CLAIMS

1. A method of producing small diameter carbon nanotubes with outer diameter below 10 nm from a feed gas obtained by heating a polyolefin-containing feedstock, comprising the steps of:
   (a) flowing the feed gas into a first reaction zone containing a first catalyst, wherein a portion of the feed gas is partially decomposed into an intermediate gas and solid carbon; and
   (b) flowing the intermediate gas into a second reaction zone containing a second catalyst, wherein a portion of the intermediate gas is converted into small diameter carbon nanotubes.

2. The method of claim 1, wherein the first catalyst and the second catalyst are independently selected from elements consisting of Groups IVB to VIIIB, IB, IIB, IIA and IIIA, or combinations thereof.

3. The method of claims 1 or 2, wherein step 1(a) further comprises simultaneously flowing a diluent gas into the first reaction zone.

4. The method of claim 2, wherein quantity of the feed gas is controlled to obtain a volumetric flow rate (L/min), and wherein an initial ratio between volumetric flow rate and molar content (mol) of the Group VIIIB elements of the first catalyst in the first reaction chamber is between 5 L/min/mol to 100 L/min/mol.

5. The method of claim 3, wherein quantities of the feed gas and the diluent gas are controlled to obtain a volumetric flow rate (L/min), and wherein an initial ratio between volumetric flow rate and molar content (mol) of the Group VIIIB elements of the first catalyst in the first reaction chamber is between 5 L/min/mol to 100 L/min/mol.

6. The method of any one of claims 1 to 5, wherein the first catalyst comprises either: (a) 40 wt.% Co, 10 wt.% Mo and 50 wt.% MgO; or (b) 26 wt.% Fe, 14 wt.% Ni, 10 wt.% 10Mo and 50 wt.% MgO.

7. The method of any one of claims 1 to 6, wherein temperature in the first reaction zone is between 500 °C to 900 °C.

8. The method of any one of claims 1 to 7, wherein the second catalyst is 3 wt.% Co, 2 wt.% Mo and 95 wt.% MgO.

9. The method of any one of claims 1 to 8, wherein temperature in the second reaction zone is between 600 °C to 1200 °C.

10. The method of any one of claims 1 to 9, wherein the second catalyst has a lower Group VIIIB metal loading content than the first catalyst.

11. The method of any one of claims 1 to 10, wherein the feed gas and the intermediate gas comprises at least one or more paraffins and one or more olefins.

12. The method of any one of claims 1 to 11, wherein the polyolefin-containing feedstock comprises one or more polyolefins selected from the group consisting of polyethylene, polypropylene, polymethylpentene, polybutene-1, ethylene-octene copolymers, olefin block copolymers, propylene–butane copolymers, polyisobutylene, poly(a-olefin)s, ethylene propylene rubber, ethylene propylene diene monomer rubber, or combinations thereof.

13. An apparatus for production of small diameter carbon nanotubes with outer diameter below 10 nm, the apparatus comprising:
a first reactor which is connected to a second reactor in series; wherein
the first reactor is configured to hold a first heated catalyst bed comprising a first catalyst, wherein the first catalyst bed generates an intermediate gas and solid carbon when the first catalyst bed is in contact with a feed gas received from an inlet;
the second reactor is configured to hold a second heated catalyst bed comprising a second catalyst, wherein the second catalyst bed generates the small diameter carbon nanotubes when the second catalyst bed is in contact with the intermediate gas received from the first reactor;
and wherein the feed gas is obtained by heating a polyolefin-containing feedstock.

14. The apparatus of claim 13, wherein the first catalyst in the first heated catalyst bed and the second catalyst in the second heated catalyst bed are independently selected from elements consisting of Groups IVB to VIIIB, IB, IIB, IIA and IIIA, or combinations thereof.

15. The apparatus of claim 14, wherein the inlet of the first reactor is connected to a pressurized gas storage vessel holding the feed gas, wherein the quantity of feed gas is controlled by a flow controlling device so that
an initial ratio between volumetric flow rate (L/min) and molar content (mol) of the Group VIIIB elements of the first catalyst of between 5 L/min/mol to 100 L/min/mol is achieved in the first reactor.

16. The apparatus of claim 14, wherein the inlet of the first reactor is connected to a pressurized gas storage vessel holding the feed gas and a diluent gas source, wherein the quantities of feed gas and diluent gas are controlled by separate flow controlling devices so that
an initial ratio between volumetric flow rate (L/min) and molar content (mol) of the Group VIIIB elements of the first catalyst of between 5 L/min/mol to 100 L/min/mol is achieved in the first reactor.

17. The apparatus of any one of claims 13 to 16, wherein the connection between the first reactor and the second reactor further comprises a particle filtration device and/or a pressure regulator.

18. The apparatus of any one of claims 13 to 17, wherein the first catalyst comprises either: (a) 40 wt.% Co, 10 wt.% Mo and 50 wt.% MgO; or (b) 26 wt.% Fe, 14 wt.% Ni, 10 wt.% 10Mo and 50 wt.% MgO.

19. The apparatus of any one of claims 13 to 18, wherein the second catalyst comprises 3 wt.% Co, 2 wt.% Mo and 95 wt.% MgO.