Claims

1. A reduced graphene oxide (rGO) film having a total thickness from 20 nm to 5 micrometer, which comprises a stack of rGO layers comprising flakes, wherein the distance between two consecutive layers is from 0.2 to 0.7 nm, wherein the reduced graphene oxide (rGO) film, which is obtainable by a process which comprises the following steps:
i) filtering a graphene oxide (GO) solution through a porous membrane thereby forming a GO film on a membrane top, wherein the graphene oxide (GO) solution is and aqueous solution, a concentration of graphene oxide (GO) in the solution is from 0.001 to 5 mg/mL, and a volume filtered is from 5 to 1000 mL;
ii) transferring the GO film from the membrane onto a sacrificial substrate, whereby the GO film is placed between the membrane at the top and the sacrificial substrate at the bottom;
iii) removing the membrane, whereby the GO film remains attached onto the sacrificial substrate;
iv) hydrothermally reducing the GO film to form a reduced GO material (rGO) at a temperature from 100 to 240 ºC, under a pressure from 10^5 to $4 \cdot 10^8$ Pa, for a time period from 1 min to 24 h, in the presence of water; and
v) detaching the rGO material from the sacrificial substrate.

2. The reduced graphene oxide (rGO) film according to claim 1, wherein the distance between two consecutive layers is from 0.3 to 0.5 nm.

3. The reduced graphene oxide (rGO) film according to any of the claims 1 to 2, wherein the total thickness is from 500 to 2000 nm.

4. The reduced graphene oxide (rGO) film according to any of the claims 1 to 3, wherein the stack of rGO layers comprises from 100 to 500000 layers of flakes.

5. The reduced graphene oxide (rGO) film according to any of the claims 1 to 4, which has a carbon-to-oxygen ratio from 0.8 to 2.0 as measured by X-ray photoelectron spectroscopy (XPS).

6. The reduced graphene oxide (rGO) film according to any of the claims 1 to 5, which shows a X-ray diffraction spectra in which a peak at 11 ± 0.5, σ = 4, degrees 2 theta measured in an X-ray diffractometer with CuKα radiation (1.540598 Å) characteristic of

non-reduced graphene oxide is substantially absent, wherein substantially absent means that the %area/area of the peak at 11 ± 0.5 is equal to or less than 1%.

7. The reduced graphene oxide (rGO) film according to any of the claims 1 to 6, which shows a peak at 23 ± 0.5, σ = 4, degrees 2 theta in the X-ray diffraction spectra measured in an X-ray diffractometer with CuKα radiation (1.540598 Å).

8. The reduced graphene oxide (rGO) film according to any of the claims 1 to 7, wherein the rGO film has an upper surface, and the upper surface of the rGO film has a root square mean roughness from 1 to 200 nm, for an area of 25x25 μm^2, as measured by Atomic force microscope (AFM).

9. The reduced graphene oxide (rGO) film according to any of the claims 1 to 8, which shows a D-to-G ratio equal to or larger than 0.9 in the Raman spectrum for an area of 20x20 μm^2.

10. The reduced graphene oxide (rGO) film according to any of the claims 1 to 9, which shows resistivity from 0.01 to 10 Ω·cm.

11. The reduced graphene oxide (rGO) film according to any of the claims 1 to 10, whose elemental composition consists essentially of carbon in an amount equal to or more than 80% of the atomic composition, and oxygen in an amount equal to or less than 20% of the atomic composition.

12. The reduced graphene oxide (rGO) film according to any of the claims 1 to 11, which is capable, when implemented in an electrode with a diameter of about 25 micrometers, of providing a charge injection limit (CIL) from 2 to 10 mC/cm^2, and/or an impedance of 10 to 100 kΩ at a frequency of 1kHz in an electrolyte-based system.

13. The reduced graphene oxide (rGO) film according to any of the claims 1 to 12, which has a surface area to volume ratio (SAVR) from 10^8 to 10^{10} m^{-1}.

14. Electrically back-contacted conductive reduced graphene oxide (rGO) structure comprising the reduced graphene oxide (rGO) film as defined in any of the claims 1 to 13, and an additional conductive support on which the rGO is deposited, wherein back-contacted means that the rGO film is placed onto the additional conductive support, such that the lower surface of the film is in contact with one of the surfaces of the conductive support.

15. The electrically back-contacted conductive structure according to claim 14, wherein the additional conductive support is selected from the group consisting of a metal, Single Layer Graphene (SLG), few layer graphene (FLG), and multilayer graphene (MLG).

16. A process for the preparation of the reduced graphene oxide (rGO) film as defined in any of the claims 1 to 13, which comprises the following steps:
i) filtering a graphene oxide (GO) solution through a porous membrane thereby forming a GO film on the membrane top, wherein the graphene oxide (GO) solution is and aqueous solution, the concentration of graphene oxide (GO) in the solution is from 0.001 to 5 mg/mL, and the volume filtered is from 5 to 1000 mL;
ii) transferring the GO film from the membrane onto a sacrificial substrate, whereby the GO film is placed between the membrane at the top and the sacrificial substrate at the bottom;
iii) removing the membrane, whereby the GO film remains attached onto the sacrificial substrate;
iv) hydrothermally reducing the GO film to form a reduced GO material (rGO) at a temperature from 100 to 240 ºC, under a pressure from 10^5 to $4 \cdot 10^8$ Pa, for a time period from 1 min to 24 h, in the presence of water; and
v) detaching the rGO material from the sacrificial substrate.

17. A process for the preparation of the electrically back-contacted conductive reduced graphene oxide (rGO) structure as defined in any of the claims 14 to 15, which comprises the following steps:
i) filtering a graphene oxide (GO) solution through a porous membrane thereby forming a GO film on the membrane top, wherein the graphene oxide (GO) solution is and aqueous solution, the concentration of graphene oxide (GO) in the solution is from 0.001 to 5 mg/mL, and the volume filtered is from 5 to 1000 mL;
ii') transferring the GO film from the membrane onto the additional conductive support, whereby the GO film is placed between the membrane at the top and an additional conductive layer at the bottom;
iii') removing the membrane, whereby the GO film remains attached onto the additional conductive support; and
iv') hydrothermally reducing the GO film to form a reduced GO material (rGO), at a temperature from 100 to 240 ºC, under a pressure from 10^5 to $4 \cdot 10^8$ Pa, for a time period from 1 min to 24 h, in the presence of water.

18. The process according to any of the claims 16 to 17, wherein the hydrothermal

reduction is carried out in a sealed container inside of an autoclave and the GO film is not in direct contact with water.

19. An electronic device for detecting, receiving and/or inducing electrical signals, comprising the reduced graphene oxide (rGO) film as defined in any of the claims 1 to 13 or the electrically back-contacted conductive reduced graphene oxide (rGO) structure material as defined in the claims 14 to 15.

20. The electronic device according to claim 19, which is a neural electrode.

21. The electronic device according to any of the claims 19 to 20, which comprises a flexible substrate patterned with conductive leads, on which the rGO film or the electrically back-contacted conductive rGO structure is deposited, and an encapsulating layer with openings on the top.