an outer conducting coating surrounding said shell which forms an electrode contact.

There is disclosed a composition of matter, in particular a photovoltaic cell, comprising:

at least one core semiconductor nanowire on a graphitic substrate, said at least one core nanowire having been grown epitaxially on said substrate wherein said nanowire comprises at least one group III-V compound or at least one group II-VI compound or at least one group IV element;

a semiconductor shell surrounding said core nanowire, said shell comprising at least one group III-V compound or at least one group II-VI compound or at least one group IV element such that said core nanowire and said shell form a n-type semiconductor and a p-type semiconductor respectively or vice versa; and

an outer contact and/or conducting layer which contacts the top of the semiconductor shell on said nanowire and which forms an electrode, e.g. a transparent graphitic layer such as graphene.

According to a first aspect of the present invention, there is provided a composition of matter, in particular a photovoltaic cell, comprising:

at least one core semiconductor nanowire on a graphene, graphane or graphene oxide substrate having a thickness of 20 nm or less~~graphitic substrate~~, said at least one core nanowire having been grown epitaxially on said substrate wherein said nanowire comprises at least one group III-V compound or at least one group II-VI compound or at least one group IV element;

a semiconductor shell surrounding said core nanowire, said shell comprising at least one group III-V compound or at least one group II-VI compound or at least one group IV element such that said core nanowire and said shell form a n-type semiconductor and a p-type semiconductor respectively or vice versa; and optionally an outer conducting coating surrounding said shell which forms an electrode contact or a contact and/or conducting layer which contacts the top of the semiconductor shell on said nanowire and which forms an electrode, e.g. a transparent graphitic layer such as graphene.

There is disclosed a process for preparing a cell as hereinbefore defined comprising:

(I) providing group II-VI elements or group III-V elements or at least

one group IV element to the surface of said graphitic substrate, preferably via a molecular beam;

(II) epitaxially growing at least one nanowire from the surface of the graphitic substrate to provide a nanowire core;

(III) coating said at least one nanowire core with a shell comprising at least one group III-V compound or at least one group II-VI compound or at least one group IV element such that said core nanowire and said shell form a n/p junction or a p/n junction respectively; and

(IV) coating said shell with an outer conducting coating surrounding said shell which forms an electrode contact, preferably a transparent electrode contact; or providing a conducting layer which contacts the top of the semiconductor shell on said nanowire and which forms an electrode, e.g. a transparent graphitic layer such as graphene.

According to a second aspect of the present invention, there is provided a composition of matter, in particular a photovoltaic cell, comprising: at least one core semiconductor nanowire on a graphene, graphane or graphene oxide substrate having a thickness of 20 nm or less~~nanowire on a graphitic substrate~~, said at least one nanowire having been grown epitaxially on said substrate wherein said nanowire comprises a bottom portion comprising at least one group III-V compound or at least one group II-VI compound or at least one group IV element which has been doped to form an n-type or p-type semiconductor; and an upper portion comprising at least one group III-V compound or at least one group II-VI compound or at least one group IV element which has been doped such that said upper portion forms a n-type semiconductor or p-type semiconductor opposite to that of the bottom portion.

According to a third aspect of the present invention, there is provided a composition of matter, in particular a tandem photovoltaic cell, comprising: at least one core semiconductor nanowire on a graphene layer, said at least one core nanowire having been grown epitaxially on said graphene layer wherein said nanowire comprises at least one group III-V compound or at least one group II-VI compound or at least one group IV element; a semiconductor shell surrounding said core nanowire, said shell comprising at least one group III-V compound or at least one group II-VI compound or at least one group IV element such that said core nanowire and said shell form an n-type semiconductor and a p-type semiconductor respectively or vice versa; and an outer conducting coating surrounding said shell which forms an electrode contact; or an outer conducting layer which contacts the top of the semiconductor shell on said nanowire and which forms an electrode, e.g. a

Claims

1. A composition of matter, in particular a photovoltaic cell, comprising:

at least one core semiconductor nanowire on a graphene, graphane or graphene oxide substrate having a thickness of 20 nm or less~~graphitic substrate~~, said at least one core nanowire having been grown epitaxially on said substrate wherein said nanowire comprises at least one group III-V compound or at least one group II-VI compound or at least one group IV element;

a semiconductor shell surrounding said core nanowire, said shell comprising at least one group III-V compound or at least one group II-VI compound or at least one group IV element such that said core nanowire and said shell form a n-type semiconductor and a p-type semiconductor respectively or vice versa; and optionally

an outer conducting coating surrounding said shell which forms an electrode contact or a contact and/or conducting layer which contacts the top of the semiconductor shell on said nanowire and which forms an electrode, e.g. a transparent graphitic layer such as graphene.

2. A composition of matter as claimed in claim 1, in particular a photovoltaic cell, comprising:

at least one core semiconductor nanowire on a graphene, graphane or graphene oxide substrate having a thickness of 20 nm or less~~graphitic substrate~~, said at least one core nanowire having been grown epitaxially on said substrate wherein said nanowire comprises at least one group III-V compound or at least one group II-VI compound or at least one group IV element;

a semiconductor shell surrounding said core nanowire, said shell comprising at least one group III-V compound or at least one group II-VI compound or at least one group IV element such that said core nanowire and said shell form an n-type semiconductor and a p-type semiconductor respectively or vice versa; and

an outer conducting coating surrounding said shell which forms an electrode contact.

3. A composition as claimed in claim 1 or 2 wherein said nanowire grows in the [111] or [0001] direction.

4. A composition as claimed in any preceding claim wherein said shell and core nanowire independently comprise a group III-V compound.

5. A composition as claimed in any preceding claim in which the nanowires comprise AlAs, ZnO, GaSb, GaP, GaN, GaAs, InP, InN, InAs, InGaAs or AlGaAs.

6. A composition as claimed in any preceding claim wherein the ~~graphitic substrate comprises~~ graphene, graphane or graphene oxide~~, preferably wherein said graphene, graphane or graphene oxide~~ comprises 10 or fewer layers.

7. A composition as claimed in any preceding claim wherein the ~~graphitic~~ substrate is ~~a laminated substrate exfoliated from a Kish graphite, a highly ordered pyrolytic graphite (HOPG),~~ CVD-grown graphene layers on metallic films or foils such as Ni, Cu, or Pt .

8. A composition as claimed in any preceding claim wherein the ~~graphitic~~ substrate is flexible and transparent.

9. A composition as claimed in any preceding claim wherein the ~~graphitic~~ substrate is doped with the same doping carriers as the contacted nanowires.

10. A composition as claimed in any preceding claim wherein the ~~graphitic~~ substrate is doped by adsorption of organic or inorganic molecules such as metal-chlorides ($FeCl_3$, $AuCl_3$ or $GaCl_3$), NO_2, HNO_3, aromatic molecules or ammonia.

11. A composition as claimed in any preceding claim wherein said surface of the ~~graphitic~~ substrate is doped by a substitutional doping method during its growth with incorporation of dopants such as B, N, S, or Si.

12. A composition as claimed in any preceding claim wherein said surface of the ~~graphitic~~ substrate is provided with nanostructures, such as nanowires or nanoparticles, with high conductivity (> 10^3 S/cm) dispersed thereon.

13. A composition as claimed in any preceding claim wherein said nanowire is no more than 500 nm in diameter and has a length of up to 8 microns, such as up to 5 microns.

14. A composition as claimed in any preceding claim wherein said substrate comprises a plurality of nanowires wherein said nanowires are substantially parallel.

15. A composition as claimed in any preceding claim wherein said nanowires are grown in the presence of a catalyst.

16. A composition as claimed in any preceding claim wherein said outer coating is a mixed metal oxide with high conductivity and transparency such as AlZnO (AZO) and InSnO (ITO) or/and a further graphitic layer.

17. A composition as claimed in any preceding claim wherein said core is p- type semiconductor and said shell is an n-type semiconductor.

18. A composition as claimed in any preceding claim wherein an undoped (intrinsic) layer is present between said core and shell layers.

19 A process for preparing a cell as claimed in claims 1 to 18 comprising:

(I) providing group II-VI elements or group III-V elements or group IV elements to the surface of said graphene, graphane or graphene oxide substrate having a thickness of 20 nm or less~~graphitic substrate~~, preferably via a molecular beam;

(II) epitaxially growing at least one nanowire from the surface of the graphitic substrate to provide a nanowire core;

(III) coating said at least one nanowire core with a shell comprising at least one group III-V compound or at least one group II-VI compound or at least one

group IV element such that said core nanowire and said shell form a n/p junction or a p/n junction respectively; and

(IV) coating said shell with an outer conducting coating surrounding said shell which forms an electrode contact, preferably a transparent electrode contact; or providing a conducting layer which contacts the top of the semiconductor shell on said nanowire and which forms an electrode, e.g. a transparent graphitic layer such as graphene.

20. A solar cell, comprising a cell as claimed in claim 1 to 18.

21. A solar cell comprising a plurality of photovoltaic cells as claimed in claim 1 to 18 preferably stacked vertically on top of each other.

22. A solar cell comprising a plurality of photovoltaic cells as claimed in claim 1 to 18 wherein at least two of said photovoltaic cells have different band gaps.

23. A process as claimed in claim 19 in which a catalyst is deposited on the substrate in step (I) prior to supply of the reactants thereto.

24. A process as claimed in claim 19 or 23 where the substrate is coated with a hole-patterned mask in step (I) prior to supply of the reactants thereto.

25. A composition of matter, in particular a photovoltaic cell, comprising:

at least one core semiconductor nanowire on a graphene, graphane or graphene oxide substrate having a thickness of 20 nm or less~~nanowire on a graphitic substrate~~, said at least one nanowire having been grown epitaxially on said substrate wherein said nanowire comprises a bottom portion comprising at least one group III-V compound or at least one group II-VI compound or at least one group IV element which has been doped to form an n-type or p-type semiconductor; and

an upper portion comprising at least one group III-V compound or at least one group II-VI compound or at least one group IV element which has been doped such that said upper portion forms a n-type semiconductor or p-type semiconductor opposite to that of the bottom portion.