Claims

1. A method for silane coupling agent compounding modification and dispersing optimization for photovoltaic-grade submicron silica micro-powder, comprising the following steps:

   drying a photovoltaic-grade submicron silica micro-powder under an inert atmosphere for 2-4 h, cooling to a room temperature, and then placing in a high-shear mixing reactor, wherein a surface hydroxyl content index of the photovoltaic-grade submicron silica micro-powder is 1.5–3.0 mmol/g;

   adding a first silane coupling agent solution and a second silane coupling agent solution sequentially, wherein after the first silane coupling agent reacts for 1.5-2.5 h, the second silane coupling agent is added; and after the first silane coupling agent is reacted completely and a temperature is lowered to 70°C, the second silane coupling agent is added;

   then adding a dispersion additive solution and continuing stirring at 70-90°C for 1.0-2.0 h;

   removing a solvent through a reduced-pressure distillation after a reaction is completed, drying an obtained solid in a vacuum drying oven at 60°C for 6-12 h to obtain a modified silica micro-powder;

   wherein the first silane coupling agent is 3-(2,3-epoxypropoxy)propyltrimethoxysilane, and a solution thereof is prepared by mixing the coupling agent with anhydrous ethanol at a mass ratio of 1:(8-12);

   the second silane coupling agent is N-(2-aminoethyl)-3-aminopropylmethyldimethoxysilane, and a solution thereof is prepared by mixing the coupling agent with anhydrous isopropanol at a mass ratio of 1:(10-15);

   the dispersion additive is a polyether-modified polysiloxane, and the solution thereof is prepared by mixing the additive with anhydrous n-hexane at a mass ratio of 1:(20-30);

   the polyether-modified polysiloxane has a number average molecular weight of 2000–4000 and an HLB value of 8-10, polyether chain segments thereof are copolymerized from ethylene oxide and propylene oxide in a molar ratio of 3:1, and an end-capping group is methyl; and a reaction chamber of the high-shear mixing reactor is made of 316L stainless steel, and an inner wall is subjected to electrolytic polishing treatment to a surface roughness Ra≤0.4 μm.

2. The method for silane coupling agent compounding modification and dispersing optimization for photovoltaic-grade submicron silica micro-powder according to claim 1, wherein an addition amount of the first silane coupling agent solution accounts for 1.5-3.0 wt% of a mass of the silica micro-powder, and an addition means is to add dropwise to a reaction system at a constant rate by a metering pump within 10-15 min, and a system temperature is maintained at 65±2°C during a dropwise addition process.

3. The method for silane coupling agent compounding modification and dispersing optimization for photovoltaic-grade submicron silica micro-powder according to claim 1, wherein an addition amount of the second silane coupling agent solution accounts for 0.8-1.5 wt% of a mass of silica micro-powder, and after a reaction of the first silane coupling agent is completed and a temperature is cooled to 70°C, the second silane coupling agent solution is injected into the reactor in a form of a spray through a bottom feed port, wherein the spray has a pressure of 0.2-0.4 MPa, and an atomization particle size controlled within the range of 20–50 μm.

4. The method for silane coupling agent compounding modification and dispersing optimization for photovoltaic-grade submicron silica micro-powder according to claim 1, wherein the high-shear mixing reactor is equipped with a double-layer jacketed temperature control system, an inner layer is a the reaction chamber and an outer layer is charged with thermal oil for temperature regulation; and three layer of serrated dispersion discs are installed inside the reaction chamber, an upper disc is 5 cm away from a liquid level, a middle disc is located at a center of the liquid level, and a lower disc is 3 cm away from a bottom, an spacing between adjacent discs is equal, and a rotating shaft is installed vertically.

5. The method for silane coupling agent compounding modification and dispersing

optimization for photovoltaic-grade submicron silica micro-powder according to claim 1, wherein the reduced-pressure distillation is carried out in a rotary evaporator until no condensate is produced, wherein a water bath temperature is 50-60°C, a vacuum degree is -0.095 to -0.098 MPa, and a distillation time is 40-60 min.

6. The method for silane coupling agent compounding modification and dispersing optimization for photovoltaic-grade submicron silica micro-powder according to claim 1, wherein the vacuum drying oven is equipped with a porous stainless steel tray inside, the tray has a pore diameter of 0.5 mm and a porosity of 40%, and a paving thickness of the silica micro-powder is not more than 5 mm; and turning-over is performed on a material every 2 h during the drying process; and the turning-over is carried out by a means of a pulse purging with clean nitrogen gas at an air pressure of 0.1 MPa, each purging lasts for 10 s, and the purging is carried out 3 times in total.

7. The method for silane coupling agent compounding modification and dispersing optimization for photovoltaic-grade submicron silica micro-powder according to claim 1, wherein the anhydrous ethanol, the anhydrous isopropanol and the anhydrous n-hexane are subjected to a molecular sieve dehydration treatment before use and are filtered through a 0.22 μm polytetrafluoroethylene membrane; and a metal ion content is confirmed by an ICP-MS detection, and the contents of sodium, iron and other metal ions and chloride ions are all below 0.1ppb.

8. The method for silane coupling agent compounding modification and dispersing optimization for photovoltaic-grade submicron silica micro-powder according to claim 1, wherein the particle size D50 of the photovoltaic-grade submicron silica micro-powder is 0.4-0.6 μm, and the number average molecular weight of the polyether-modified polysiloxane is 2500-3500.

9. A modified photovoltaic-grade submicron silica micro-powder according to any one of claims 1-8, wherein the surface thereof is grafted with a compound coating layer of 3-(2,3-epoxypropoxy)propyltrimethoxysilane and N-(2-aminoethyl)-3-

aminopropylmethyldimethoxysilane, with a coating rate of 5-10 wt%, a sodium/iron/chloride ion content of ≤0.5 ppm, and a dispersion uniformity in EVA of ≤5 μm (agglomerate particle size).

10. The method for silane coupling agent compounding modification and dispersing optimization for photovoltaic-grade submicron silica micro-powder according to any one of claims 1-8, which is used in preparation of highly-filled composite materials for photovoltaic encapsulants, thermal interface materials or battery backsheets, wherein when the highly-filled composite materials are used for photovoltaic encapsulants, the yellowing index of the encapsulated parts is ≤1.0 (after 1000h aging), and when the highly-filled composite materials are used for the thermal interface material, the thermal conductivity is ≥1.8 W/(m·K).