Claims

[Claim 1]

Heteroatom-doped nanodiamond particles having a fluorescence emission peak derived from heteroatom-vacancy (Heteroatom-V) centers and satisfying conditions consisting of:

(i) when 1 μL of a 1 mass% aqueous suspension of the heteroatom-doped nanodiamond particles is added dropwise onto a glass substrate, and fluorescence spectra are acquired for 101 × 101 spots using a microscopic Raman apparatus at a spatial resolution of 1 μm and in a sample range of 100 μm × 100 μm, a percentage of the number of bright spots emitting fluorescence with a zero-phonon line (ZPL) peak at ZPL ± X nm ($0 \leq X \leq 5$) of the Heteroatom-V centers is 50% or greater; and

(ii) an average size of primary particles is from 2 to 70 nm.

[Claim 2]

The heteroatom-doped nanodiamond particles according to claim 1, wherein a heteroatom is a Group 14 element selected from the group consisting of Si, Ge, Sn, and Pb.

[Claim 3]

The heteroatom-doped nanodiamond particles according to claim 1 or 2, wherein a heteroatom is Si, and (i) when 1 μL of a 1 mass% aqueous suspension of the heteroatom-doped nanodiamond particles is added dropwise onto a glass substrate, and fluorescence spectra are acquired for 101 × 101 spots using a microscopic Raman apparatus at a spatial resolution of 1 μm and in a sample range of 100 μm × 100 μm with an excitation light of 532 nm, a percentage of the number of bright spots emitting fluorescence with a ZPL peak at ZPL 738 nm ± X nm ($0 \leq X \leq 5$) of Si-V centers is 50% or greater.

[Claim 4]

The heteroatom-doped nanodiamond particles according to claim 1 or 2, wherein a heteroatom is Ge, and (i) when 1 μL of a 1 mass% aqueous suspension of the heteroatom-doped nanodiamond particles is added dropwise onto a glass substrate, and fluorescence spectra are acquired for 101 × 101 spots using a microscopic Raman apparatus at a spatial resolution of 1 μm and in a sample range of 100 μm × 100 μm with an excitation light of 532 nm, a percentage of the number of bright spots emitting fluorescence with a ZPL peak at ZPL 602 nm ± X nm ($0 \leq X \leq 5$) of Ge-V centers is 50% or greater.

[Claim 5]

The heteroatom-doped nanodiamond particles according to any one of claims 1 to 4, wherein a peak area ratio of sp^2-carbon to sp^3-carbon (sp^2-carbon/ sp^3-carbon) of the heteroatom-doped nanodiamond particles obtained by Raman spectroscopy is from 0.01 to 7.0.

[Claim 6]

The heteroatom-doped nanodiamond particles according to any one of claims 1 to 5, wherein the heteroatom-doped nanodiamond particles satisfy one or more conditions selected from the group consisting of:

(a) the heteroatom-doped nanodiamond particles have a zeta potential from -70 mV to 70 mV; and

(b) when the heteroatom-doped nanodiamond particles are dispersed in water at a concentration of 3 wt.%, a pH is from 1 to 12.

[Claim 7]

The heteroatom-doped nanodiamond particles according to any one of claims 1 to 6, wherein the heteroatom-doped nanodiamond particles have a shape that is spherical, ellipsoidal, or polyhedral.

[Claim 8]

The heteroatom-doped nanodiamond particles according to any one of claims 1 to 7, wherein the heteroatom-doped nanodiamond particles have a BET specific surface area from 20 to 900 m^2/g.

[Claim 9]

The heteroatom-doped nanodiamond particles according to any one of claims 1 to 8, wherein the percentage of the number of bright spots is 90% or greater.

[Claim 10]

A production method for producing heteroatom-doped nanodiamond particles having a fluorescence emission peak derived from heteroatom-vacancy (Heteroatom-V) centers, the method comprising subjecting a heteroatom-doped nanodiamond raw material produced by detonation method to one or more treatments selected from the group consisting of:

(I) an oxidation treatment at a temperature from 510 to 590 °C; and

(II) a hydrogenation treatment at a temperature from 300 to 1200°C, wherein the heteroatom-doped nanodiamond particles satisfy the following conditions (i)

and (ii):

(i) when 1 μL of a 1 mass% aqueous suspension of the heteroatom-doped nanodiamond particles is added dropwise onto a glass substrate, and fluorescence spectra are acquired for 101 × 101 spots using a microscopic Raman apparatus at a spatial resolution of 1 μm and in a sample range of 100 μm × 100 μm, a percentage of the number of bright spots emitting fluorescence with a zero-phonon line (ZPL) peak at ZPL ± X nm ($0 \leq X \leq 5$) of the Heteroatom-V centers is 50% or greater; and

(ii) an average size of primary particles is from 2 to 70 nm.

[Claim 11]

The production method according to claim 10, wherein the oxidation treatment is performed in an atmosphere having an oxygen concentration from 1 to 100%.

[Claim 12]

The production method according to claim 10, wherein the hydrogenation treatment is performed in an atmosphere having a hydrogen concentration from 1 to 100%.