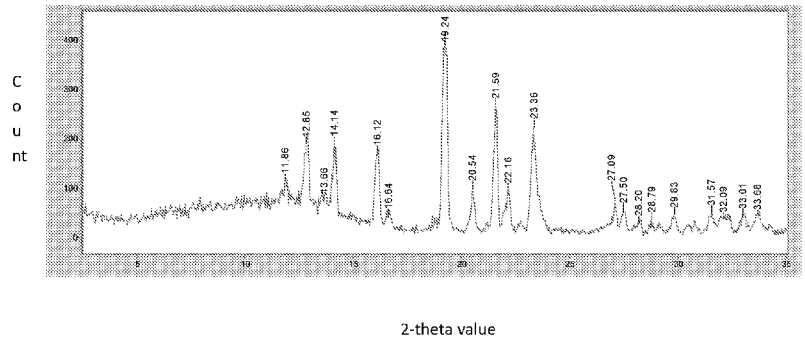


FIG. 1

(57) Abstract: Polymorphic forms of tetrahydro-N,N-dimethyl-2,2-diphenyl-3- furanmethanamine hydrochloride (ANAVEX2-73) and a metabolite of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73) are disclosed and characterized. Compositions and method for treatment of Alzheimer's disease that includes the polymorphic forms and metabolite of tetrahydro-N,N-dimethyl-2,2- diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73).

WO 2017/013498 A2

CRYSTAL FORMS OF TETRAHYDRO-N,N-DIMETHYL-2,2-DIPHENYL-3-FURANMETHANAMINE HYDROCHLORIDE, PROCESSES OF MAKING SUCH FORMS, AND THEIR PHARMACEUTICAL COMPOSITIONS

FIELD

[0001] The present disclosure is directed to crystalline forms of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride, as well as compositions, processes of preparation, and uses thereof.

BACKGROUND

[0002] Because improved drug formulations showing, for example, better bioavailability or better stability are consistently sought, there is an ongoing need for more fully characterized, new, polymorphic and derivative forms of drug molecules. Characterization of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride, and crystalline polymorphs and a metabolite of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride are described herein toward this end.

SUMMARY OF THE PRESENT DISCLOSURE

[0003] The present disclosure comprises crystalline forms of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride characterized by the PXRD pattern shown in FIG. 1, FIG. 4, or FIG. 8. The crystalline forms are further characterized by the FTIR spectrum shown in FIG. 5 or FIG. 9. The crystalline forms are further characterized by the ^{1}H-NMR spectrum shown in FIG. 6 or FIG. 10. The crystalline forms are further characterized by the particle shapes depicted in FIG. 2, FIG. 3, FIG. 7 or FIG. 11. The crystalline forms are further characterized by the particle sizes depicted in FIG. 2, FIG. 3, FIG. 7 or FIG. 11. The

crystalline forms can have a plate-like habit. The crystalline forms can also have a needle-like habit. The crystalline forms can have a lath-like habit. Further included, is a method of making the crystalline forms using a supercritical fluid (SCF) technique. Further included is a dosage form comprising a therapeutically neuroprotective amount of the crystalline forms. Further included is a pharmaceutical composition for the treatment of Alzheimer's disease comprising a therapeutically effective amount of the crystalline forms. Further included is a method of treating Alzheimer's disease in a subject comprising administering to the subject a therapeutically effective amount of the crystalline forms.

[0004] The present disclosure also comprises crystalline Form I of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride characterized by the PXRD pattern shown in FIG. 1. The crystalline Form I according is also characterized by the particle shapes as depicted in FIG. 2. The crystalline Form I is also characterized by the particle shapes as depicted in FIG. 3. The crystalline Form I is also characterized by the particle sizes as depicted in FIG. 2. The crystalline Form I is also characterized by the particle sizes as depicted in FIG. 3. Crystalline Form I is also characterized by a plate-like habit. Further included is a method of making crystalline Form I using a supercritical fluid (SCF) technique. Further included is a dosage form comprising a therapeutically neuroprotective amount of crystalline Form I. Further included is a pharmaceutical composition for the treatment of Alzheimer's disease comprising a therapeutically effective amount of crystalline Form I. Further included is a method of treating Alzheimer's disease in a subject comprising administering to the subject a therapeutically effective amount of the crystalline Form I.

[0005] The present disclosure also comprises crystalline Form II of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride

characterized by the PXRD pattern shown in FIG. 4. Crystalline Form II is also characterized by the FTIR spectrum shown in FIG. 5. Crystalline Form II is also characterized by the ^{1}H-NMR spectrum shown in FIG. 6. Crystalline Form II is also characterized by particle shapes as depicted in FIG. 7. Crystalline Form II is also characterized by particle sizes as depicted in FIG. 7. Crystalline Form II can also have a plate-like habit. Further included is a method of making crystalline Form II using a supercritical fluid (SCF) technique. Further included is a dosage form comprising a therapeutically neuroprotective amount of crystalline Form II. Further included is a pharmaceutical composition for the treatment of Alzheimer's disease comprising a therapeutically effective amount of crystalline Form II. Further included is a method of treating Alzheimer's disease in a subject comprising administering to the subject a therapeutically effective amount of crystalline Form II.

[0006] The present disclosure also comprises crystalline Form III of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride characterized by the PXRD pattern shown in FIG. 8. Crystalline Form III is also characterized by the FTIR spectrum shown in FIG. 9. Crystalline Form III is also characterized by the ^{1}H-NMR spectrum shown in FIG. 10. Crystalline Form III is also characterized by particle shapes as depicted in FIG. 11. Crystalline Form III is also characterized by particle sizes as depicted in FIG. 11. Crystalline Form III can also have a lath-like habit. Further included is a method of making crystalline Form III using a supercritical fluid (SCF) technique. Further included is a dosage form comprising a therapeutically neuroprotective amount of crystalline Form III. Further included is a pharmaceutical composition for the treatment of Alzheimer's disease comprising a therapeutically effective amount of crystalline Form III. Further included is a method of treating Alzheimer's

disease in a subject comprising administering to the subject a therapeutically effective amount of crystalline Form III.

[0007] The present disclosure also comprises metabolite ANAVEX19-144 characterized by the PXRD pattern shown in FIG. 12. Metabolite ANAVEX19-144 is also characterized by the DSC-TGA data shown in FIG. 13. Metabolite ANAVEX19-144 is also characterized by the FTIR spectrum shown in FIG. 14. Metabolite ANAVEX19-144 can also be characterized by particle shapes as depicted in FIG. 15. Metabolite ANAVEX19-144 can also be characterized by particle sizes as depicted in FIG. 15. Metabolite ANAVEX19-144 can also have a needle-like habit. Further included is a method of making the metabolite ANAVEX19-144 using a supercritical fluid (SCF) technique. Further included is a dosage form comprising a therapeutically neuroprotective amount of the metabolite ANAVEX19-144. Further included is a pharmaceutical composition for the treatment of Alzheimer's disease comprising a therapeutically effective amount of the metabolite ANAVEX19-144. Further included is a method of treating Alzheimer's disease in a subject comprising administering to the subject a therapeutically effective amount of the metabolite ANAVEX19-144.

[0008] The present disclosure also comprises metabolite ANAVEX19-144 characterized by the PXRD pattern shown in FIG. 17. Metabolite ANAVEX19-144 is also characterized by the DSC-TGA data shown in FIG. 18. Metabolite ANAVEX19-144 can also be characterized by particle shapes as depicted in FIG. 16. Metabolite ANAVEX19-144 can also be characterized by particle sizes as depicted in FIG. 16. Further included is a method of making the metabolite ANAVEX19-144 using a supercritical fluid (SCF) technique. Further included is a dosage form comprising a therapeutically neuroprotective amount of metabolite ANAVEX19-144. Further included is a pharmaceutical composition for the treatment of Alzheimer's disease comprising a therapeutically effective amount of

metabolite ANAVEX19-144. Further included is a method of treating Alzheimer's disease in a subject comprising administering to the subject a therapeutically effective amount of metabolite ANAVEX19-144.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] In order to describe the manner in which the advantages and features of the disclosure can be obtained, reference is made to embodiments thereof which are illustrated in the appended drawings. Understanding that these drawings depict only exemplary embodiments of the disclosure and are not therefore to be considered to be limiting of its scope, the principles herein are described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[0010] FIG. 1 depicts a powder X-ray diffraction (PXRD) pattern characteristic of polymorph Form I of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73);

[0011] FIG. 2 depicts scanning electron microscope (SEM) micrographs demonstrating the size and morphology of particles of polymorph Form 1 of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73) produced using acetonitrile as the solvent in the supercritical fluid process;

[0012] FIG. 3 depicts SEM micrographs demonstrating the size and morphology of particles of polymorph Form 1 of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73) produced using ethanol as the solvent in the supercritical fluid process;

[0013] FIG. 4 depicts a PXRD pattern characteristic of polymorph Form II of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73);

[0014] FIG. 5 depicts a fourier transform infrared (FTIR) spectrum characteristic of polymorph Form II of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73);

[0015] FIG. 6 depicts a proton nuclear magnetic resonance (^{1}H-NMR) spectrum characteristic of polymorph Form II of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73);

[0016] FIG. 7 depicts SEM micrographs demonstrating the size and morphology of particles of polymorph Form II of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73);

[0017] FIG. 8 depicts a PXRD pattern characteristic of polymorph Form III of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73);

[0018] FIG. 9 depicts an FTIR spectrum characteristic of polymorph Form III of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73);

[0019] FIG. 10 depicts a ^{1}H-NMR spectrum characteristic of polymorph Form III of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73);

[0020] FIG. 11 depicts SEM micrographs demonstrating the size and morphology of particles of polymorph Form III of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73);

[0021] FIG. 12 depicts a PXRD pattern characteristic of metabolite ANAVEX19-144 produced using ethanol as the solvent in the supercritical fluid process;

[0022] FIG. 13 depicts DSC-TGA data characteristic of metabolite ANAVEX19-144 produced using ethanol as the solvent in the supercritical fluid process;

[0023] FIG. 14 depicts a FTIR spectrum characteristic of metabolite ANAVEX19-144 produced using ethanol as the solvent in the supercritical fluid process;

[0024] FIG. 15 depicts SEM micrographs demonstrating the size and morphology of particles of metabolite ANAVEX19-144 produced using ethanol as the solvent in the supercritical fluid process;

[0025] FIG. 16 depicts SEM micrographs demonstrating the size and morphology of particles of metabolite ANAVEX19-144 produced using dichloromethane as the solvent in the supercritical fluid process;

[0026] FIG. 17 depicts a PXRD pattern characteristic of metabolite ANAVEX19-144 produced using dichloromethane as the solvent in the supercritical fluid process; and

[0027] FIG. 18 depicts DSC-TGA data characteristic of metabolite ANAVEX19-144 produced using dichloromethane as the solvent in the supercritical fluid process.

DETAILED DESCRIPTION

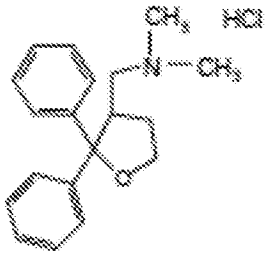
[0028] Various embodiments of the disclosure are discussed in detail below. While specific implementations are discussed, it should be understood that this is done for illustration purposes only. A person skilled in the relevant art will recognize that other components and configurations may be used without parting from the spirit and scope of the disclosure.

[0029] It should be understood at the outset that although illustrative implementations of one or more embodiments are illustrated below, the disclosed method may be implemented using any number of techniques. The disclosure should in no way be limited to the illustrative implementations, drawings, and techniques illustrated herein, but may be

modified within the scope of the appended claims along with their full scope of equivalents.

[0030] In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to …". The various characteristics described in more detail below, will be readily apparent to those skilled in the art with the aid of this disclosure upon reading the following detailed description, and by referring to the accompanying drawings.

[0031] The present disclosure relates to tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride, also referred to as ANAVEX2-73:



[0032] It has been reported that ANAVEX2-73 shows neuroprotective potential against amyloid toxicity in mice. In particular, ANAVEX2-73 has been reported as attenuating oxidative stress, caspases induction, cellular loss and learning and memory deficits observed in mice one week after the i.c.v. injection of an oligomeric preparation of amyloid $ß_{25-35}$ peptide ($Aβ_{25-35}$). See J. Psychopharmacol. 25(8), 1101-1117 (2011). More recently, it has been reported that ANAVEX2-73 blocked the $Aβ_{25-35}$-induced P-Akt decrease and P-GSK-3β increase, indicating activation at the PI3K neuroprotective pathway. See Neuropsychopharmacology 38, 1706-1723 (2013). In the dose-range tested, ANAVEX2-73 attenuated the hyperphosphorylation of Tau on physiological epitopes (AT-8 antibody clone) and on pathological epitopes (AT-100 clone). ANAVEX2-73 also

has been reported to decrease the $A\beta_{25-35}$-induced endogenous $A\beta_{1-42}$ seeding.

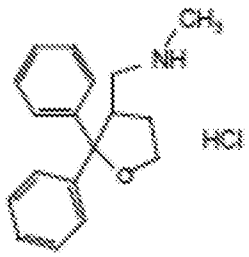
[0033] Reference is made to U.S. Patent Publication No. 2014/0296211 entitled "ANAVEX2-73 AND CERTAIN ANTICHOLINESTERASE INHIBITORS COMPOSITION AND METHOD FOR NEUROPROTECTION," to Vamvakides et al., filed July 12, 2013; USSN 62/065,833 entitled "A19-144, A2-73 AND CERTAIN ANTICHOLINESTERASE INHIBITOR COMPOSITIONS AND METHOD FOR ANTI-SEIZURE THERAPY," filed October 20, 2014; U.S. Patent application entitled "ANAVEX2-73 FOR THE TREATMENT OF ALZHEIMER'S DISEASE" and filed on date even herewith; U.S. Patent application entitled "ENANTIOMERS OF A2-73, ANALOGUES, AND SIGMA AGONIST ACTIVITY" and filed on date even herewith. The teaching of these applications and publications and all references cited herein are incorporated by reference in their entirety.

[0034] The present disclosure, provides a crystalline polymorph (Form I) of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride , characterized by PXRD and other data provided herein.

[0035] The present disclosure provides another crystalline polymorph (Form II) of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride characterized by the PXRD and other data provided herein.

[0036] The present disclosure further provides another crystalline polymorph (Form III) of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride characterized by the PXRD and other data provided herein.

[0037] The present disclosure also provides a metabolite of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride, referred to as ANAVEX19-144, characterized by the PXRD and other data provided herein and having the structure:



[0038] The present disclosure further provides use of the polymorphs and metabolite material in the treatment of Alzheimer's disease.

[0039] Tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73) was characterized by powder X-ray diffraction (PXRD), thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), fourier transform infrared (FTIR) spectroscopy, proton nuclear magnetic resonance (^{1}H-NMR) and scanning electron microscopy (SEM), as detailed in FIGS. 1-15.

[0040] The present disclosure further provides processes of preparing the polymorphic forms of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73). In one embodiment, the polymorphic forms, disclosed herein, can be prepared by a supercritical fluid (SCF) anti-solvent process. In an embodiment, the anti-solvent is a supercritical fluid, although in some embodiments near-critical fluids may also be suitable. A "supercritical fluid" is a fluid at or above its critical pressure (Pc) and critical temperature (Tc) simultaneously. In practice, the pressure of the fluid is likely to be in the range between 1.01 and 7.0 of its critical pressure, and its temperature in the range between 1.01 and 4.0 of its critical temperature (in Kelvin). However, some fluids (e.g., helium and neon) have particularly low critical pressures and temperatures, 10 and may need to be used under operating conditions well in excess of those critical values, such as up to 200 times the relevant critical value. The term "near-critical fluid" encompasses both high pressure liquids, which are fluids at or above their

critical pressure but below (although preferably close to) their critical temperature, and dense vapors, which are fluids at or above their critical 15 temperature but below (although preferably close to) their critical pressure. By way of example, a high pressure liquid might have a pressure between about 1.01 and 7 times its Pc, and a temperature between about 0.5 and 0.99 times its Tc. A dense vapor might, correspondingly, have a pressure between about 0.5 and 0.99 times its Pc, and a temperature between about 1.01 and 4 times its Tc.

[0041] Suitably, the anti-solvent and solution may be introduced into a precipitation chamber via respective passages with respective outlets, the outlets being arranged relative to one another such that anti-solvent introduced through a first passage and solution introduced through a second passage both enter the precipitation chamber at substantially the same point, which is substantially the point at which the anti-solvent and solution meet. To provide for good levels of mixing and dispersion, the anti-solvent and the solution may, for example, be co-fed into a precipitation chamber via a nozzle having co-axial passages which terminate adjacent to one another. Alternatively, one or more streams of the antisolvent may be arranged to impinge on a stream of the solution to provide good levels of mixing and dispersion. However, other mixing architectures are also possible. Examples of suitable apparatus are known, *inter alia*, from WO-30 95/01221, WO-96/00610, WO-98/36825, WO-99/44733, WO-99/59710, WO-01/03821, and WO-03/008082, which are incorporated herein by reference.

[0042] According to the present disclosure, new crystalline forms of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73) were prepared by a supercritical fluid (SCF) process. The basic process involved preparing a solution of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73) in a

suitable solvent, such as acetonitrile or ethanol, and introducing the solution to an SCF environment, typically supercritical CO_2, in a pressure vessel. The supercritical CO_2 acted as a powerful antisolvent allowing particles to be rapidly precipitated. Different polymorphic forms of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73) were produced by manipulating SCF process parameters, including the solvent used, flow rate, pressure, and temperature. Additionally, manipulation of SCF process parameters determined the size, morphology, and habit of crystalline particles produced by the SCF process.

[0043] The SCF process parameters used to produce the three polymorphic forms of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride (ANAVEX2-73), Forms I-III, are provided in Tables 1-3. As shown in Table 1, crystalline Form I was produced by placing the ANAVEX2-73 starting material in a solvent of acetonitrile or ethanol and processed by the supercritical fluid technique. The resulting particle shape differed depending upon the solvent. The particle shape for the crystalline Form I produced using acetonitrile solvent was plate-like. As used herein, the term "plate-like" refers to a flat particle of similar length and width. The particle shape for the crystalline Form I produced using ethanol solvent was a conglomerate. As used herein, the term "conglomerate" refers to a mixture of two or more types of particle shapes. The resulting material was characterized by PXRD and SEM. The PXRD for crystalline Form I of ANAVEX2-73 is shown in FIG. 1. SEM micrographs showing the particle size and morphology of crystalline Form I are shown in FIGs. 2-3. FIG. 2 shows the particle size and morphology of crystalline Form I produced using acetonitrile solvent (plate-like morphology). FIG. 3 shows the particle

size and morphology of crystalline Form I produced using ethanol as the solvent (conglomerate morphology).

[0044] As shown in Table 2, crystalline Form II was produced by placing the ANAVEX2-73 starting material in a solvent of acetonitrile, 1:9 v/v trifluoroethanol + ethanol, 1:1 v/v acetone + ethanol, or 3-methyl-1-butanol, and processed by the supercritical fluid technique. In all cases, crystalline Form II was characterized by a plate-like habit. The resulting material was characterized by PXRD and SEM. The PXRD for crystalline Form II of ANAVEX2-73 is shown in FIG. 4. Crystalline Form II is further characterized by the FTIR spectrum shown in FIG. 5 and the ^{1}H-NMR shown in FIG. 6. SEM micrographs showing the particle size and morphology of crystalline Form II are shown in FIG. 7.

[0045] As shown in Table 3, crystalline Form III was produced by placing the ANAVEX2-73 starting material in a solvent of ethanol or 1:9 v/v trifluoroethanol + ethanol and processed by the supercritical fluid technique. In all cases, crystalline Form III was characterized by a lath-like habit. As used herein, "lath-like" refers to a long, thin blade-like particle. The resulting material was characterized by PXRD and SEM. The PXRD for crystalline Form III of ANAVEX2-73 is shown in FIG. 8. Crystalline Form III is further characterized by the FTIR spectrum shown in FIG. 9 and the ^{1}H-NMR shown in FIG. 10. SEM micrographs showing the particle size and morphology of crystalline Form III are shown in FIG. 11.

Table 1 – Crystalline Form I Samples

SCF sample No	Solvent	Solution Conc (mg/ml)	P (bar)	T°C	density (g/cm^3)	TS flow (g/min)	CO_2 flow (g/min)	mole fraction CO_2	mole fraction sol	Mass Ratio Flows	Particle shape	Surface characteristics
B2202022	acetonitrile	27.3	105	60	0.322	0.4716	20	0.977	0.023	42.41	plate	smooth
B2202038	ethanol	40	125	80	0.318	0.0789	20	0.996	0.004	253.49	conglomerate	N/A

Table 2 – Crystalline Form II Samples

SCF sample No	Solvent	Solution Conc (mg/ml)	P (bar)	T°C	density (g/cm^3)	TS flow (g/min)	CO^2 flow (g/min)	mole fraction CO_2	mole fraction sol	Mass Ratio Flows	Particle shape	Surface characteristics
B2201017	acetonitrile	27.3	85	40	0.354	0.9432	20	0.955	0.045	21.20	plate	smooth
B2201018	acetonitrile	27.3	200	40	0.84	0.9432	20	0.955	0.045	21.20	plate	smooth
B2201020	acetonitrile	27.3	200	80	0.594	0.9432	20	0.955	0.045	21.20	plate	smooth
B2201028	acetonitrile	27.3	85	40	0.354	1.5720	20	0.927	0.073	12.72	plate	smooth
B2201039	acetonitrile	13	105	60	0.322	1.5720	20	0.927	0.073	12.72	plate	smooth
B2201052	1:9v/v trifluoroethanol+ethanol	50	85	40	0.354	1.0120	20	0.952	0.048	19.76	plate	smooth
B2201053	1:9v/v trifluoroethanol+ethanol	50	85	40	0.354	1.0120	20	0.952	0.048	19.76	plate	smooth

B2201055	1:9v/v trifluoroethanol+ethanol	50	200	40	0.84	0.1687	20	0.992	0.008	118.57	plate	smooth
B2201057	1:9v/v trifluoroethanol+ethanol	20	200	40	0.84	1.6867	20	0.922	0.078	11.86	plate	smooth
B2201067	1:1 v/v acetone+ethanol	50	85	40	0.354	1.5800	20	0.927	0.073	12.66	plate	smooth
B2201072	1:1 v/v acetone+ethanol	50	200	40	0.84	1.5800	20	0.927	0.073	12.66	plate	smooth
B2201076	3-methyl-1-butanol	10	85	40	0.354	0.9725	20	0.954	0.046	20.57	plate	smooth
B2201077	3-methyl-1-butanol	10	85	40	0.354	1.6208	20	0.925	0.075	12.34	plate	smooth

Table 3 – Crystalline Form III Samples

SCF sample No	**Solvent**	**Solution Conc (mg/ml)**	**P (bar)**	**T°C**	**density (g/cm^3)**	**TS flow (g/min)**	**CO_2 flow (g/min)**	**mole fraction CO_2**	**mole fraction sol**	**Mass Ratio Flows**	**Particle shape**	**Surface characteristics**
B2201011	ethanol	40	85	40	0.354	0.4734	20	0.977	0.023	42.25	lath	smooth
B2201036	ethanol	40	200	40	0.84	1.5780	20	0.927	0.073	12.67	lath	smooth
B2201054	1:9v/v trifluoroethanol+ethanol	50	85	40	0.354	0.1687	20	0.992	0.008	118.57	lath	cracked

[0046] The present disclosure also provides a metabolite of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride, ANAVEX19-144. ANAVEX19-144 has documented anti-amnesic and neuroprotective potentials similar to ANAVEX2-73. See for example J. of Psychopharmacol. 25(8), 1101-1117 (2011). Crystalline forms of ANAVEX19-144 were produced by placing the ANAVEX19-144 starting material in a solvent of ethanol or dichloromethane and processed by the supercritical fluid technique. The crystalline form of ANAVEX19-144 produced by the supercritical fluid technique under process parameters of 40 mg/mL ethanol solution, 200 bars of pressure, temperature of 80°C, supercritical CO_2 solution with a flow rate of 20g/min and a TS flow of 0.4mL/min, was characterized by PXRD, FTIR, DSC, and SEM, as shown in FIGs. 12-15. As shown in FIG. 15, the crystalline form of ANAVEX19-144 was characterized by needle-like crystals. In contrast, the crystalline form of ANAVEX19-144 produced by similar process parameters using the solvent dichloromethane exhibited a mixed habit of needle-like and lath-type particles, as shown in FIG. 16. The crystalline form of ANAVEX19-144 produced using the dichloromethane supercritical fluid technique produced a powder with better flow characteristics and improved flow properties for downstream processing. The crystalline form of ANAVEX19-144 was further characterized by PXRD and DSC, as shown in FIGs. 17-18. The two crystalline forms of ANAVEX19-144, produced according to the supercritical fluid technique in ethanol or dichloromethane were stored at 40°C at 75% relative humidity in uncapped vessels for 1 week and then characterized by PXRD to determine stability of the two forms. After one week, the PXRDs for the two forms did not show any differences and

therefore indicated that the two forms were stable under the conditions tested.

CLAIMS

What is claimed is:

1. A crystalline form of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride characterized by the PXRD pattern shown in FIG. 1, FIG. 4, or FIG. 8.

2. The crystalline form of claim 1, further characterized by the FTIR spectrum shown in FIG. 5 or FIG. 9.

3. The crystalline form of claim 1, further characterized by the ^{1}H-NMR spectrum shown in FIG. 6 or FIG. 10.

4. The crystalline form of claim 1, further characterized by the particle shapes depicted in FIG. 2, FIG. 3, FIG. 7 or FIG. 11.

5. The crystalline form of claim 1, further characterized by the particle sizes depicted in FIG. 2, FIG. 3, FIG. 7 or FIG. 11.

6. The crystalline form of claim 1, wherein the habit is plate-like.

7. The crystalline form of claim 1, wherein the habit is needle-like.

8. The crystalline form of claim 1, wherein the habit is lath-like.

9. A method of making the crystalline form of claim 1, wherein the method uses a supercritical fluid (SCF) technique.

10. A dosage form comprising a therapeutically neuroprotective amount of the crystalline form of claim 1.

11. A pharmaceutical composition for the treatment of Alzheimer's disease comprising a therapeutically effective amount of the crystalline form of any of claims 1-8.

12. A method of treating Alzheimer's disease in a subject comprising administering to the subject a therapeutically effective amount of the crystalline form of any of claims 1-8.

13. Crystalline Form I of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride characterized by the PXRD pattern shown in FIG. 1.

14. The crystalline Form I according to claim 13, characterized by the particle shapes as depicted in FIG. 2.

15. The crystalline Form I according to claim 13, characterized by the particle shapes as depicted in FIG. 3.

16. The crystalline Form I according to claim 13, characterized by the particle sizes as depicted in FIG. 2.

17. The crystalline Form I according to claim 13, characterized by the particle sizes as depicted in FIG. 3.

18. The crystalline form of claim 13, wherein the habit is plate-like.

19. A method of making the crystalline form of any of claims 13-18, wherein the method uses a supercritical fluid (SCF) technique.

20. A dosage form comprising a therapeutically neuroprotective amount of the crystalline form of any of claims 13-18.

21. A pharmaceutical composition for the treatment of Alzheimer's disease comprising a therapeutically effective amount of the crystalline form of any of claims 13-18.

22. A method of treating Alzheimer's disease in a subject comprising administering to the subject a therapeutically effective amount of the crystalline form of any of claims 13-18.

23. Crystalline Form II of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride characterized by the PXRD pattern shown in FIG. 4.

24. Crystalline Form II of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride characterized by the FTIR spectrum shown in FIG. 5.

25. Crystalline Form II of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride characterized by the ^{1}H-NMR spectrum shown in FIG. 6.

26. The crystalline Form II according to any of claims 23-25, characterized by particle shapes as depicted in FIG. 7.

27. The crystalline Form II according to any of claims 23-25, characterized by particle sizes as depicted in FIG. 7.

28. The crystalline Form II of any of claims 23-25, wherein the habit is plate-like.

29. A method of making the crystalline Form II of any of claims 23-28, wherein the method uses a supercritical fluid (SCF) technique.

30. A dosage form comprising a therapeutically neuroprotective amount of the crystalline Form II of any of claims 23-28.

31. A pharmaceutical composition for the treatment of Alzheimer's disease comprising a therapeutically effective amount of the crystalline Form II of any of claims 23-28.

32. A method of treating Alzheimer's disease in a subject comprising administering to the subject a therapeutically effective amount of the crystalline Form II of any of claims 23-28.

33. Crystalline Form III of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride characterized by the PXRD pattern shown in FIG. 8.

34. Crystalline Form III of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride characterized by the FTIR spectrum shown in FIG. 9.

35. Crystalline Form III of tetrahydro-N,N-dimethyl-2,2-diphenyl-3-furanmethanamine hydrochloride characterized by the ^{1}H-NMR spectrum shown in FIG. 10.

36. The crystalline Form III according to any of claims 33-35, characterized by particle shapes as depicted in FIG. 11.

37. The crystalline Form III according to any of claims 33-35, characterized by particle sizes as depicted in FIG. 11.

38. The crystalline Form III of any of claims 33-35, wherein the habit is lath-like.

39. A method of making the crystalline Form III of any of claims 33-38, wherein the method uses a supercritical fluid (SCF) technique.

40. A dosage form comprising a therapeutically neuroprotective amount of the crystalline Form III of any of claims 33-38.

41. A pharmaceutical composition for the treatment of Alzheimer's disease comprising a therapeutically effective amount of the crystalline Form III of any of claims 33-38.

42. A method of treating Alzheimer's disease in a subject comprising administering to the subject a therapeutically effective amount of the crystalline Form III of any of claims 33-38.

43. The metabolite ANAVEX19-144 characterized by the PXRD pattern shown in FIG. 12.

44. The metabolite ANAVEX19-144 characterized by the DSC-TGA data shown in FIG. 13.

45. The metabolite ANAVEX19-144 characterized by the FTIR spectrum shown in FIG. 14.

46. The metabolite ANAVEX19-144 of any of claims 43-45 characterized by particle shapes as depicted in FIG. 15.

47. The metabolite ANAVEX19-144 of any of claims 43-45 characterized by particle sizes as depicted in FIG. 15.

48. The metabolite ANAVEX19-144 of any of claims 43-45, wherein the habit is needle-like.

49. A method of making the metabolite ANAVEX19-144 of any of claims 43-48, wherein the method uses a supercritical fluid (SCF) technique.

50. A dosage form comprising a therapeutically neuroprotective amount of the metabolite ANAVEX19-144 of any of claims 43-48.

51. A pharmaceutical composition for the treatment of Alzheimer's disease comprising a therapeutically effective amount of the metabolite ANAVEX19-144 of any of claims 43-48.

52. A method of treating Alzheimer's disease in a subject comprising administering to the subject a therapeutically effective amount of the metabolite ANAVEX19-144 of any of claims 43-48.

53. The metabolite ANAVEX19-144 characterized by the PXRD pattern shown in FIG. 17.

54. The metabolite ANAVEX19-144 characterized by the DSC-TGA data shown in FIG. 18.

55. The metabolite ANAVEX19-144 of any of claims 53-54 characterized by particle shapes as depicted in FIG. 16.

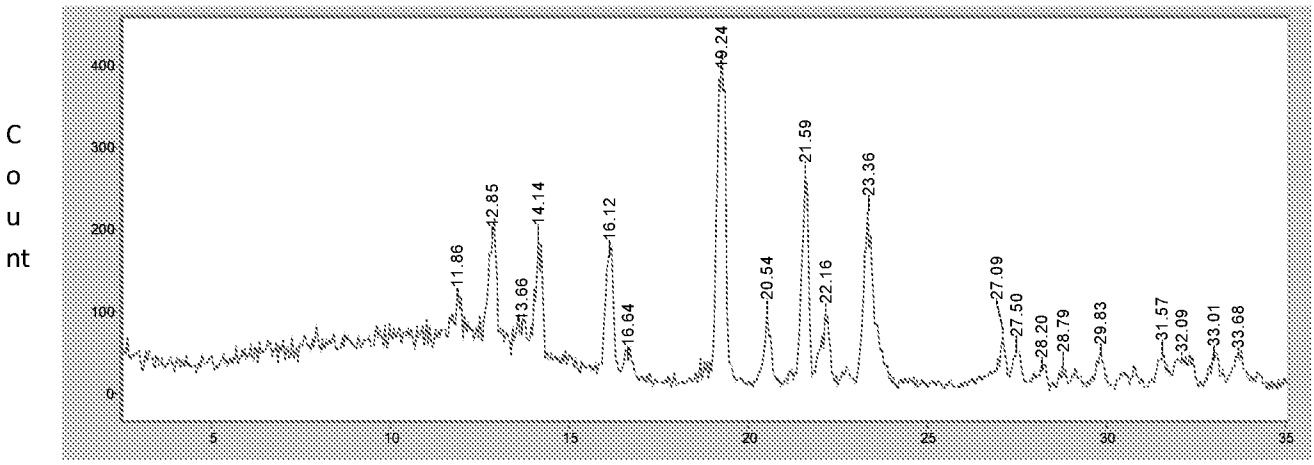
56. The metabolite ANAVEX19-144 of any of claims 53-54 characterized by particle sizes as depicted in FIG. 16.

57. A method of making the metabolite ANAVEX19-144 of any of claims 53-56, wherein the method uses a supercritical fluid (SCF) technique.

58. A dosage form comprising a therapeutically neuroprotective amount of the metabolite ANAVEX19-144 of any of claims 53-56.

59. A pharmaceutical composition for the treatment of Alzheimer's disease comprising a therapeutically effective amount of the metabolite ANAVEX19-144 of any of claims 53-56.

60. A method of treating Alzheimer's disease in a subject comprising administering to the subject a therapeutically effective amount of the metabolite ANAVEX19-144 of any of claims 53-56.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19.24
20.54
21.59
22.16
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27.50
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29.83
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32.09
33.01
33.68
2-theta value

FIG. 1

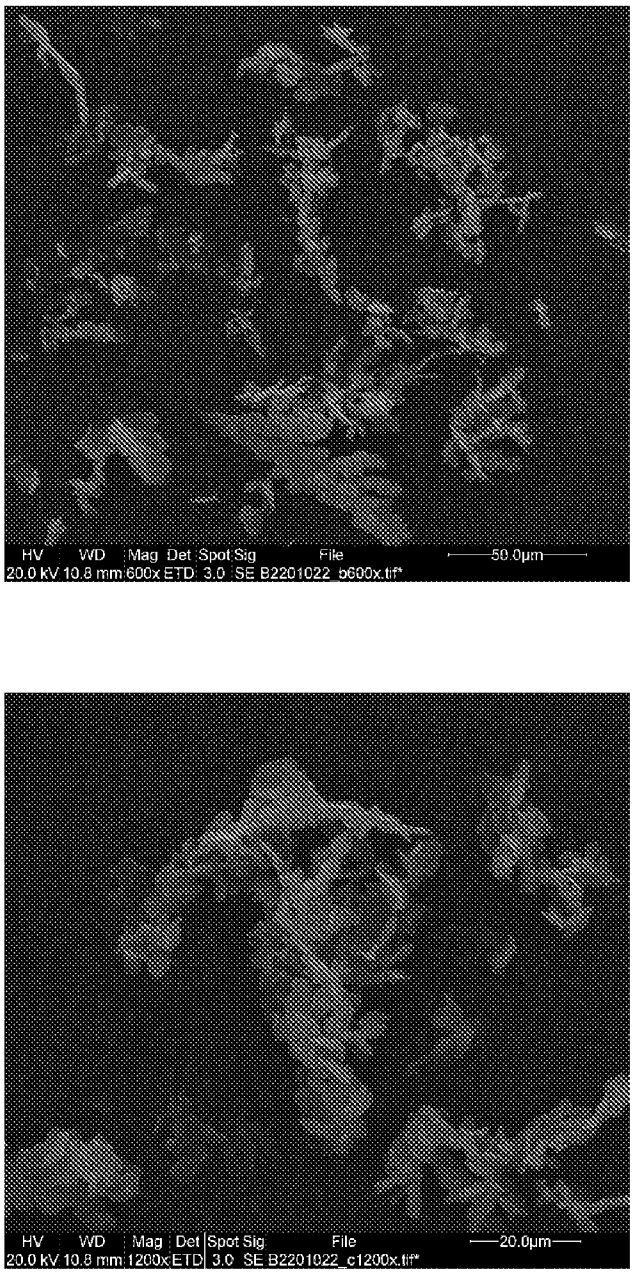
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FIG. 2

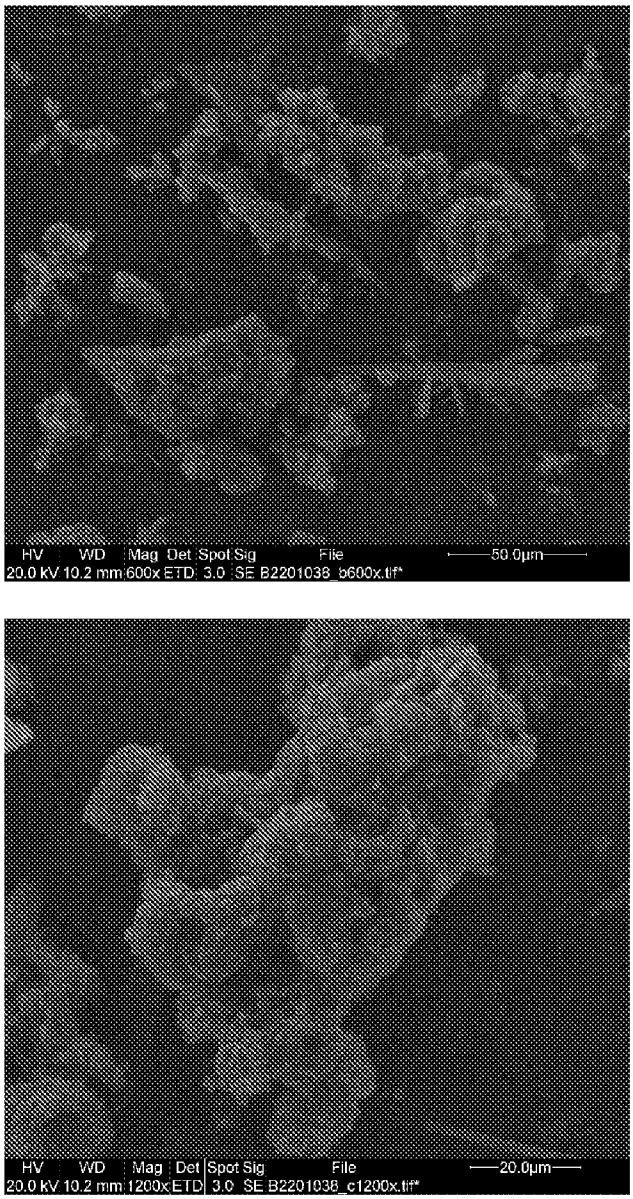
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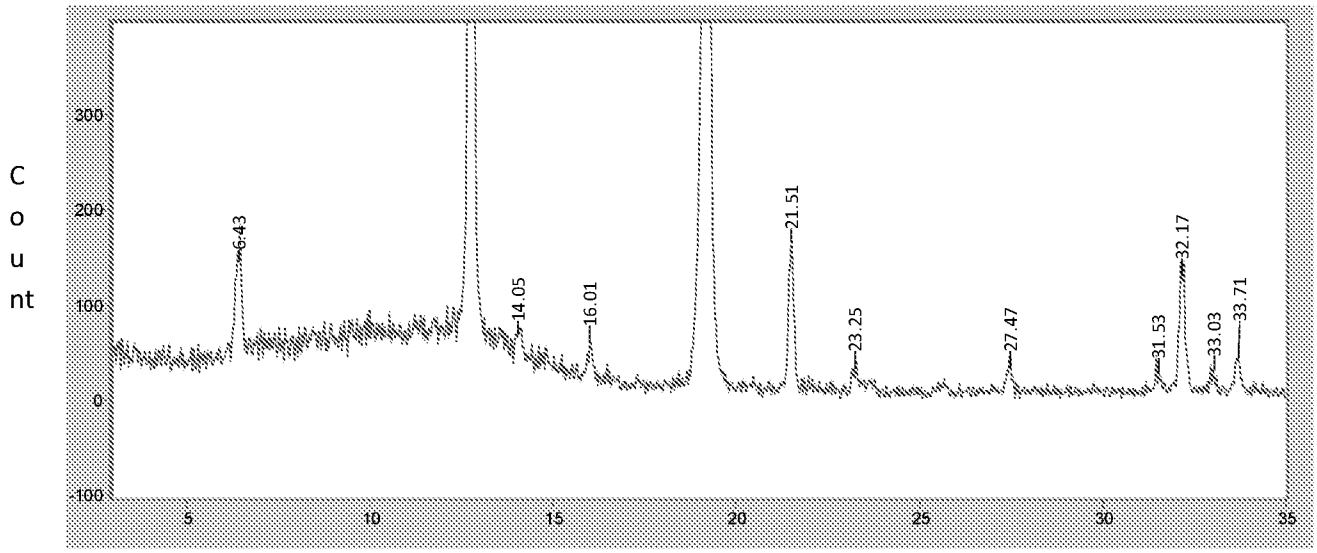
FIG. 3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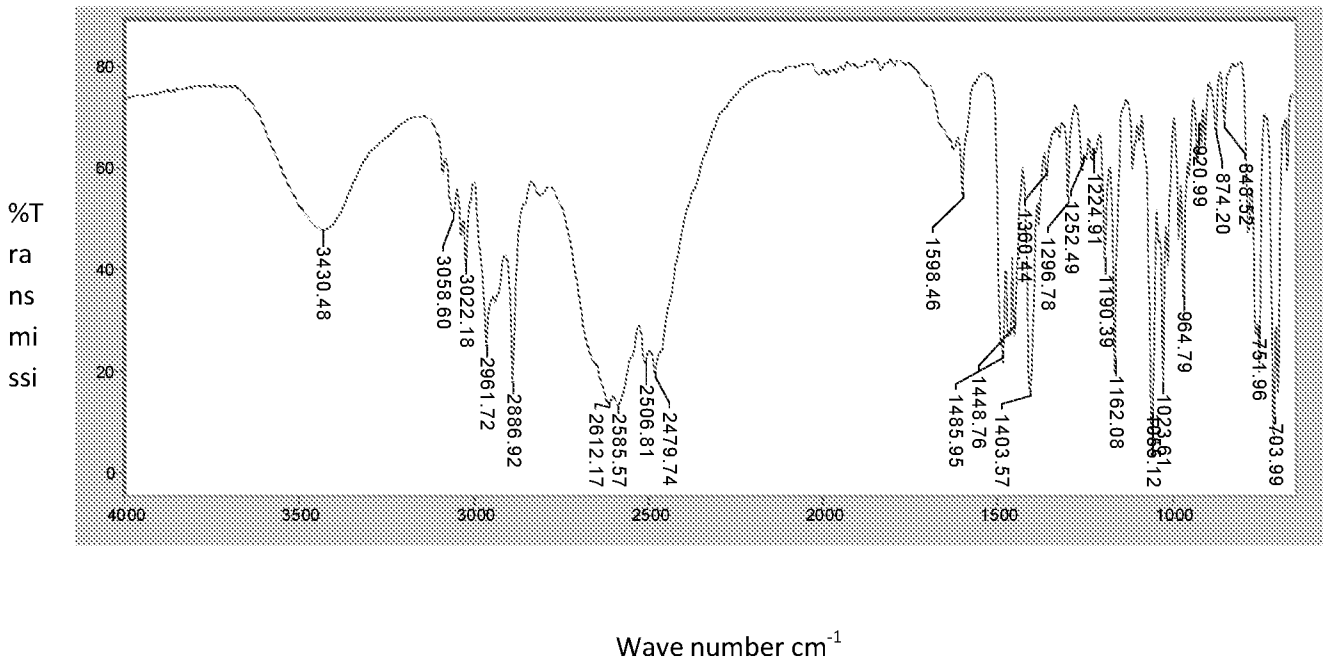
33.03
33.71
5
10
15
20
25
30
35
2-theta value

FIG. 4



Wave number cm^{-1}

FIG. 5

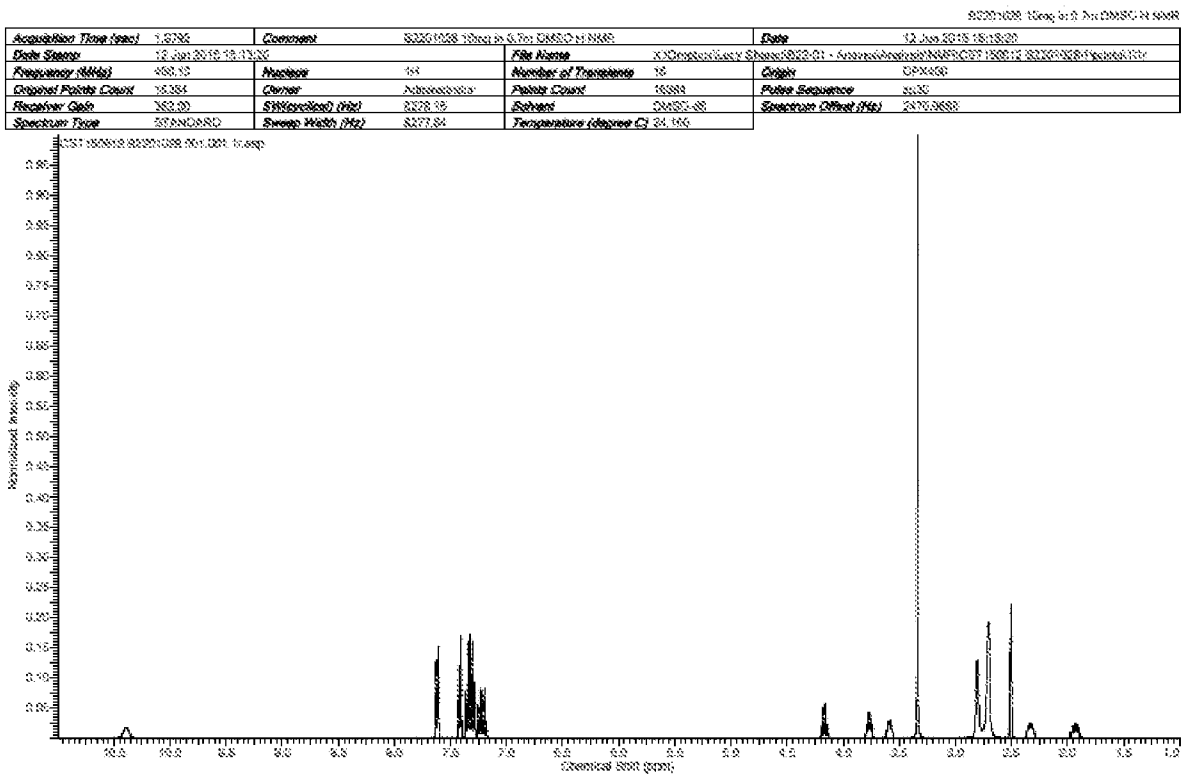


FIG. 6

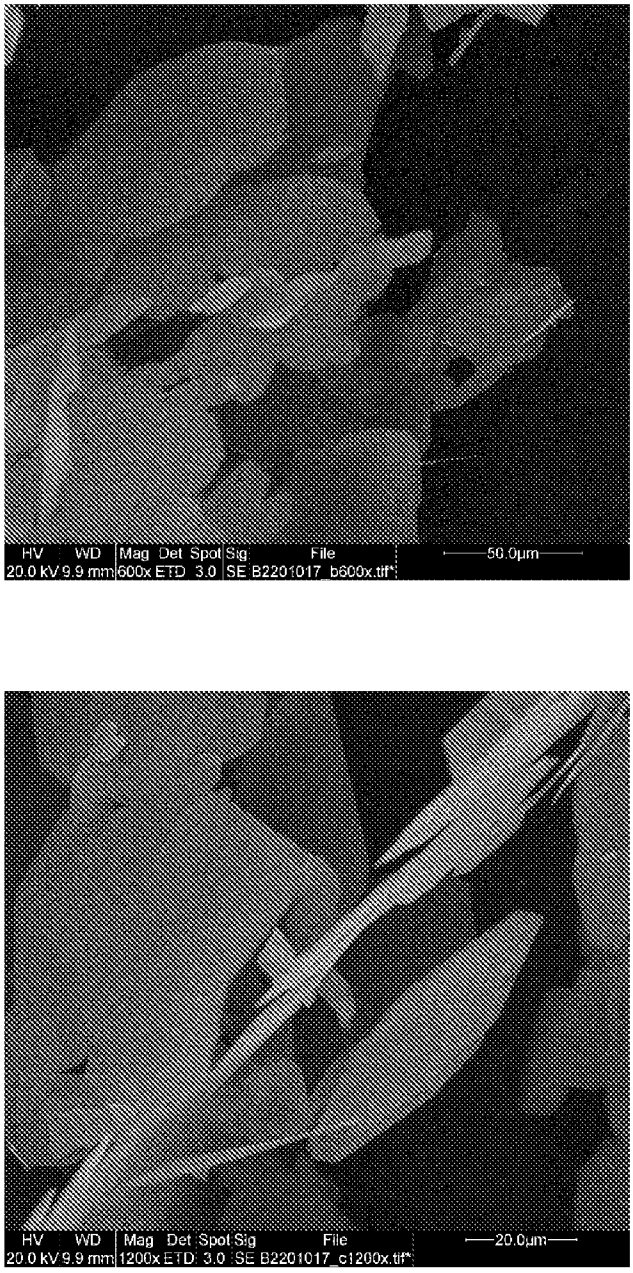

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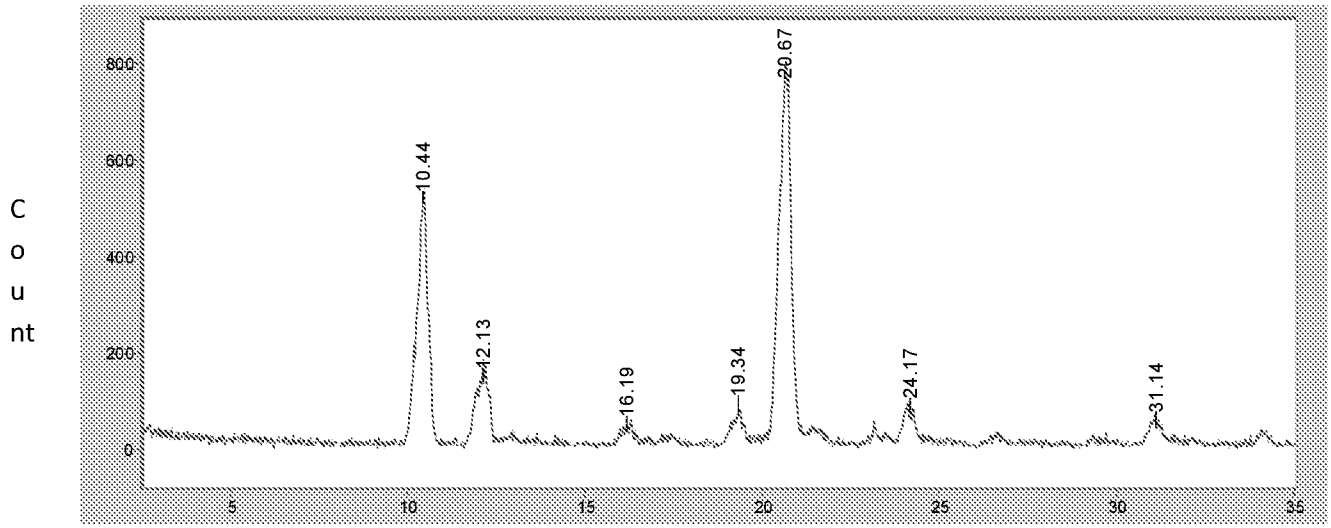
FIG. 7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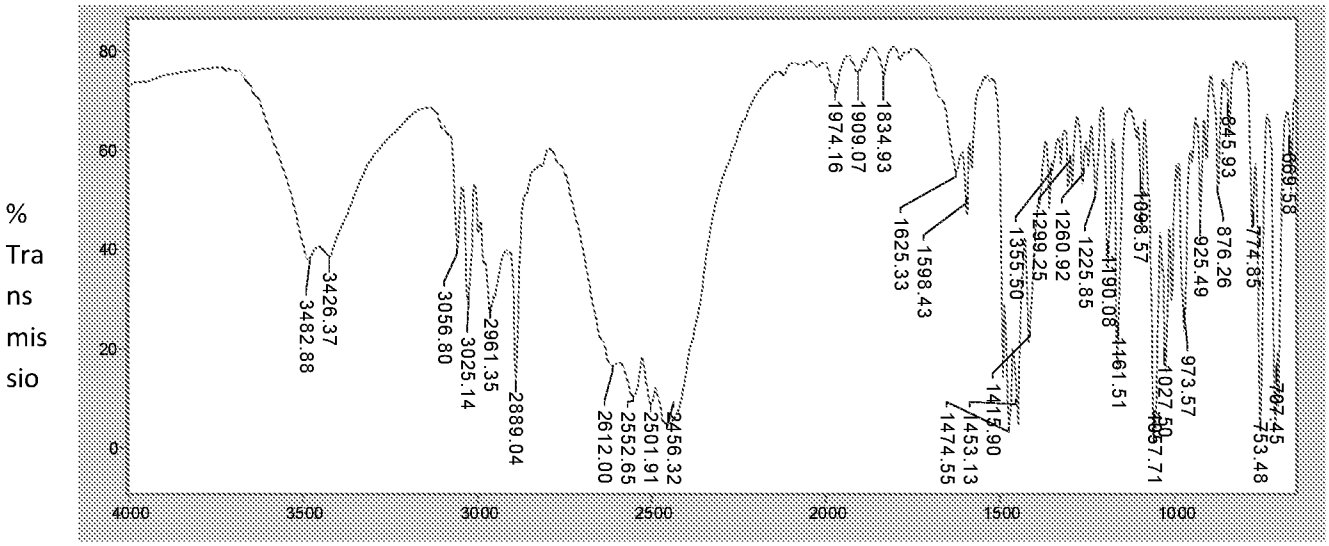
15
20
25
30
35
2-theta value

FIG. 8



Wave number cm^{-1}

FIG. 9

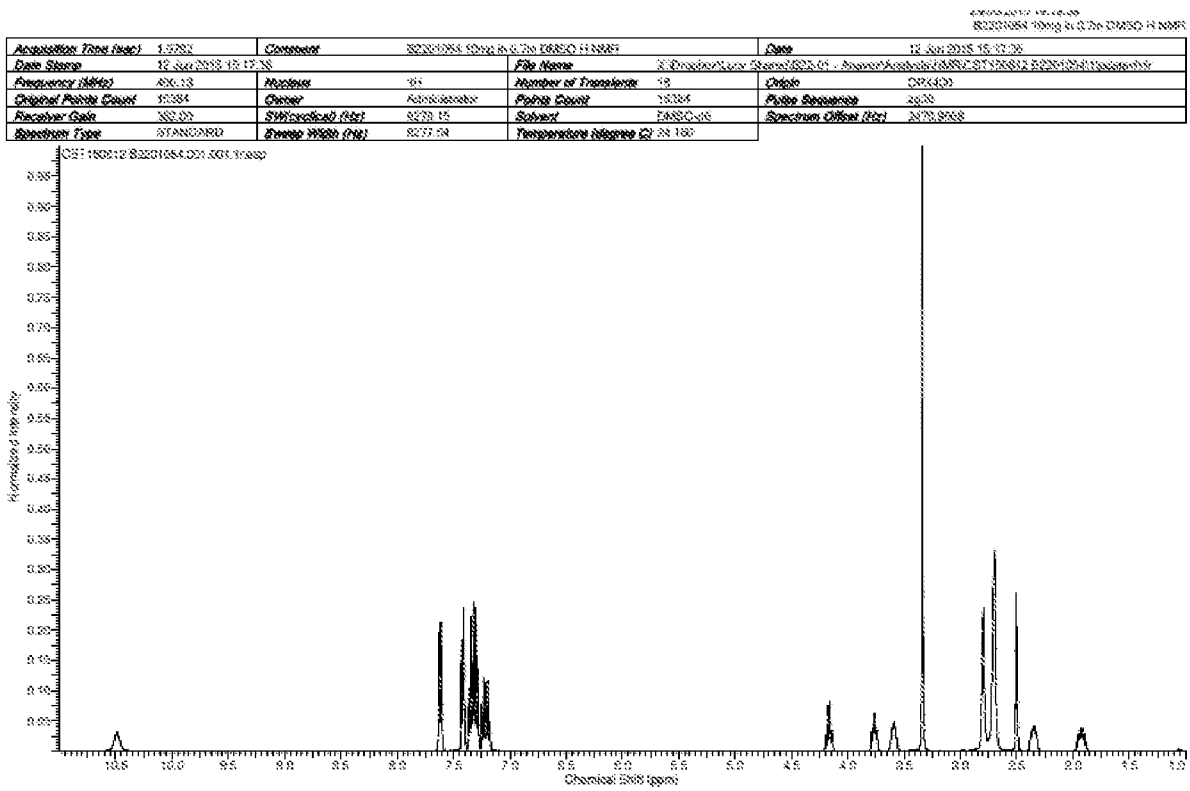


FIG. 10

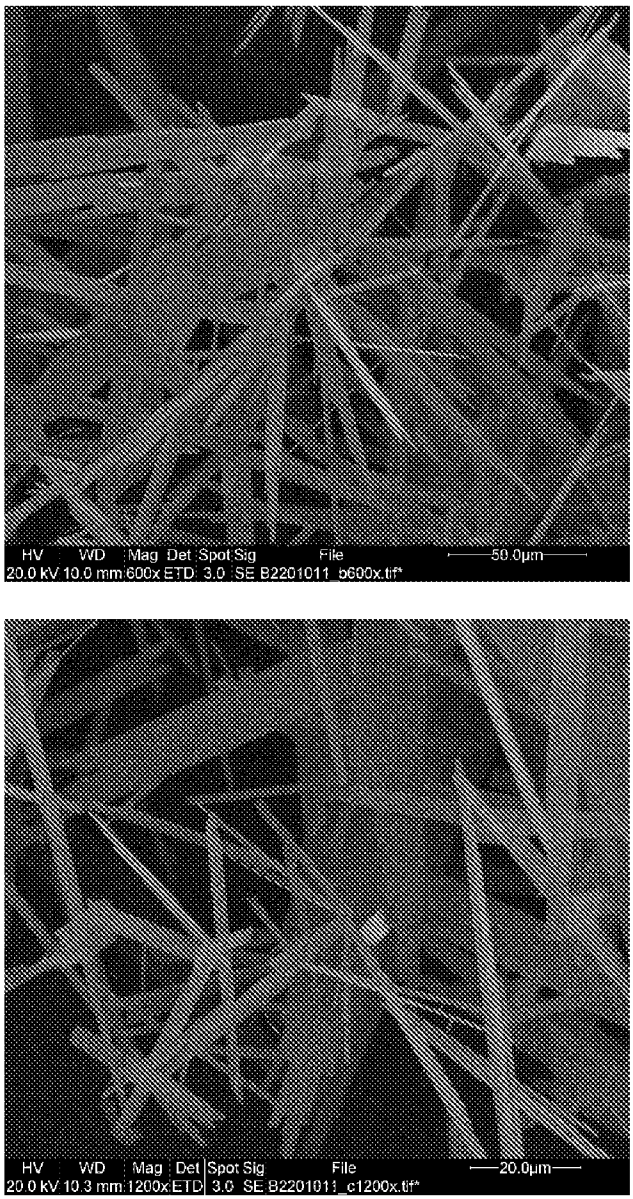

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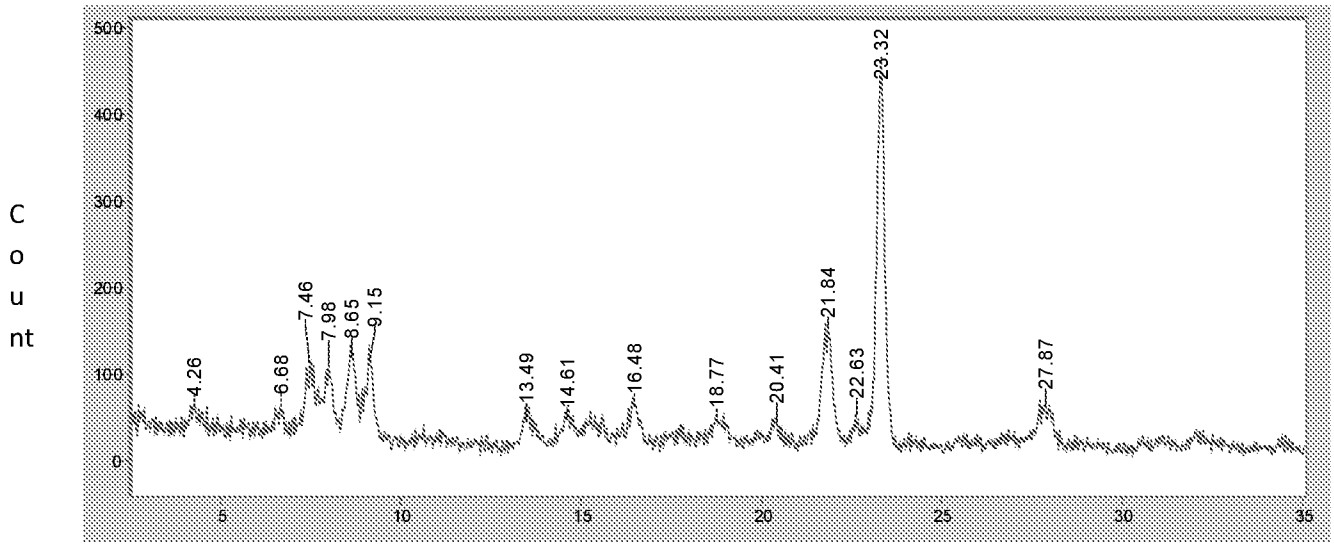
FIG. 11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9.15
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16.48
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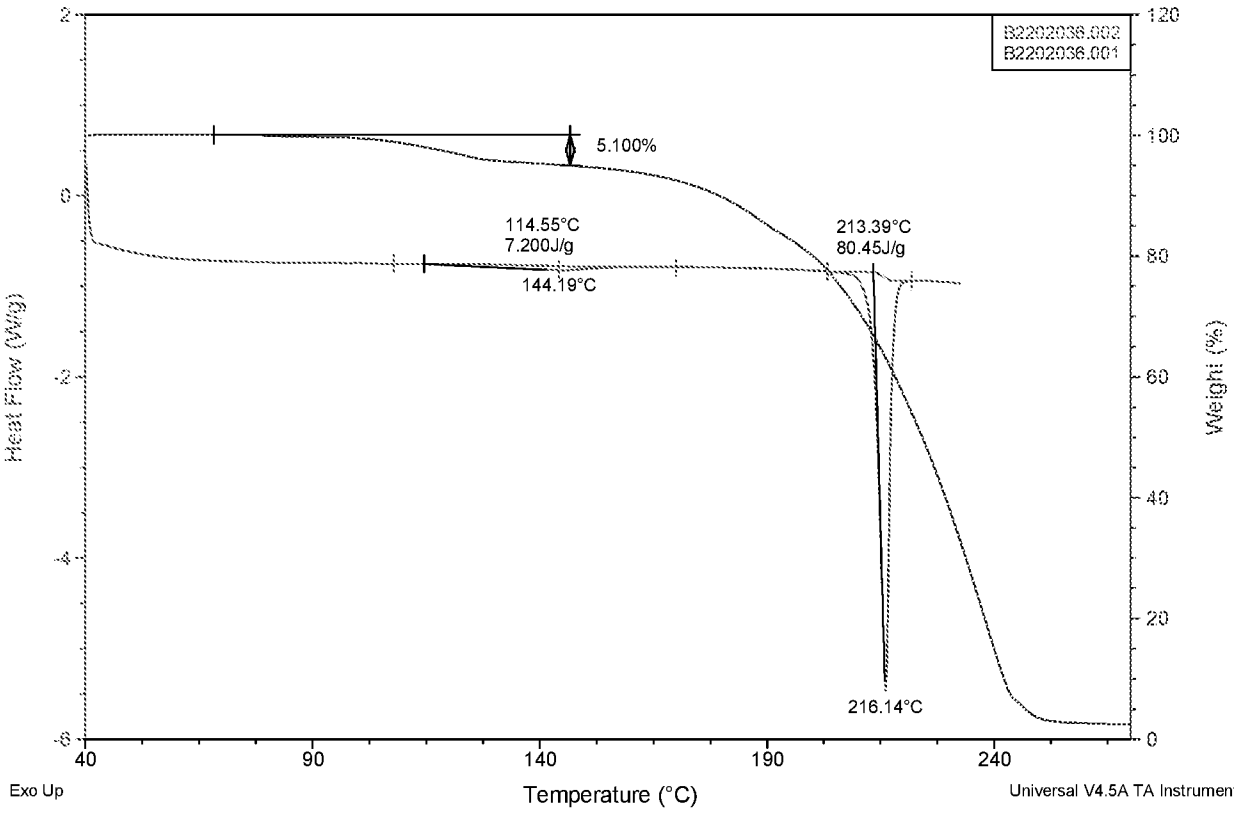
10
15
20
25
30
35
2-theta value

FIG. 12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B2202036.001
5.100%
114.55°C
7.200J/g
144.19°C
213.39°C
80.45J/g
216.14°C
Heat Flow (W/g)
Weight (%)
Exo Up
Temperature (°C)
Universal V4.5A TA Instrumen
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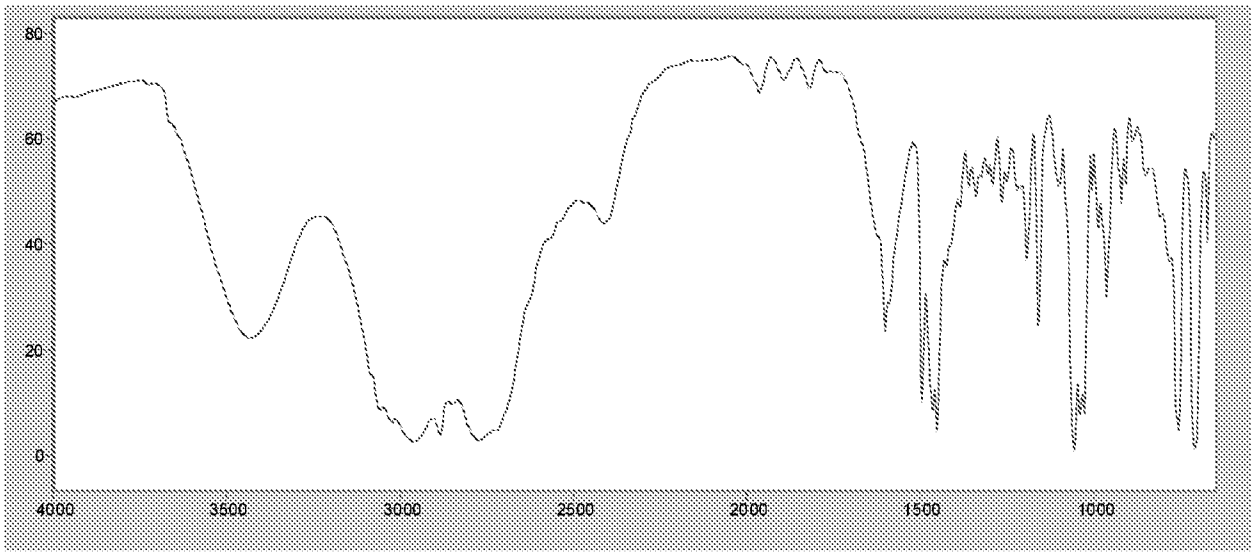
0
-2
-4
-6
120
100
80
60
40
20
0
40
90
140
190
240

FIG. 13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Wave number cm-1

FIG. 14

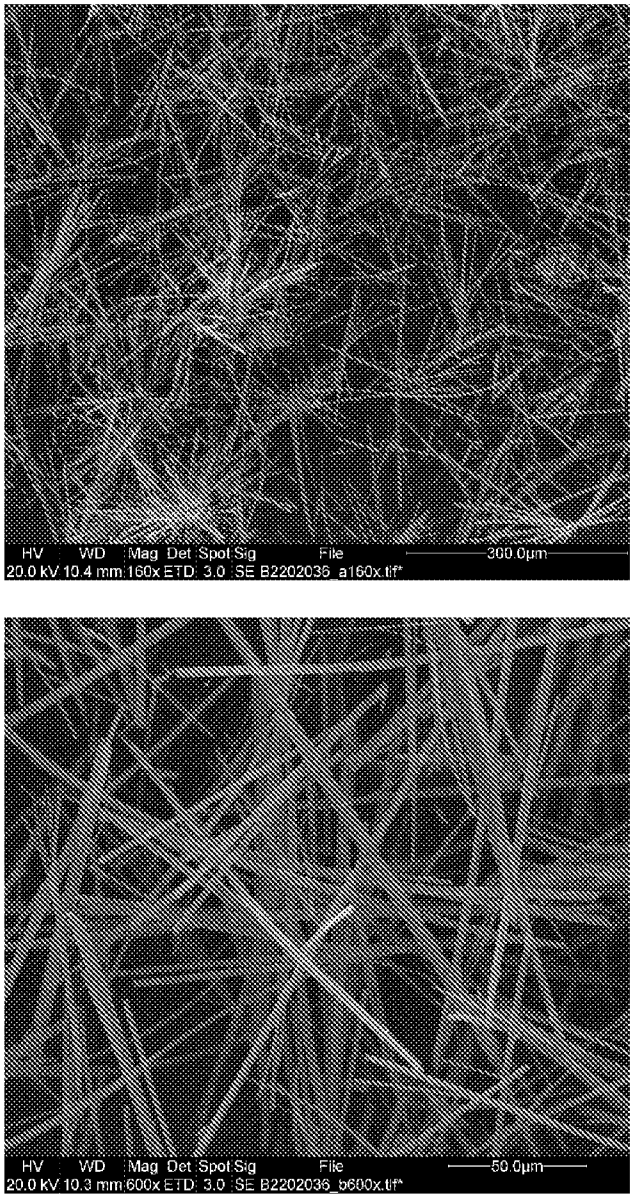
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FIG. 15

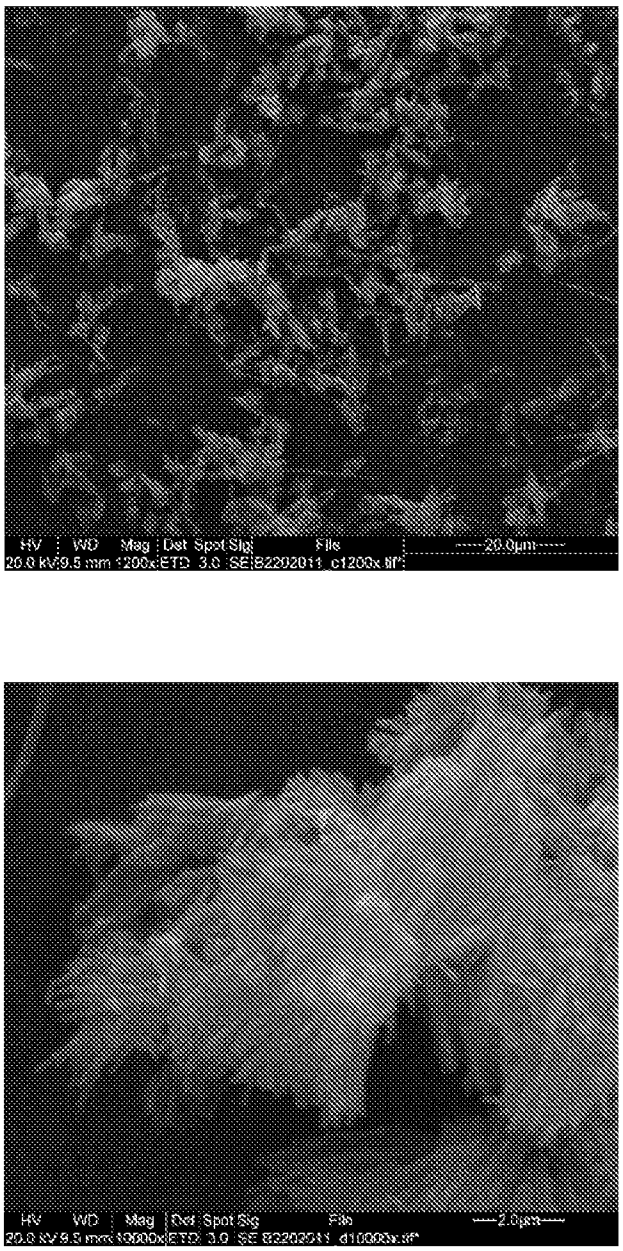
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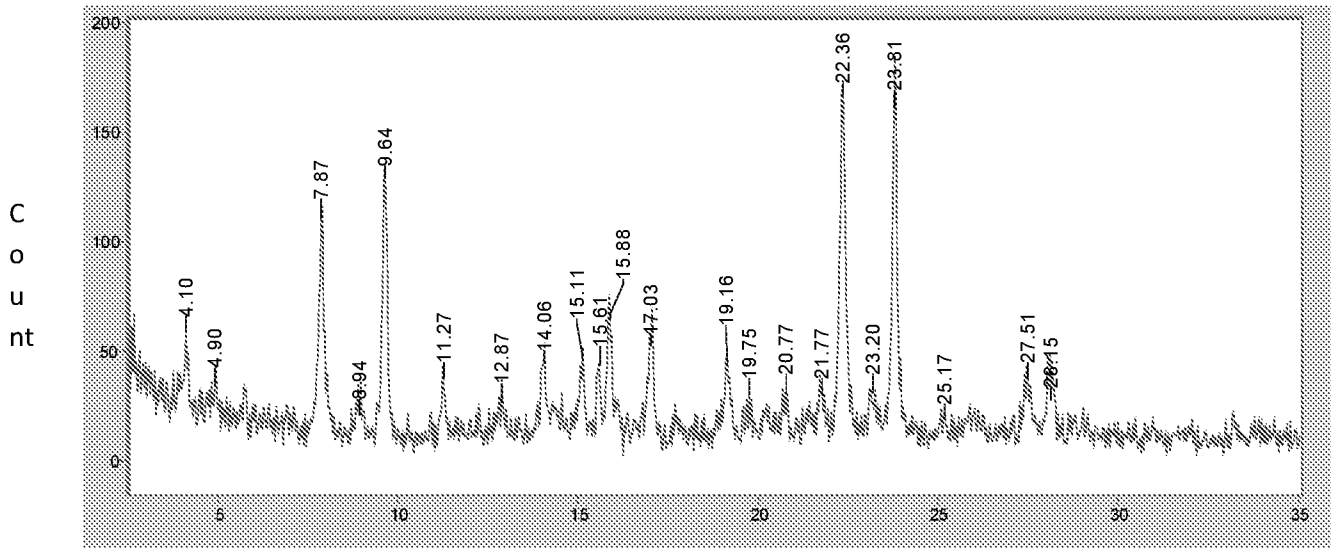
FIG. 16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15.11
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15.88
17.03
19.16
19.75
20.77
21.77
22.36
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5
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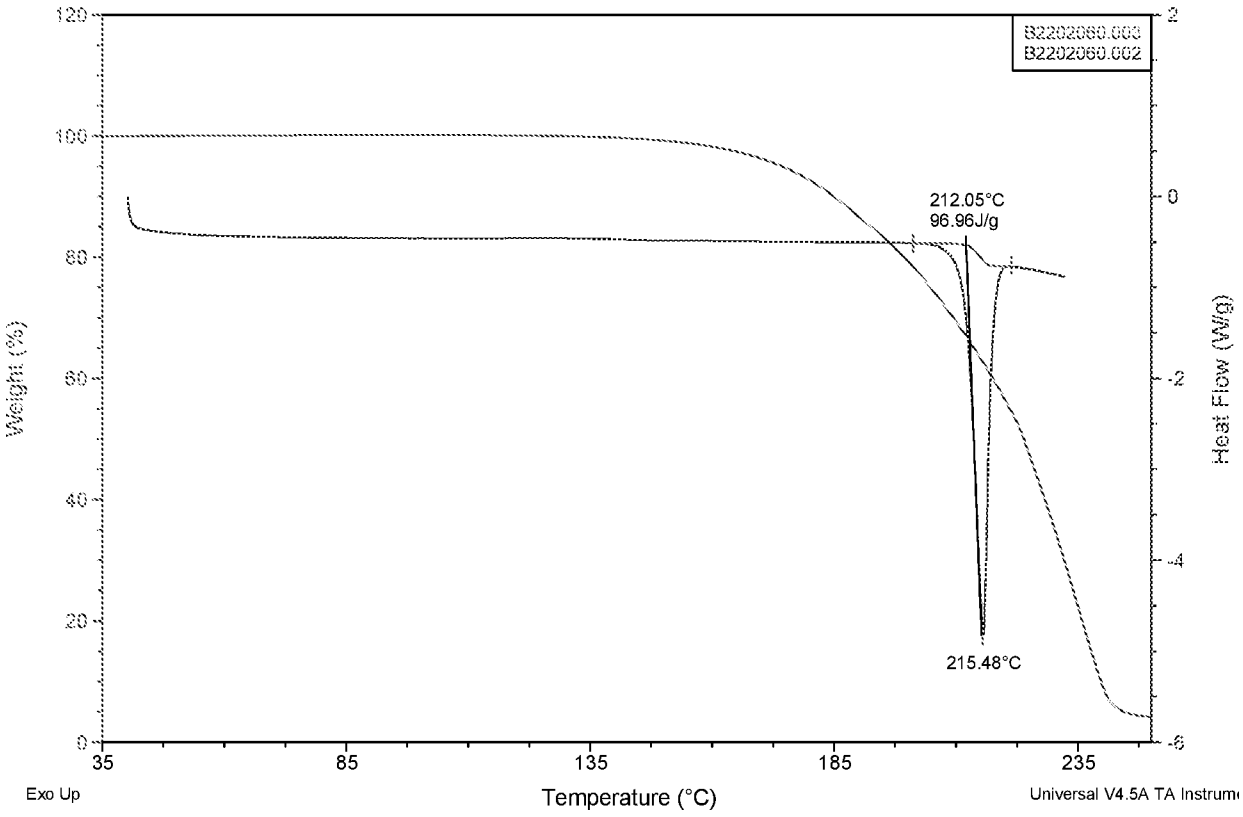
15
20
25
30
35
2-theta value

FIG. 17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B2202060.002
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96.96J/g
215.48°C
Weight (%)
Heat Flow (W/g)
Temperature (°C)
Exo Up
Universal V4.5A TA Instrum
120
100
80
60
40
20
0
2
0
-2
-4
-6
35
85
135
185
235

FIG. 18