Catalytic Conversion of Graphene into Carbon Nanotubes via Gold Nanoclusters at Low Temperatures

Enkeleda Dervishi,*,† Shawn Bourdo,† Joshua A. Driver,† Fumiya Watanabe,† Alexandru R. Biris,‡ Anindya Ghosh,§ Brian Berry,§ Viney Saini,† and Alexandru S. Biris*,†

†Nanotechnology Center, University of Arkansas at Little Rock, Arkansas 72204, United States
‡National Institute for Research and Development of Isotopic and Molecular Technologies, Cluj-Napoca, Romania
§Chemistry Department, University of Arkansas at Little Rock, Arkansas 72204, United States

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Soujit Sengupta
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Introduction

- Noble metal nanoparticles have huge potential in sensing, energy, spectroscopy, and catalysis.

- Gold nanoclusters deposited on a variety of metal oxide support materials can efficiently catalyze oxidation and reduction reactions as well as C-C bond formation.

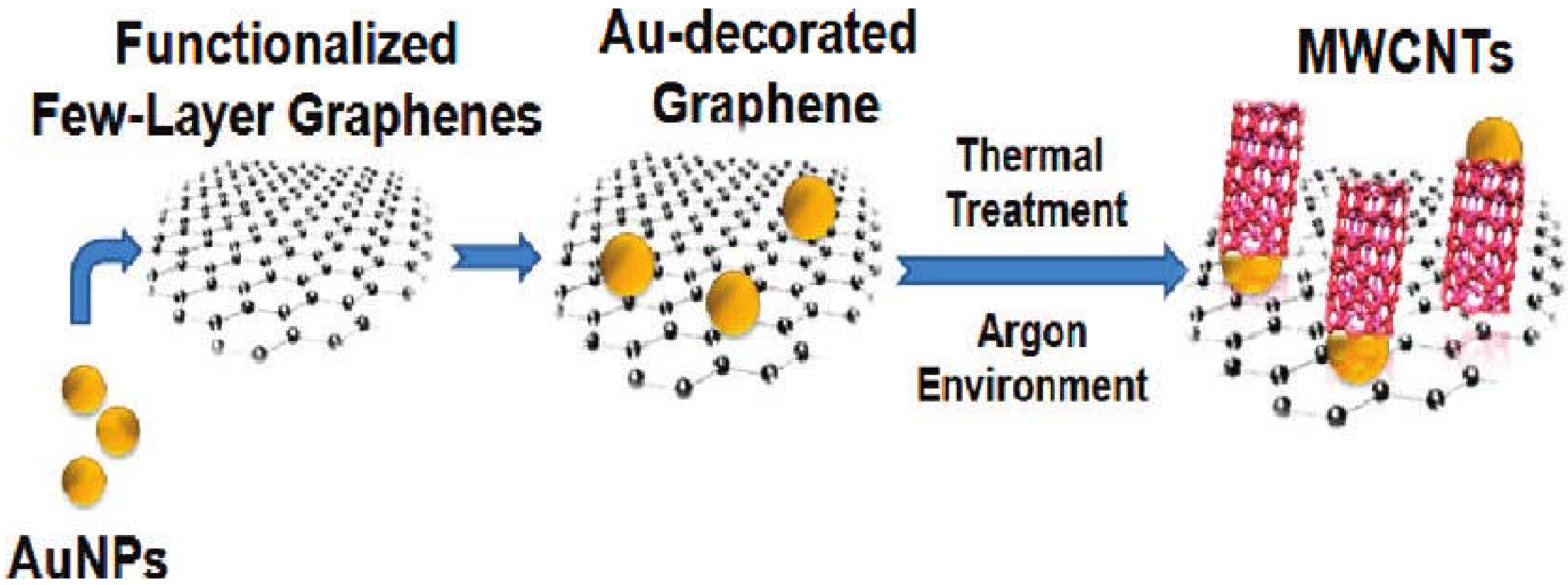
- Au-based catalysts have been used in a range of organic transformations such as nucleophilic addition, cascade reactions, Fridel-Crafts reaction, C-H bond activation, hydrogenation and dehydrogenation reactions, asymmetric catalysis and total organic synthesis.

- Synthesizing carbon nanomaterials on an Au catalyst or decorating graphitic nanostructures with AuNPs opens the door to a wide range of new applications.

- Gold has been previously found to be a challenging catalytic element in the synthesis of CNTs and other carbon nanostructures.

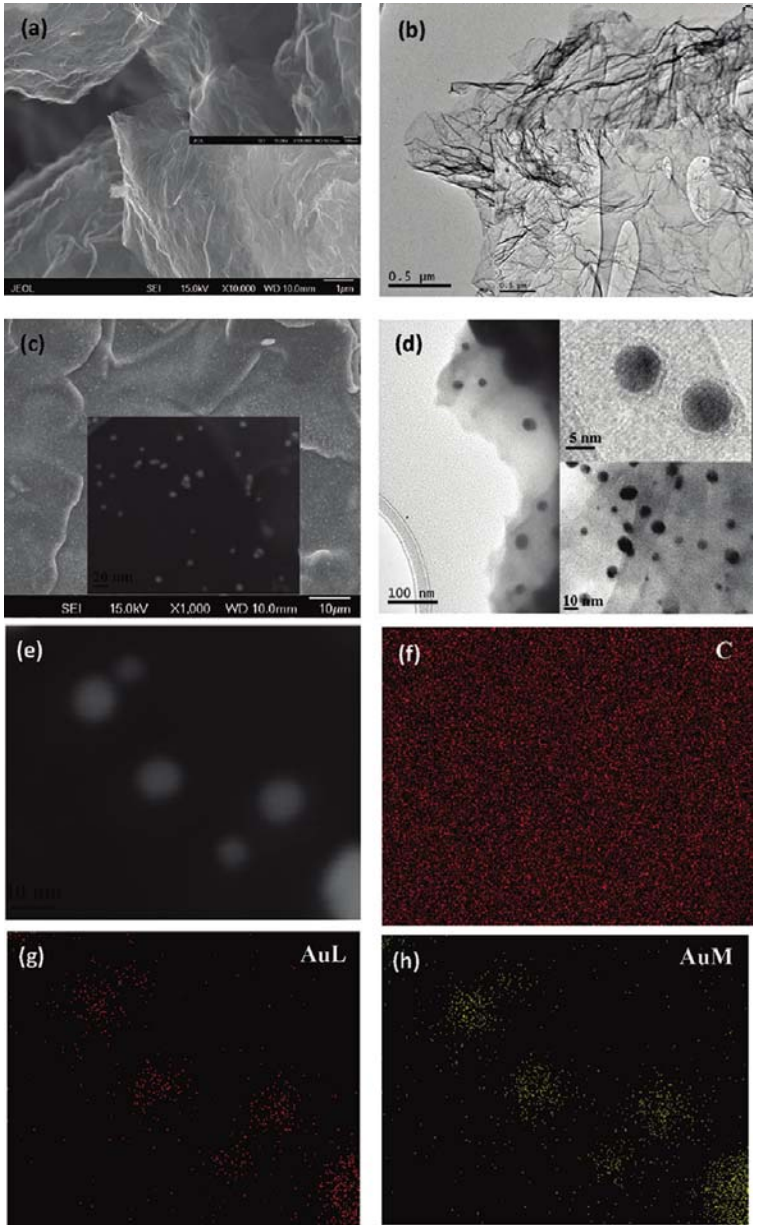
- They are the first one to report the catalytic conversion of Au-decorated graphene to nanotubes at relatively low temperatures (500 ^{o}C) without the need of a hydrocarbon source by utilizing a radio frequency chemical vapor deposition (RF-CVD) reactor.

Experimental section



RF-CVD reactions were carried out under an Ar flow and without the addition of any hydrocarbon source, utilizing the functionalized graphene decorated with Au nanoclusters as the catalytic system.

Results and discussion

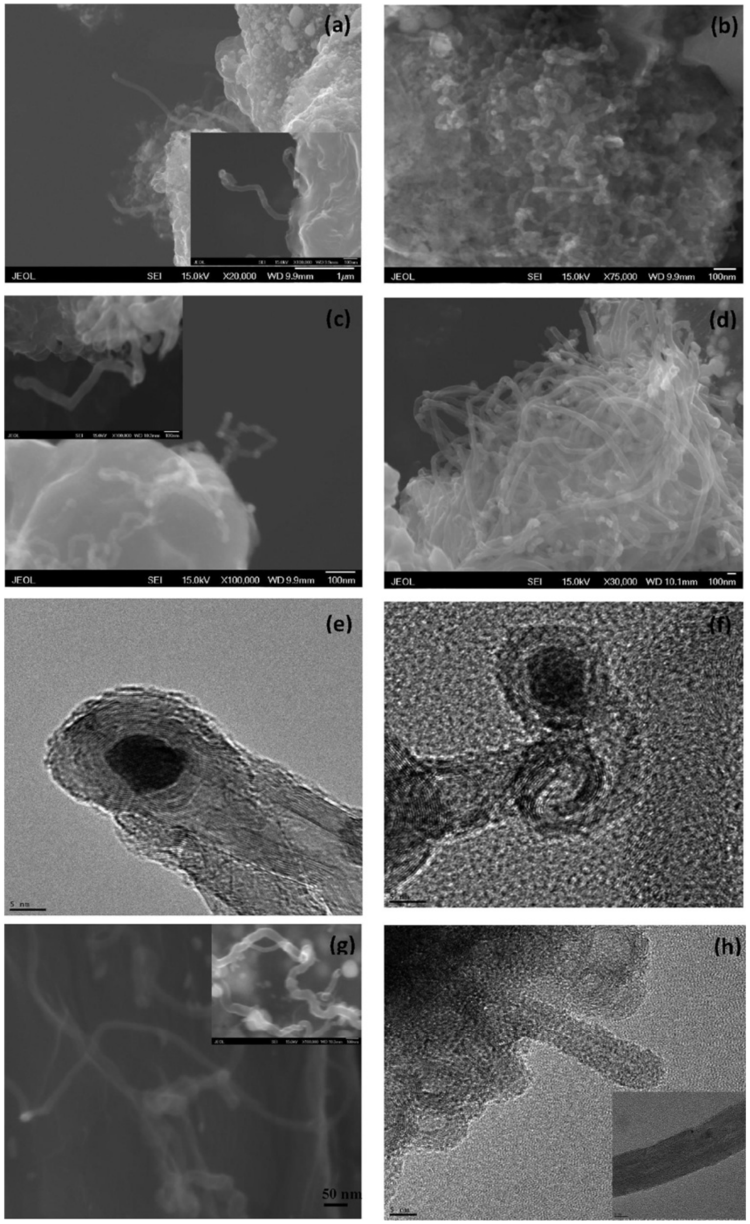


SEM & TEM images of graphene sheets.

SEM & TEM images of Au decorated graphene sheets.

EDS maps confirms the presence of Au on the graphene sheets.

Results and discussion



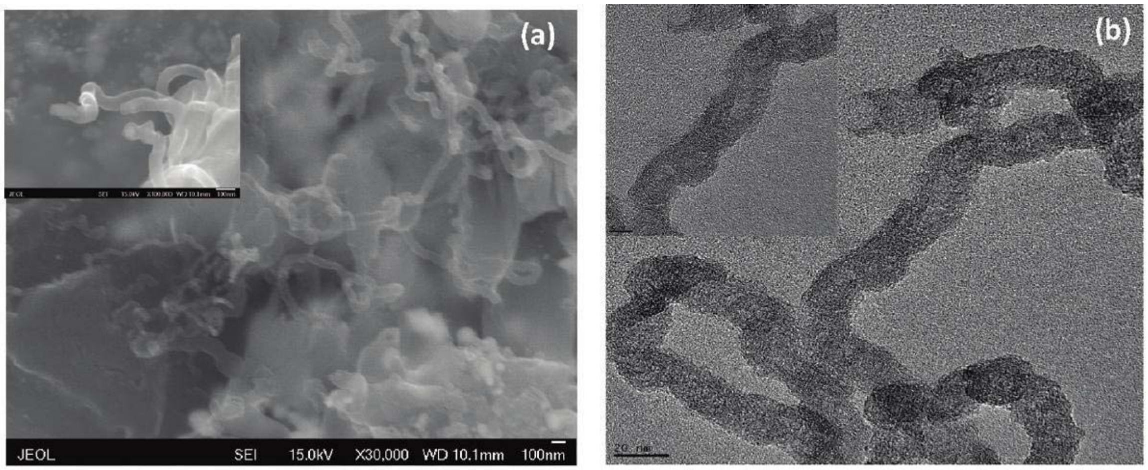
SEM images of the CNTs synthesized over the Au-decorated graphene sheets at 500 ^{o}C.

SEM images indicating high yield toward the synthesis of random networks of CNTs at 600 ^{o}C.

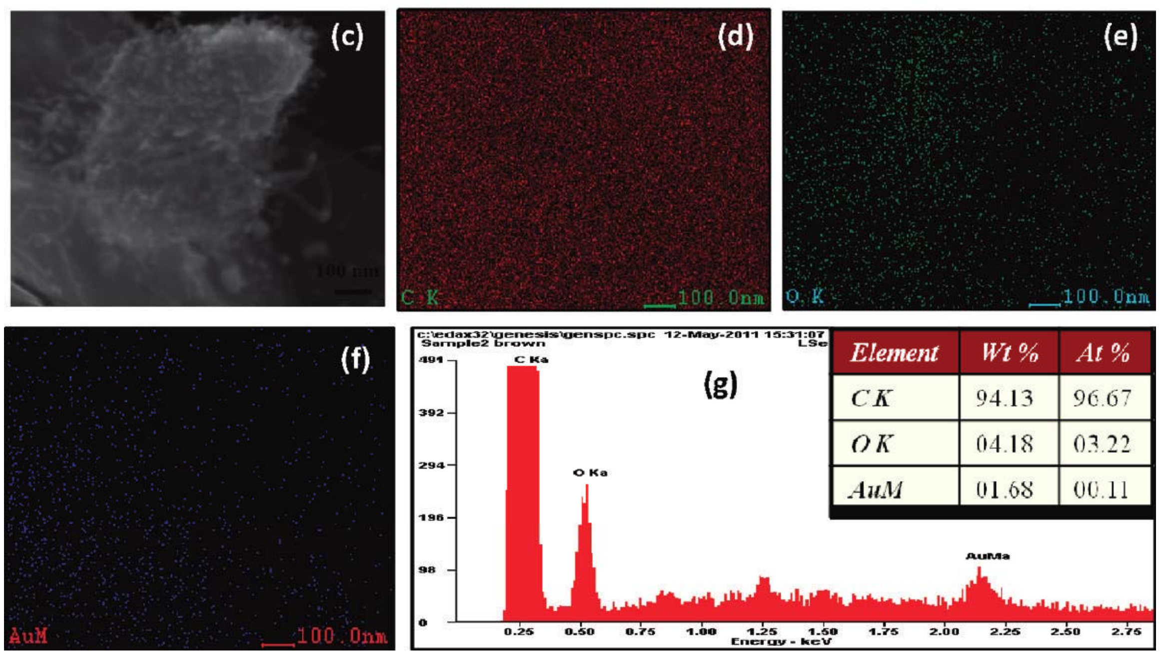
HRTEM images of the CNTs synthesized at 600 ^{o}C over the graphene sheets decorated with AuNPs.

SEM and TEM images at 650 ^{o}C. The SEM image indicates the presence of tangled tubular structures over the surface of graphene.

Results and discussion



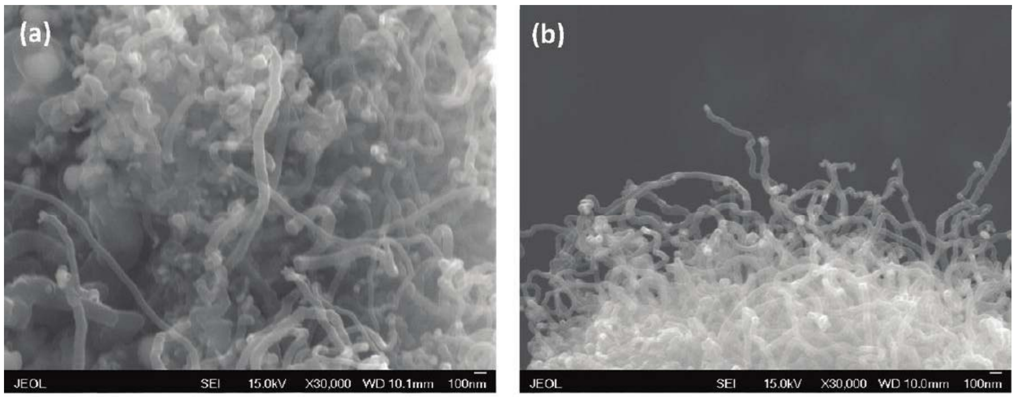
SEM and TEM images of the nanotubes synthesized on the Au-decorated graphene sheets at 600 C.



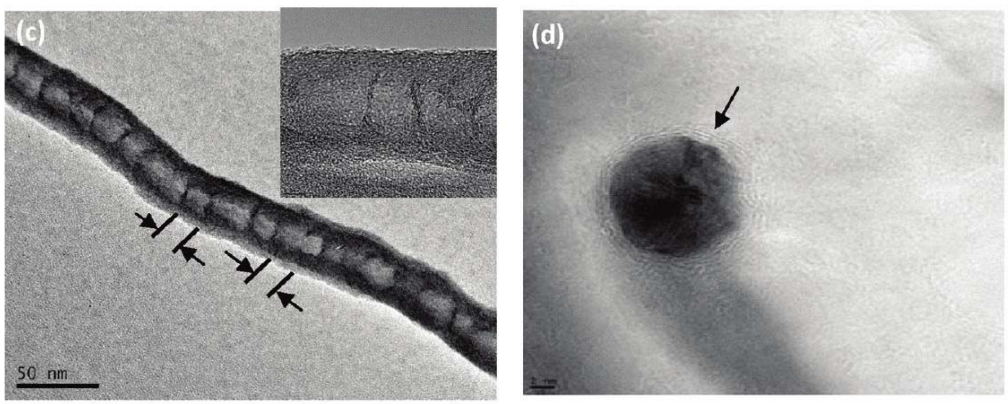
Element	Wt %	At %
C K	94.13	96.67
O K	04.18	03.22
AuM	01.68	00.11

SEM/EDS analysis indicating the presence of C, O2, and Au.

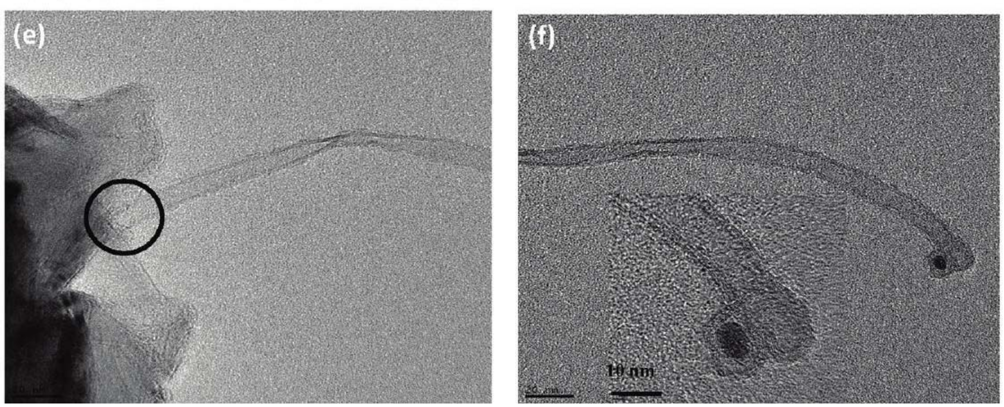
Results and discussion



SEM images of the synthesized CNTs on the Au-decorated graphene at 650 ^{o}C using ethylene.



TEM images of the synthesized CNTs on the Au-decorated graphene at 650 ^{o}C using ethylene.



TEM images showing tip growth mechanism.

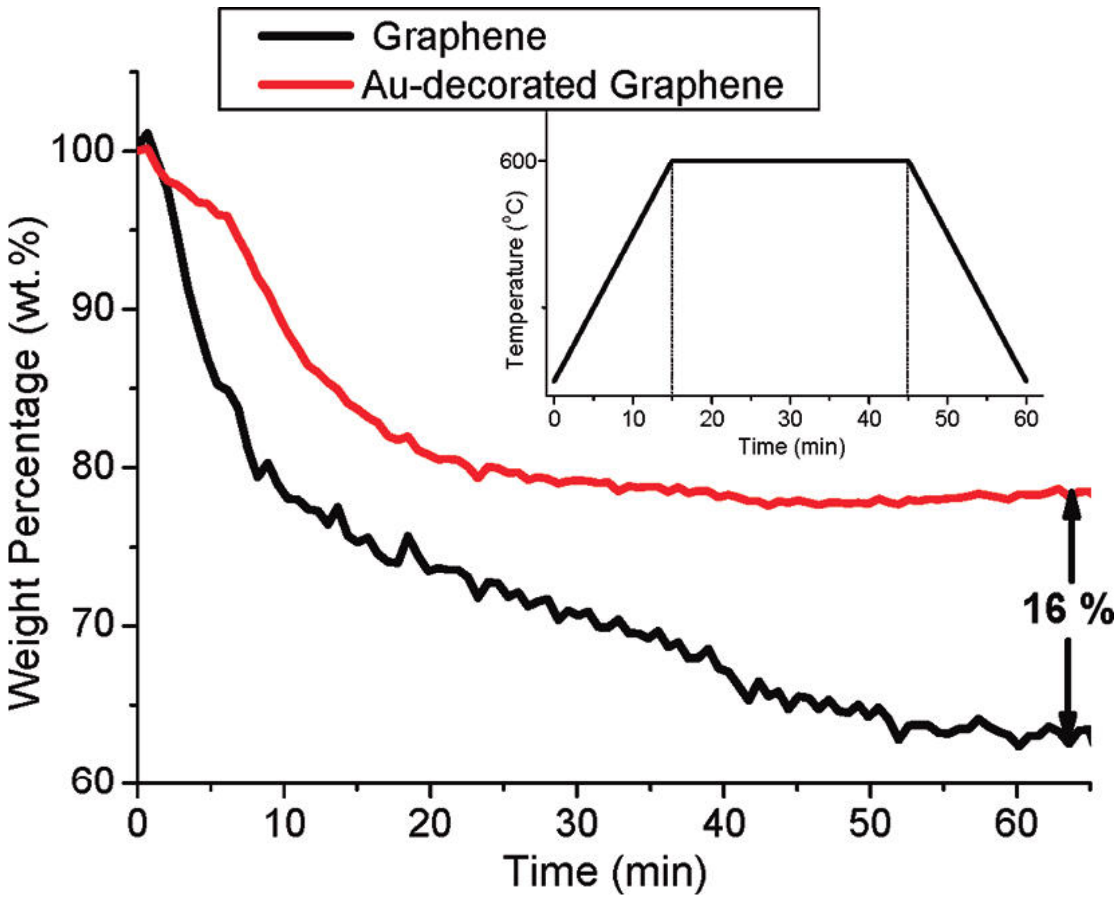
Results and discussion

This process was explained by two mechanisms:

(1) In the absence of carbon source gas, under the thermal excitation, the AuNPs create small defects in the graphitic structure of the graphene layers and through a catalytic reaction process initiate the carbon nanotube formation. During the reaction, graphene decomposes providing a necessary source of carbon for further nanotube growth on the AuNPs.

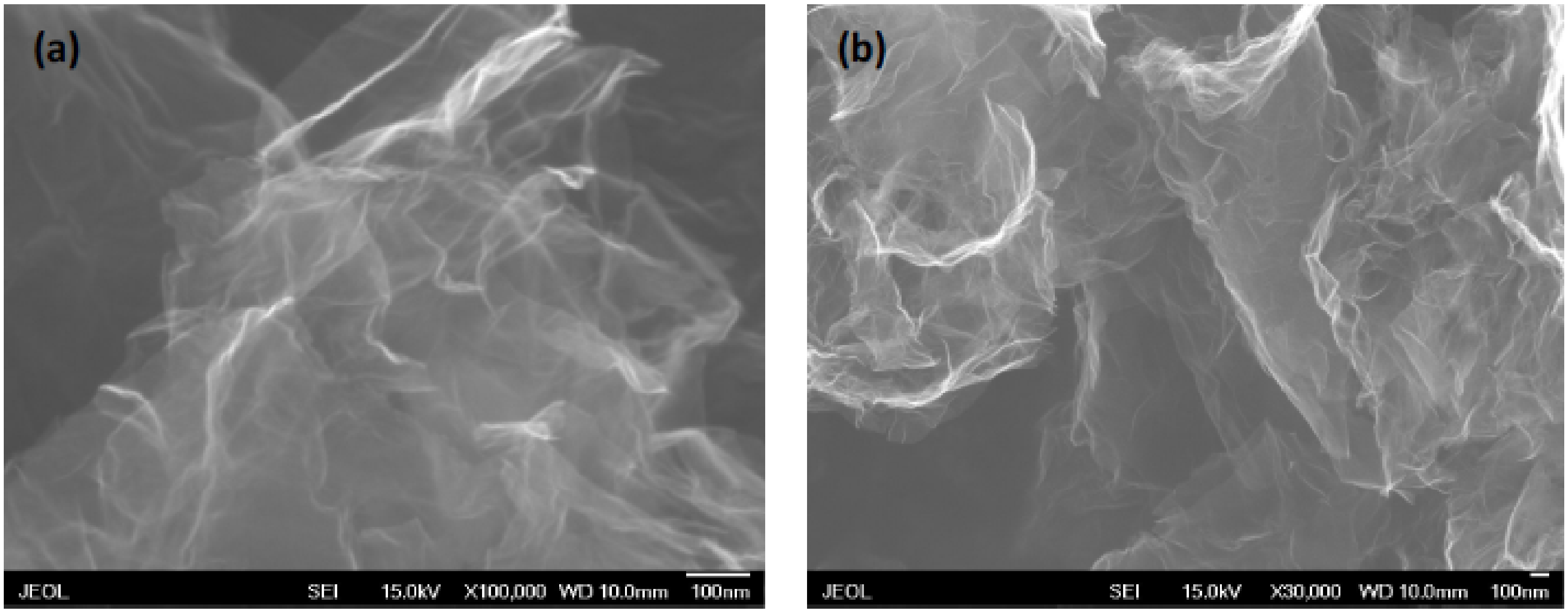
(2) In the presence of a carbon source, the catalytic nanotube growth is further enhanced due to the presence of a higher concentration of the carbon atoms. It may be possible that under these particular reaction conditions, graphene interacts with the AuNPs leading to the formation of nanotubes.

Results and discussion



This figure presents the (TGA) mass loss curve of the commercial graphene and the Au-decorated graphene heated to 600 ^{o}C under Ar atmosphere.

Results and discussion



RF reactions were performed on the nonfunctionalized graphene with and without acetylene at 600 and 650 ^{o}C. It is seen, after thorough SEM analyses that no CNT growth was detected at various temperatures.

Summary and conclusion

- AuNPs have the ability to convert the 2D structure of graphene into the 1D morphology of nanotubes, by the formation of C-C bonds that are required for the change in the crystalline geometrical structures of the two nanomaterials.

- Non functionalized graphene sheets containing no nanoparticles or other impurities failed to yield CNT or other carbon nanostructure growth.

- Graphene structures play a major role in the catalytic activity of AuNPs and that they can be responsible for the catalytic formation of CNTs.

- The catalytic reaction temperature (500 ^{o}C) was found to be lower than any other similar value reported in the literature, indicating that graphene could lower the CNT synthesis temperature, when used as a catalytic support material.

Thank you