In Appl. Phys Lett. 95, 213101 (2009), Kim *et al.* report vertically aligned ZnO nanostructures grown on graphene layers. These were grown using catalyst free metal-organic vapour phase epitaxy (MOVPE) and the surface morphology of the ZnO nanostructures was dependent on the growth temperature.

The present inventors have found that epitaxial nanowires of certain compounds/elements can be grown on graphitic substrates. Since graphitic substrates have no dangling bonds at the surface and very short atomic bond length compared with typical semiconductors like silicon and GaAs there is no reason to anticipate nucleation and epitaxial growth of nanowires thereon. As surprisingly noted below, there is a good lattice match with many semiconductors when using graphene depending on how the semiconductor atoms are placed on the surface of graphene.

In particular, the use of molecular beam epitaxy offers excellent results in terms of nanowire growth. In particular the invention enables the growth of group IV, group II-VI or in particular group III-V semiconductor nanowires on graphitic substrates. The present inventors have used this surprising ability to grow epitaxial nanowires on conductive graphitic substrates and developed the concept to form photovoltaic cells which can absorb photons and therefore offer value in solar technology and as photodetectors.

Summary of Invention

~~Thus, viewed from one aspect the invention provides~~ 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 conducting coating surrounding said shell which forms an electrode contact.

~~Viewed from another aspect the invention provides~~ 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.

~~Viewed from another~~ According to a first aspect of the present invention, there is ~~provides~~ provided 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 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.

~~Viewed from another aspect the invention provides~~ 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 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

transparent graphitic layer such as graphene; and a thin-film p-n junction cell having a bottom electrode and a top electrode; where said graphene layer serves as the top electrode for the thin-film p-n junction cell.

~~Viewed from another aspect the invention provides~~ There is disclosed a process for preparing a cell as hereinbefore defined wherein at least one nanowire is grown epitaxially on a graphitic substrate in the presence of a catalyst.

Optionally, the surface of the graphitic substrate can be chemically/ physically modified to enhance the epitaxial growth of nanowires.

~~Viewed from another aspect the invention provides~~ There is disclosed a device, such as a solar cell, comprising a cell as hereinbefore defined.

~~Viewed from another aspect the invention provides~~ There is disclosed a solar cell comprising a plurality of photovoltaic cells as hereinbefore defined.

~~Viewed from another aspect the invention provides~~ There is disclosed a solar cell comprising a plurality of photovoltaic cells as hereinbefore defined wherein at least two of said photovoltaic cells have a different band gap and thereby absorb light of different wavelengths.

Definitions

By a group III-V compound is meant one comprising at least one ion from group III and at least one ion from group V. Similarly, a group II-VI compound is one comprising at least one group II ion and at least one group VI ion. In this