CLAIMS

1. An optical filter, comprising:

a matrix including an optically transparent matrix material, and

nanoparticles embedded in the matrix material, the nanoparticles comprising carbon atoms arranged in a hexagonal structure and including one or more of graphene nanoparticles, carbon nanotubes, and fullerenes,

wherein at least one nanoparticle aggregate including a plurality of the nanoparticles has a maximum diameter of less than 30 nm, each of the nanoparticles of the at least one nanoparticle aggregate being in physical contact with at least another one of the nanoparticles of the at least one nanoparticle aggregate.

2. The optical filter of claim 1, wherein a maximum variation of refractive index of the optical filter is $\pm 50 \cdot 10^{-6}$ and/or the optical filter has a maximum density of striae causing an optical path difference of 30 nm of 10 %.

3. The optical filter according to claim 1 or 2, wherein the nanoparticles include endohedral fullerenes.

4. The optical filter according to claim 3, wherein the nanoparticles include endohedral fullerenes containing within their carbon complex structure one or more of metal dopants, semimetal dopants, or their respective oxides, chlorides, fluorides, iodides, or nitrates.

5. The optical filter according to any one of claims 1 to 4, wherein one or more of the nanoparticles include one or more functional groups.

6. The optical filter according to claim 5, wherein the one or more functional groups are or include one or more of: amide, amine, carbonyl, carboxyl, epoxide, ester, halide, hydroxyl, isocyanate, isothiocyanate, thiol, and sulfur containing groups.

7. The optical filter according to any one of claims 1 to 6, wherein the matrix material includes one or more of: an acrylate-based polymer, a polycarbonate-based polymer, a urethane-based polymer, a thiourethane-based polymer, an epoxy-based polymer, and an episulphide-based polymer or other polymer or resin exhibiting aromatic structure.

8. The optical filter according to any one of claims 1 to 7, wherein the matrix material includes an inorganic material, optionally an inorganic glass material, in an amount of at least 50 wt%, optionally at least 80 wt%, further optionally at least 95 wt%, based on the total mass of the matrix material.

9. A multilayer optical filter comprising a plurality of filter layers stacked in a thickness direction of the multilayer optical filter, wherein one or more filter layers of the plurality of filter layers are configured as an optical filter according to any one of claims 1 to 8.

10. The multilayer optical filter according to claim 9, wherein the plurality of filter layers includes first and second filter layers configured as optical filters according to any one of claims 1 to 9 with mutually different nanoparticle compositions or with mutually different matrix materials or with mutually different nanoparticle compositions and mutually different matrix materials.

11. The multilayer optical filter according to claim 9 or 10, wherein at least one filter layer of the plurality of filter layers is free of nanoparticles comprising carbon atoms arranged in a hexagonal structure.

12. The multilayer optical filter according to claim 11, wherein the at least one filter layer that is free of nanoparticles comprising carbon atoms arranged in a hexagonal structure includes an inorganic material, optionally an inorganic glass material, in an amount of at least 50 wt%, optionally at least 80 wt%, further optionally at least 95 wt%, based on the total weight of the at least one filter layer.

13. The multilayer optical filter according to any one of claims 9 to 12, wherein at least two filter layers of the plurality of filter layers have mutually different dimensions or mutually different shapes or mutually different dimensions and shapes in a direction orthogonal to the thickness direction.

14. A method of manufacturing an optical filter, the method comprising:

adding nanoparticles comprising carbon atoms arranged in a hexagonal structure to an optically transparent matrix material or to a precursor of an optically transparent matrix material to obtain a mixture, the nanoparticles including one or more of graphene nanoparticles, carbon nanotubes, and fullerenes;

homogenizing the mixture to obtain a homogenized mixture, wherein the homogenizing the mixture involves mixing with shear rates between 60000 s^{-1} and 350000 s^{-1}; and

inserting the homogenized mixture into a mold to form the optical filter.

15. The method according to claim 14, wherein the homogenizing the mixture includes one or both of:

a high-speed homogenization at mixing speeds above 5000 rpm, optionally above 10000 rpm, further optionally between 10000 rpm and 80000 rpm, and

a sonication at frequencies above 5 kHz, optionally above 10 kHz, further optionally between 10 kHz and 80 kHz.

16. The method according to any one of claims 14 or 15, wherein

during the adding the nanoparticles to the optically transparent matrix material or to the precursor of an optically transparent matrix material the optically transparent matrix material or the precursor of an optically transparent matrix material is in a liquid state to obtain a liquid mixture, and/or

during the homogenizing the mixture the mixture is in a liquid state.

17. The method according to claim 16, wherein a surfactant is added to the liquid mixture or the homogenized mixture.

18. The method according to claim 17, wherein a mass ratio of surfactant to nanoparticles is in the range of 1:1 to 50:1, optionally of 10:1 to 35:1.

19. The method according to claim 17 or 18, wherein the surfactant is selected from the group consisting of non-ionic surfactants, anionic surfactants, cationic surfactants, and amphoteric surfactants, or mixtures thereof.

20. The method according to any one of claims 17 to 19, wherein the surfactant is added to the homogenized mixture and the homogenized mixture is subjected to a low-speed homogenization at mixing speeds below 10000 rpm, optionally between 200 rpm and 10000 rpm, before inserting the homogenized mixture into the mold.

21. The method according to any one of claims 16 to 20, wherein

the nanoparticles are dissolved in a solvent miscible with the liquid matrix material or the liquid precursor of an optically transparent matrix material to obtain a first pre-mixture,

the first pre-mixture is added to the liquid optically transparent matrix material or to the liquid precursor of an optically transparent matrix material to obtain a second pre-mixture, and

the second pre-mixture is heated to a temperature above a boiling point of the solvent and below a boiling or decomposition temperature of the optically transparent matrix material or the precursor of an optically transparent matrix material to obtain the liquid mixture.

22. The method according to any one of claims 14 to 21, wherein the optically transparent matrix material or the precursor of an optically transparent matrix material includes a thermoplastic polymer, a thermosetting polymer, a resin precursor, or mixtures thereof.