CVD-GRAPHENE SYNTHESIS USING DIFFERENT TRANSITION METALS AS CATALYST

Mª del Prado Lavín López

Graphene Canada

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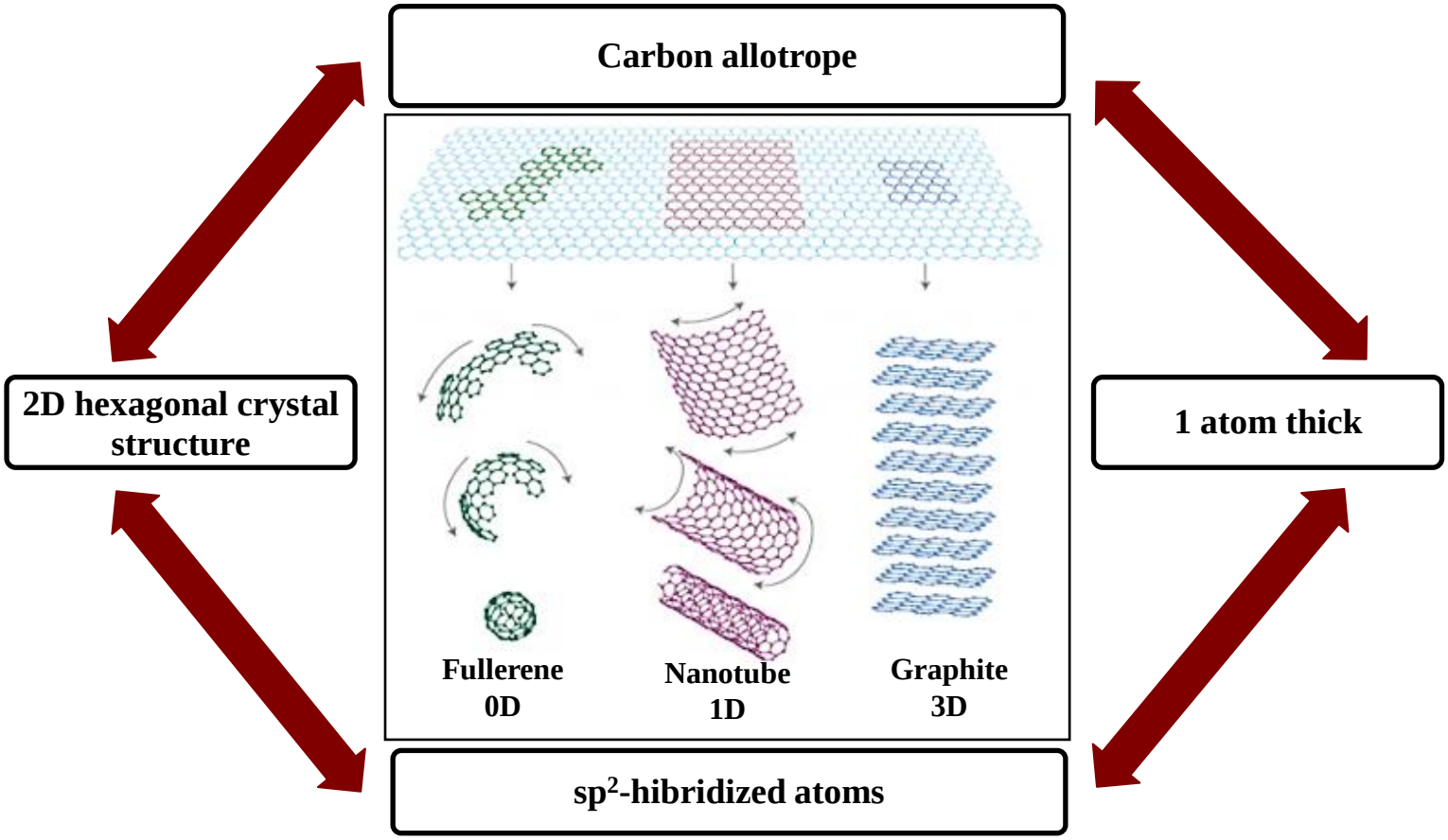
Graphene & 2D Materials International Conference and Exhibition

INTRODUCTION



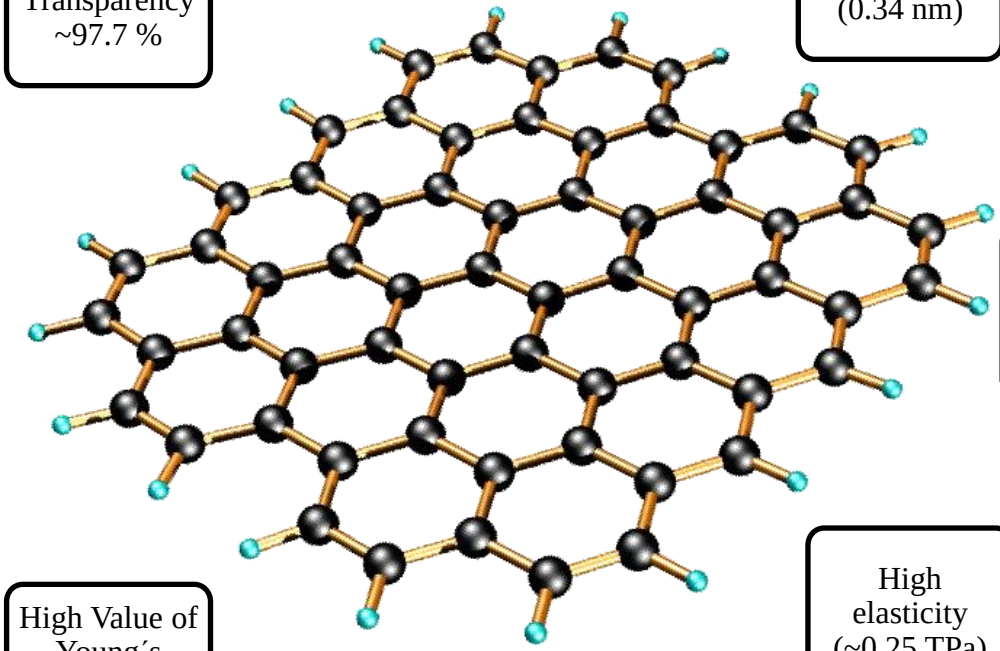
Geim, A.K. and K.S. Novoselov, *The rise of graphene.* Nature Materials, 2007. **6**(3): p. 183-191.

INTRODUCTION

High Thermal Conductivity (~5000 $Wm^{-1}K^{-1}$)

Optical Transparency ~97.7 %

Minimum thickness (0.34 nm)



High Specific Surface Area (2630 m^2/g)

High fracture resistance (~130 GPa)

High Value of Young´s ModuLus (~1 TPa)

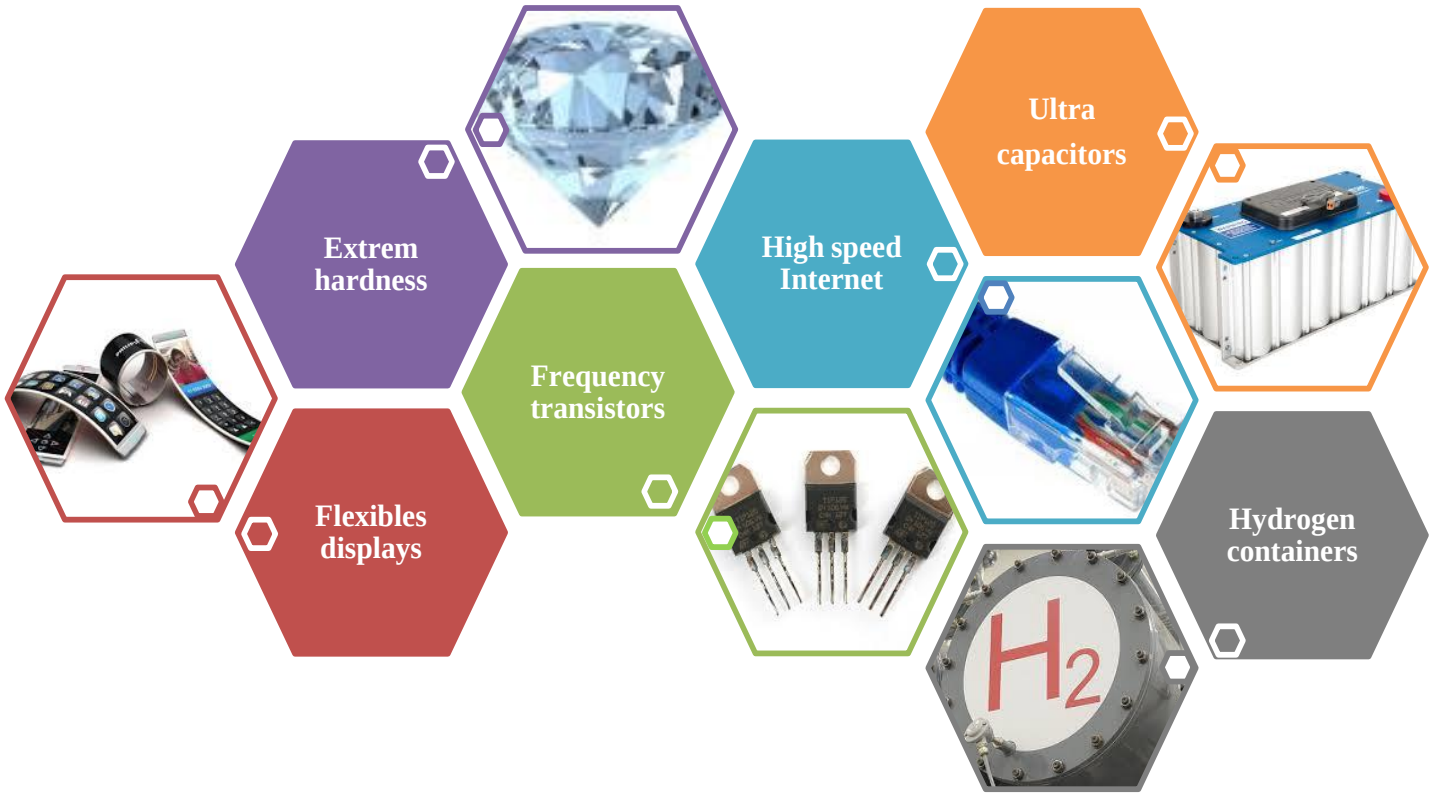
High elasticity (~0.25 TPa)

High Mobility (10^5 $cm^2V^{-1}s^{-1}$)

Zhu, Y., et al., *Graphene and graphene oxide: Synthesis, properties, and applications.* Advanced Materials, 2010. **22**(35): p. 3906-3924.

Dong, L.-X. and Q. Chen (2010). *Properties, synthesis, and characterization of graphene*. Frontiers of Materials Science in China **4**(1): 45-51.

INTRODUCTION



Zhu, Y., et al., *Graphene and graphene oxide: Synthesis, properties, and applications.* Advanced Materials, 2010. **22**(35): p. 3906-3924.

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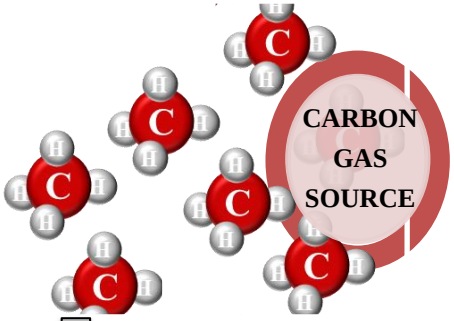
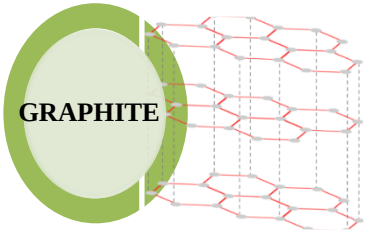
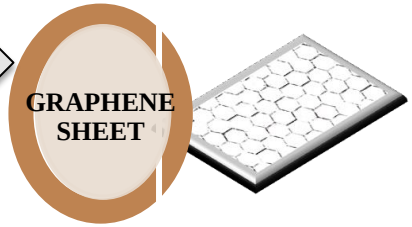
INTRODUCTION





BOTTOM-UP

TOP-DOWN



Epitaxial Growth on SiC

Chemical Vapor Deposition (CVD)

Micromechanical Exfoliation

Intercaled Graphite Compounds Exfoliation

Graphite Exfoliation in solvents

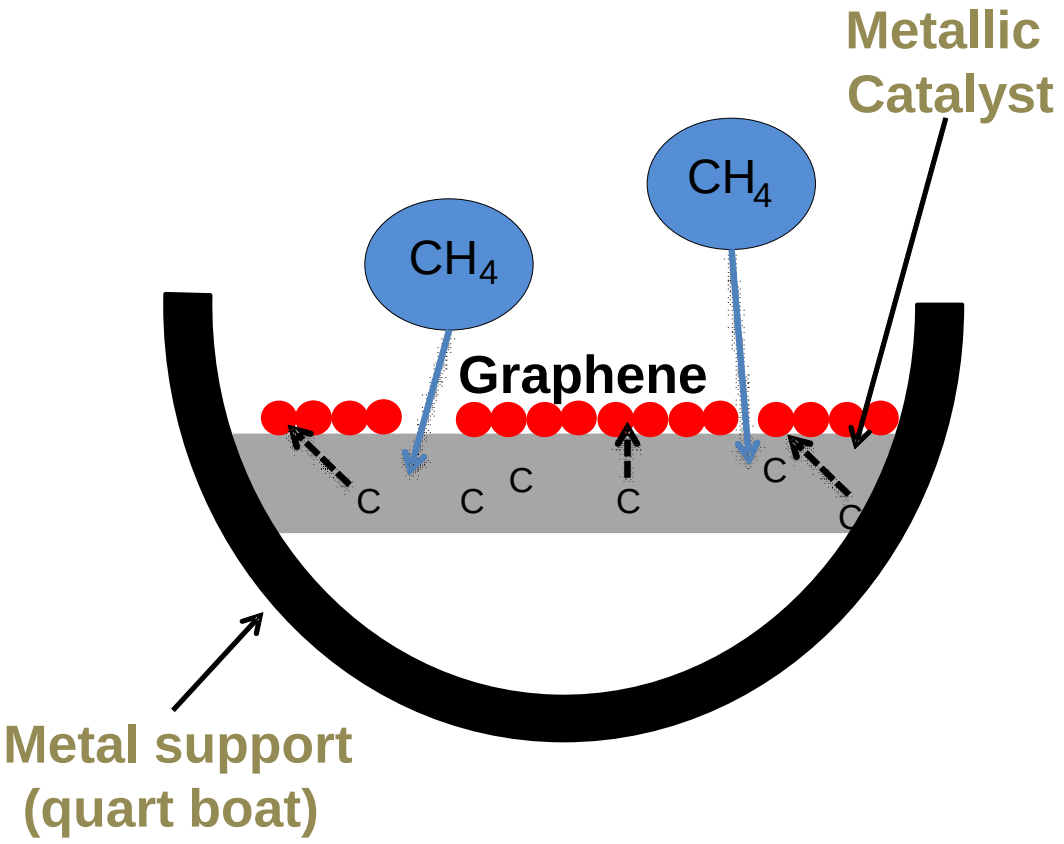
Unzipping CNTs

Avouris, P. and C. Dimitrakopoulos, *Graphene: Synthesis and applications.* Materials Today, 2012. **15**(3): p. 86-97.

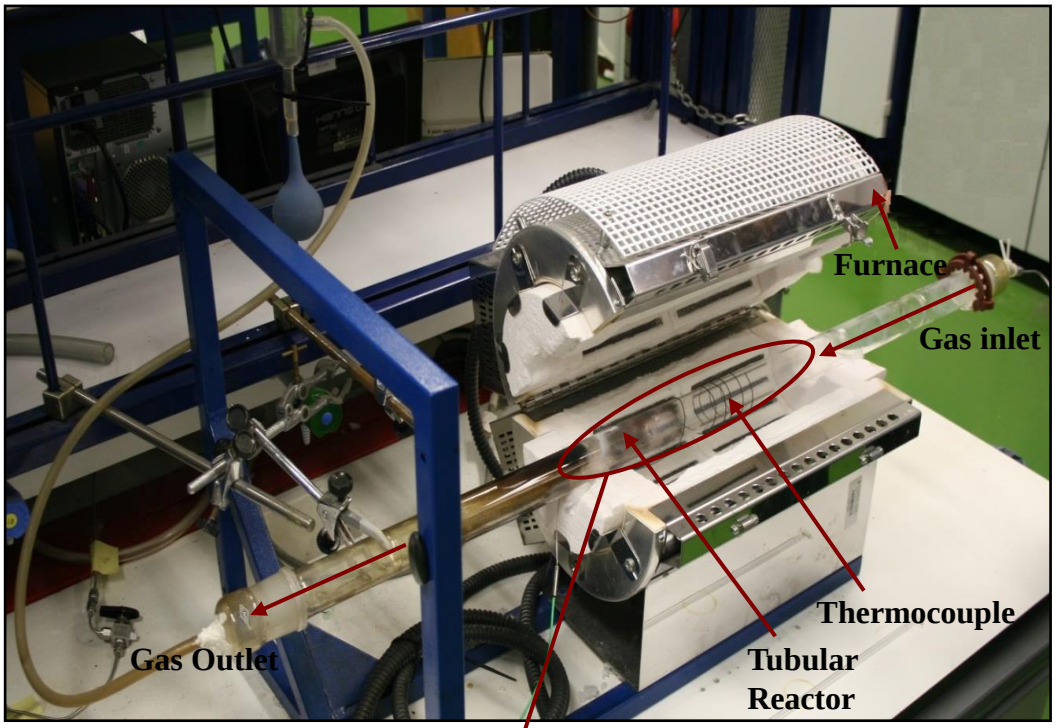
INTRODUCTION

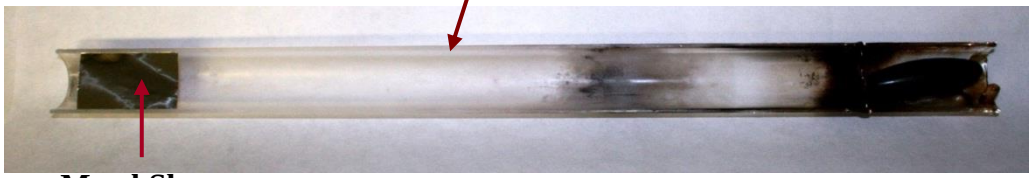
Chemical Vapor Deposition (CVD)

Chen, Z., et al., *Bulk growth of mono- to few-layer graphene on nickel particles by chemical vapor deposition from methane.* Carbon, 2010. **48**(12): p. 3543-3550.

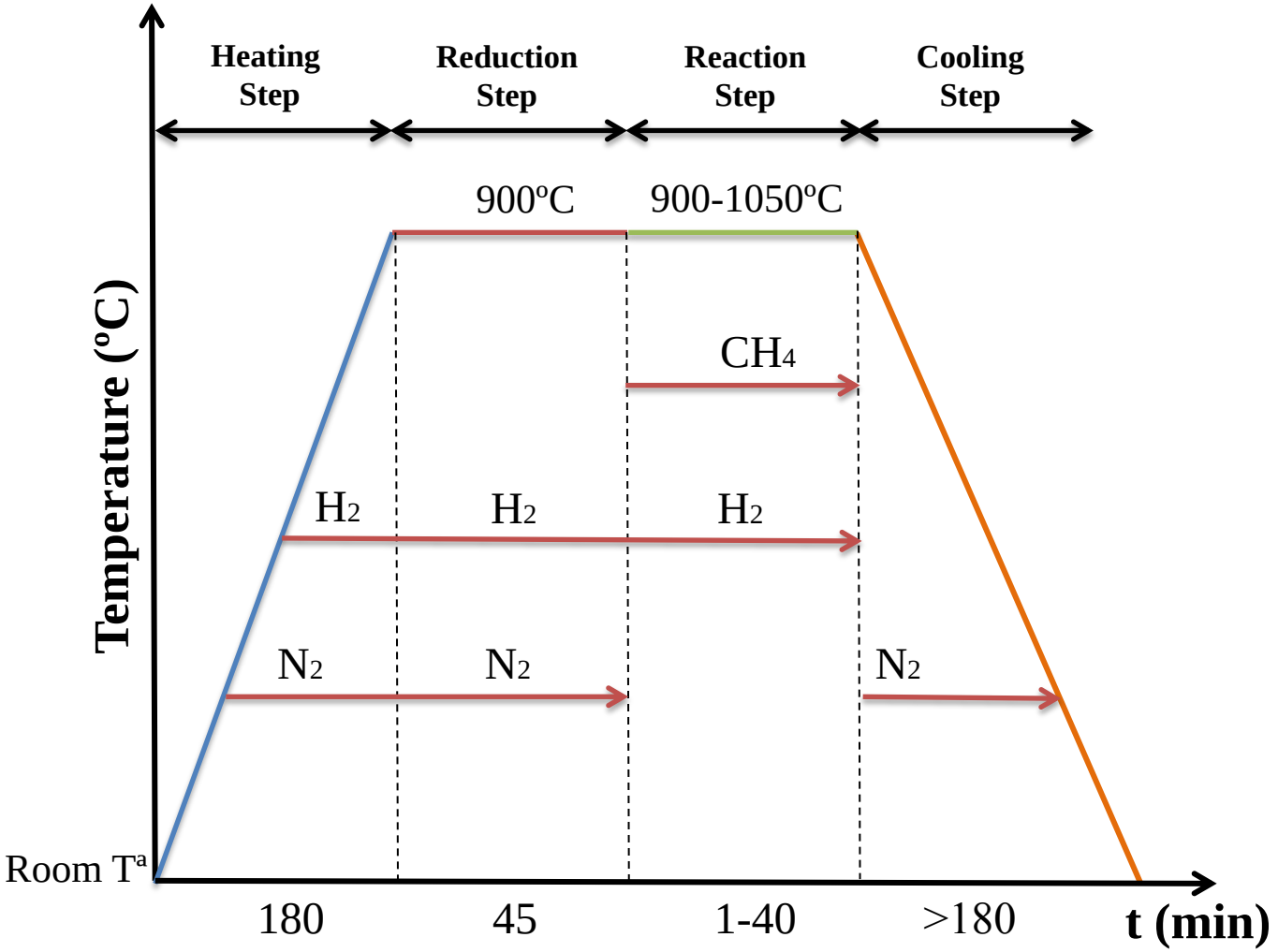


EXPERIMENTAL

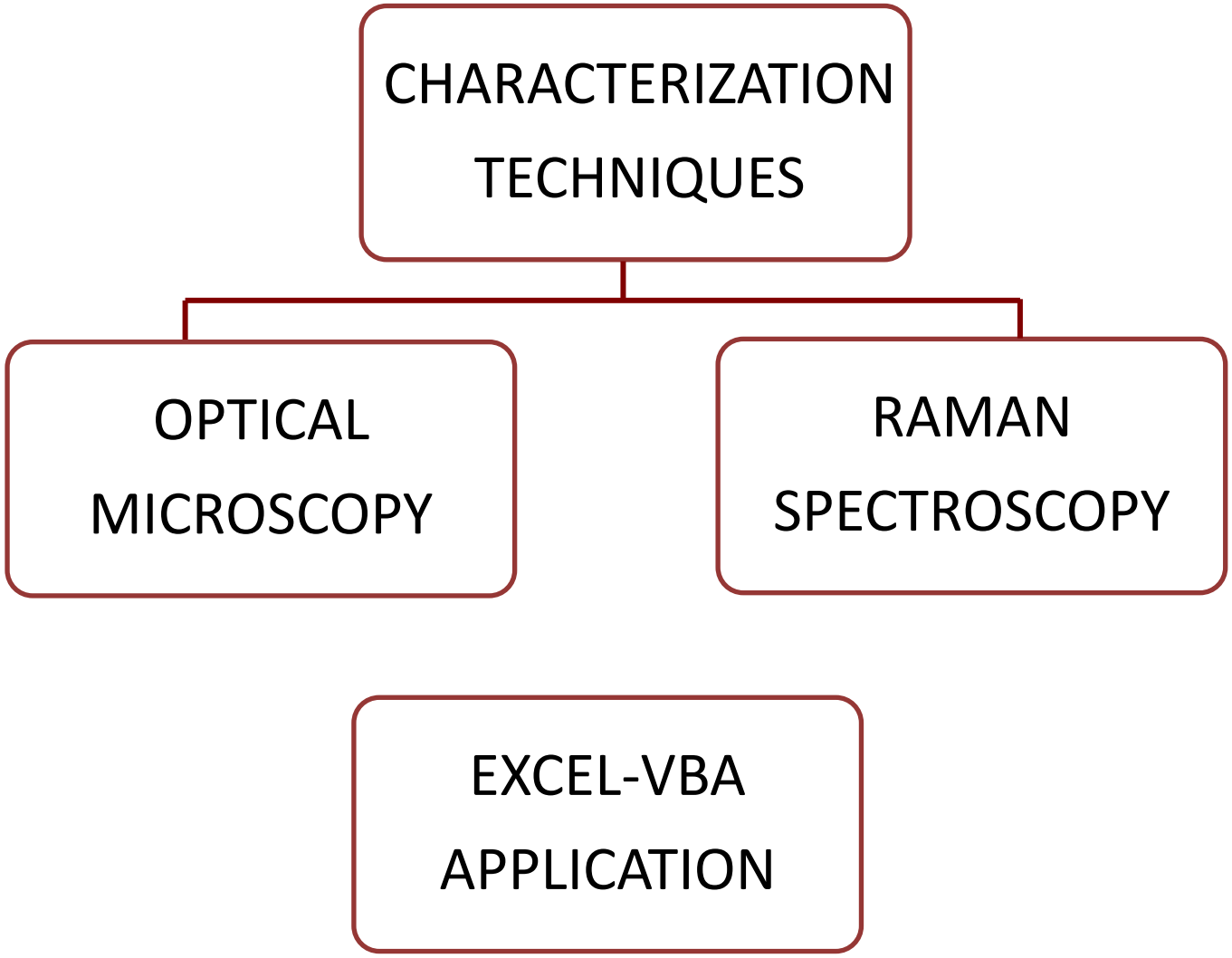




EXPERIMENTAL

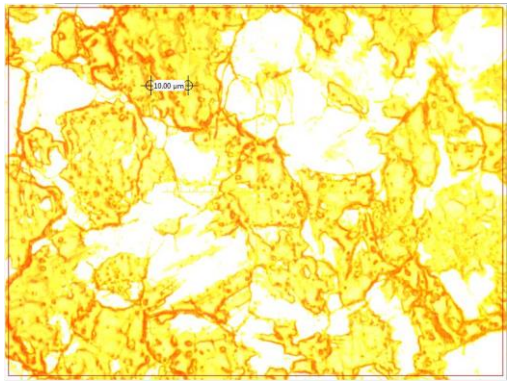


EXPERIMENTAL

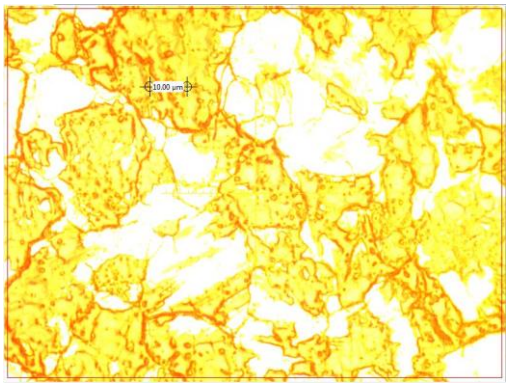


EXPERIMENTAL

OPTICAL MICROSCOPY



EXCEL-VBA APPLICATION

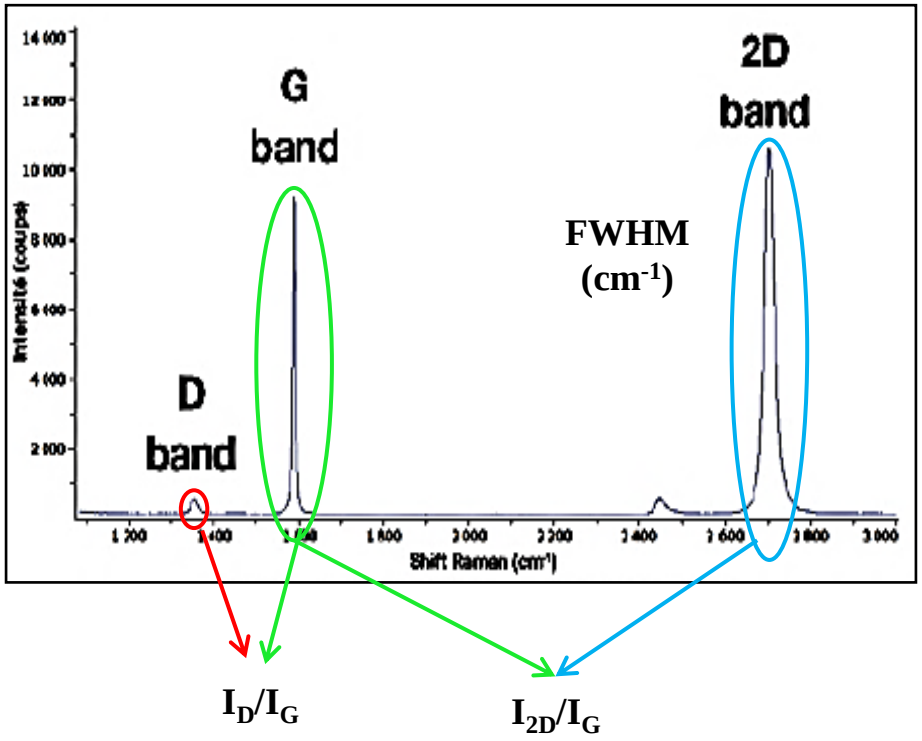


QUALITY: 1 – 1000

EXPERIMENTAL

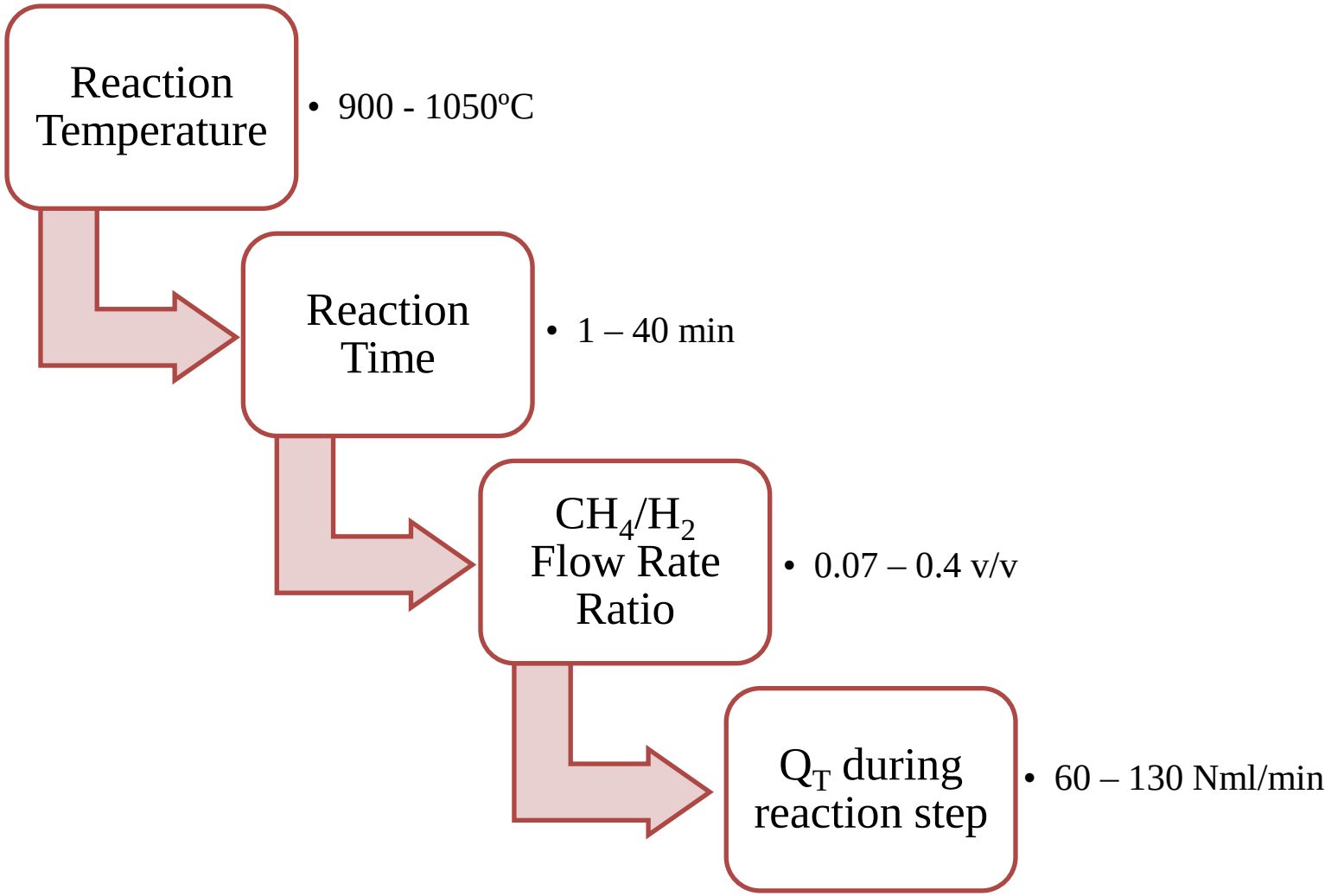
RAMAN SPECTROCOPY

Lavin-Lopez, M.P., et al., *Synthesis and characterization of graphene: Influence of synthesis variables.* Physical Chemistry Chemical Physics, 2014. **16**(7): p. 2962-2970.



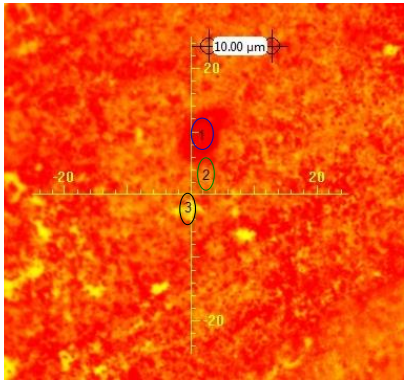
Ferrari, A. C., J. C. Meyer, y col. (2006). *Raman Spectrum of Graphene and Graphene Layers*. Physical Review Letters **97**(18): 187401.

RESULTS AND DISCUSSION



RESULTS AND DISCUSSION

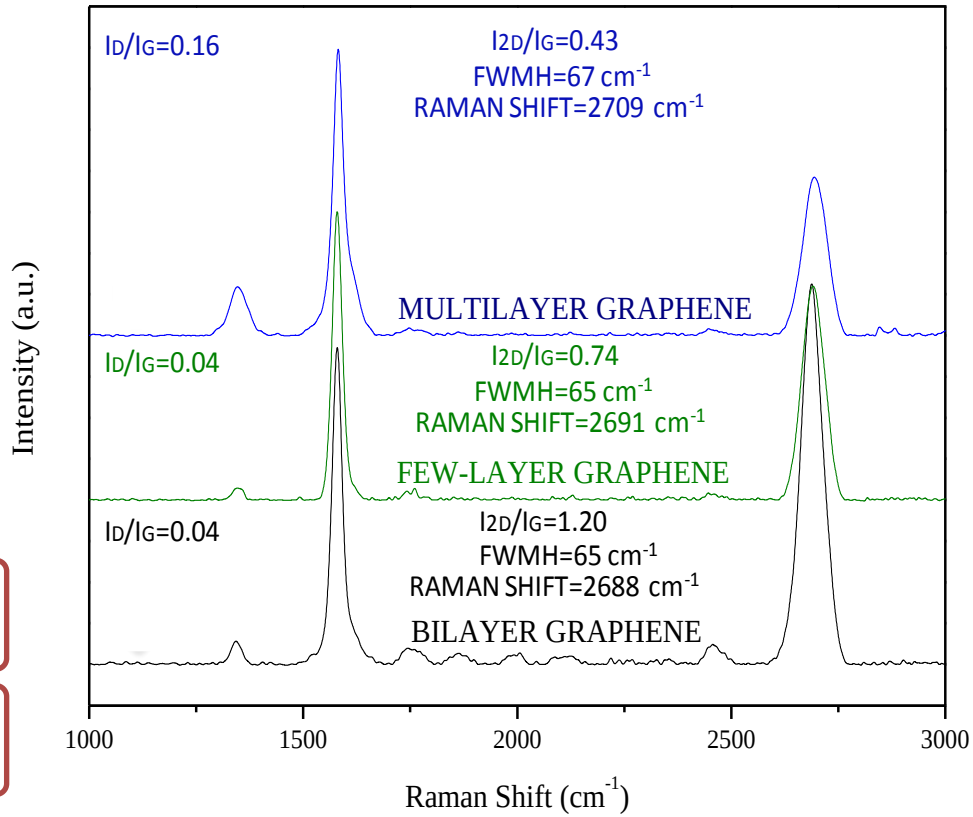
Influence of the reaction T^a at different reaction times



Lavin-Lopez, M.P., et al., *Synthesis and characterization of graphene: Influence of synthesis variables.* Physical Chemistry Chemical Physics, 2014. **16**(7): p. 2962-2970.

$T^a_{reaction}$=1050°C, CH_4/H_2=0.3 v/v, $time_{reaction}$=10 min, Q_T=130 Nml/min

% MULTILAYER GRAPHENE	% FEW-LAYERS GRAPHENE	% BILAYER GRAPHENE	QUALITY
81.34	17.00	1.66	4.2



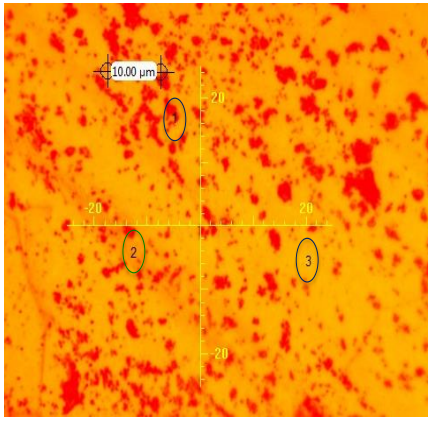
COPPER

OPTIMUM CONDITIONS

- **T^a=1050°C**
- **Time=10 min**

RESULTS AND DISCUSSION

Influence of the CH_4/H_2 Flow Rate Ratio



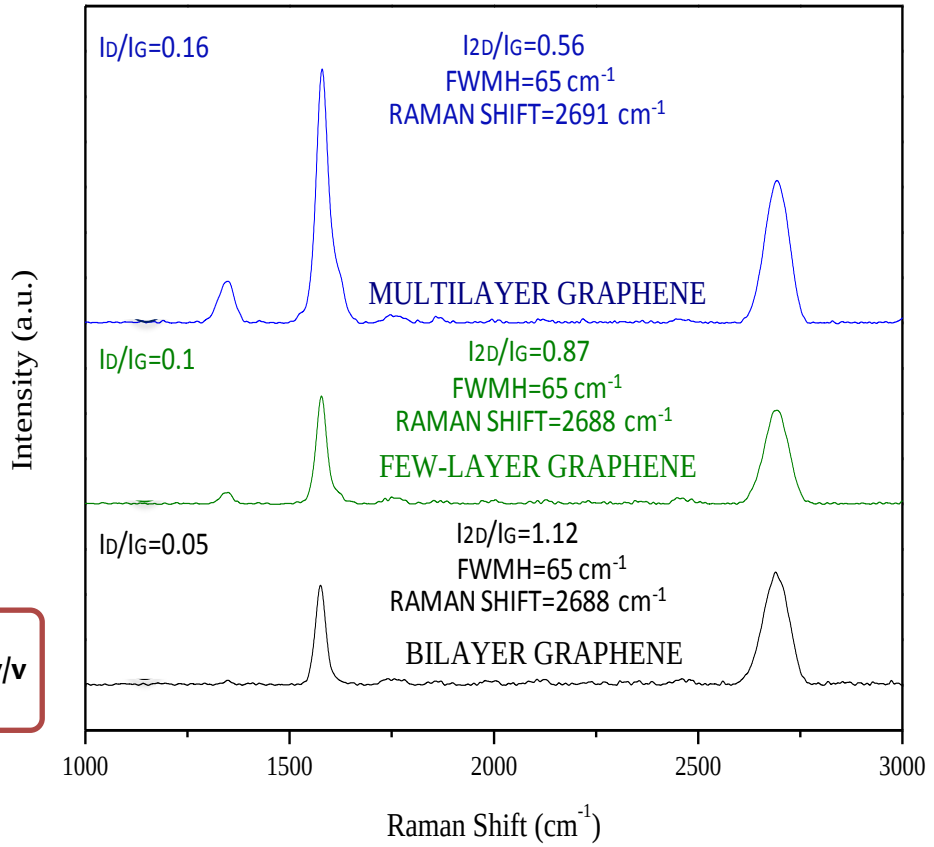
Lavin-Lopez, M.P., et al., *Synthesis and characterization of graphene: Influence of synthesis variables.* Physical Chemistry Chemical Physics, 2014. **16**(7): p. 2962-2970.

COPPER

OPTIMUM CONDITIONS — **CH_4/H_2=0,07 v/v**

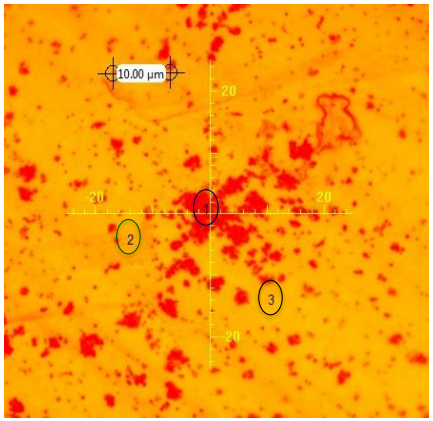
$T^a_{reaction}$=1050°C, CH_4/H_2=0.07 v/v, $time_{reaction}$=10 min, Q_T=130 Nml/min

% MULTILAYER GRAPHENE	% FEW-LAYERS GRAPHENE	% BILAYER GRAPHENE	QUALITY
19.67	50.92	29.41	34.7



RESULTS AND DISCUSSION

Influence of the Q_T during the reaction step



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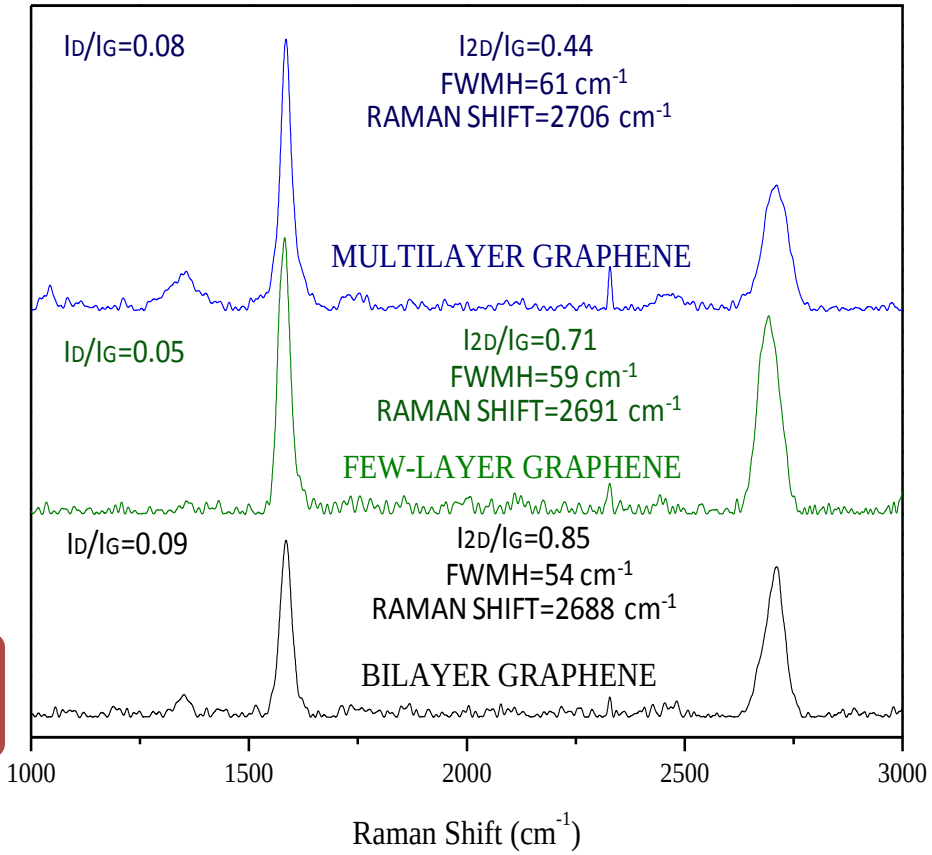
$T^a_{reaction}$=1050°C, CH_4/H_2=0.3 v/v, $time_{reaction}$=10 min, Q_T=130 Nml/min			
% MULTILAYER GRAPHENE	% FEW-LAYERS GRAPHENE	% BILAYER GRAPHENE	QUALITY
10.87	33.27	55.86	59.3

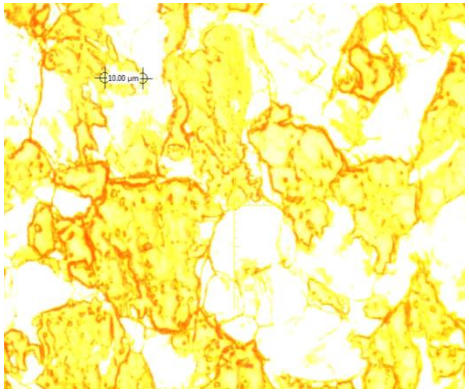


COPPER

OPTIMUM CONDITIONS — **Q_T=60 Nml/min**

RESULTS AND DISCUSSION

Influence of the reaction temperature



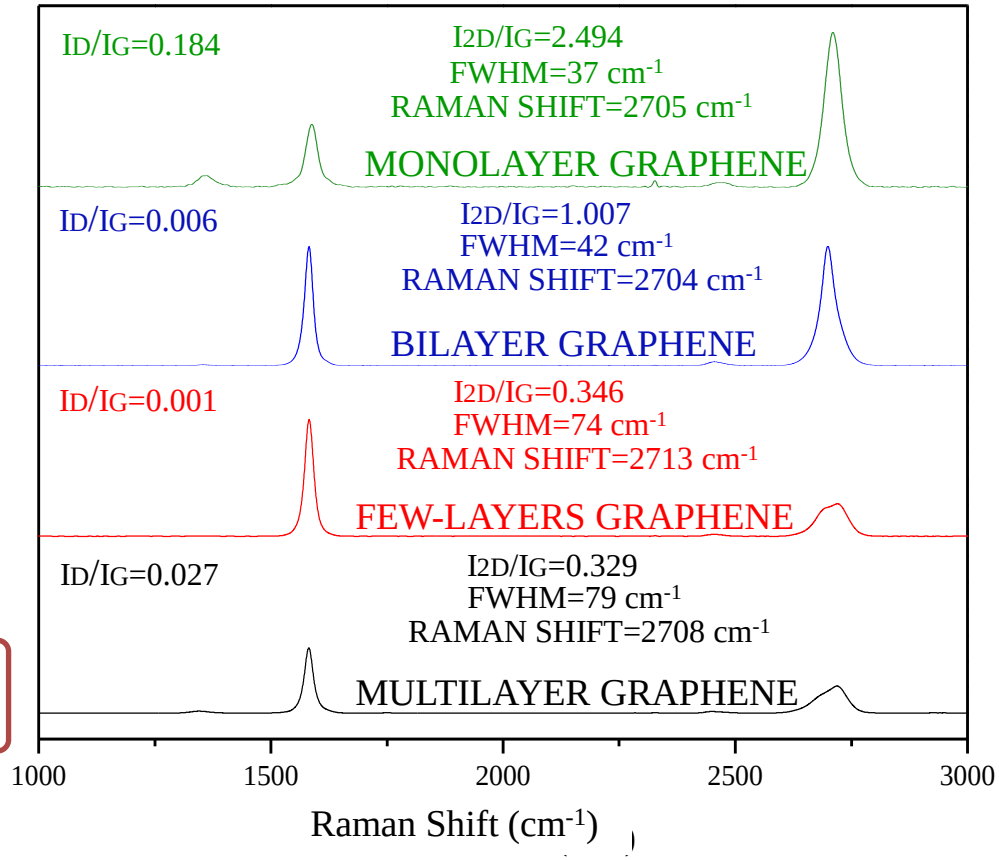
Lavin-Lopez, M.P., et al., *Thickness control of graphene deposited over polycrystalline nickel.* New Journal of Chemistry, 2015.

NICKEL

OPTIMUM CONDITIONS — **T^a=980°C**

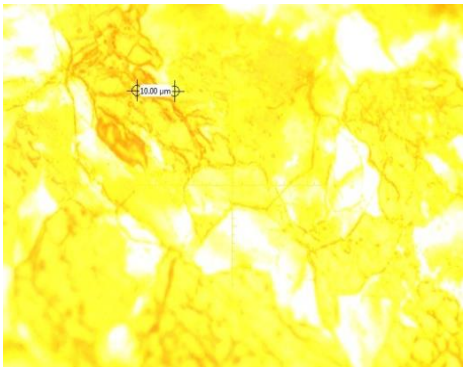
$T^a_{reaction}$=980°C, CH_4/H_2=0.3 v/v, $time_{reaction}$=10 min, Q_T=130 Nml/min

% MULTILAYER GRAPHENE	% FEW-LAYERS GRAPHENE	% BILAYER GRAPHENE	% MONOLAYER GRAPHENE	QUALITY
0.87	40.20	21.80	37.13	397



RESULTS AND DISCUSSION

Influence of the CH_4/H_2 Flow Rate Ratio



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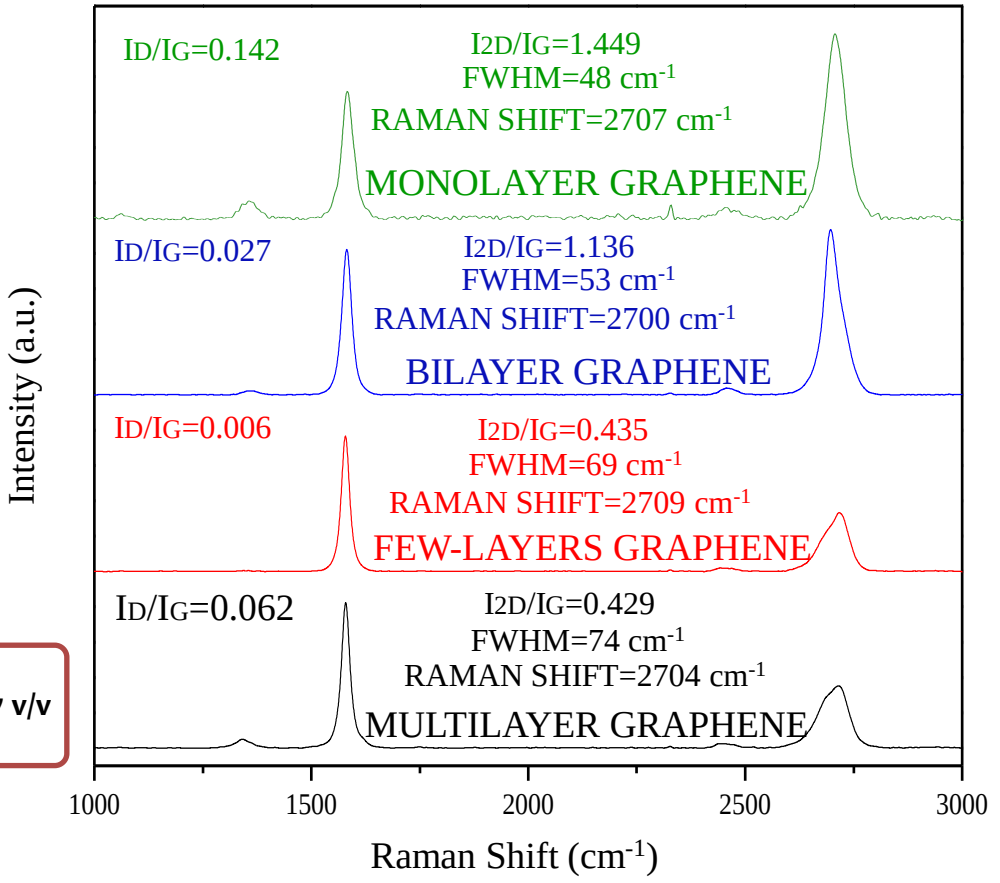
NICKEL

$T^a_{reaction}$=980°C, CH_4/H_2=0.07 v/v, $time_{reaction}$=10 min, Q_T=130 Nml/min

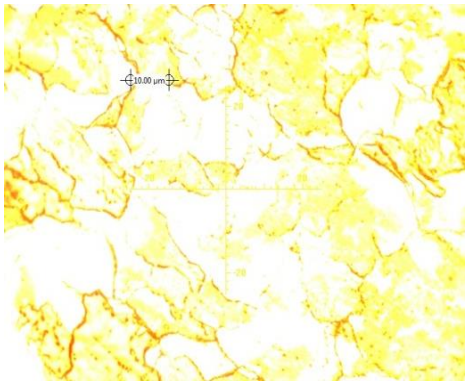
% MULTILAYER GRAPHENE	% FEW-LAYERS GRAPHENE	% BILAYER GRAPHENE	% MONOLAYER GRAPHENE	QUALITY
0.45	27.15	20.39	51.99	536



OPTIMUM CONDITIONS — CH_4/H_2=0,07 v/v

RESULTS AND DISCUSSION

Influence of the QT during the reaction step at different times



Lavin-Lopez, M.P., et al., *Thickness control of graphene deposited over polycrystalline nickel.* New Journal of Chemistry, 2015.

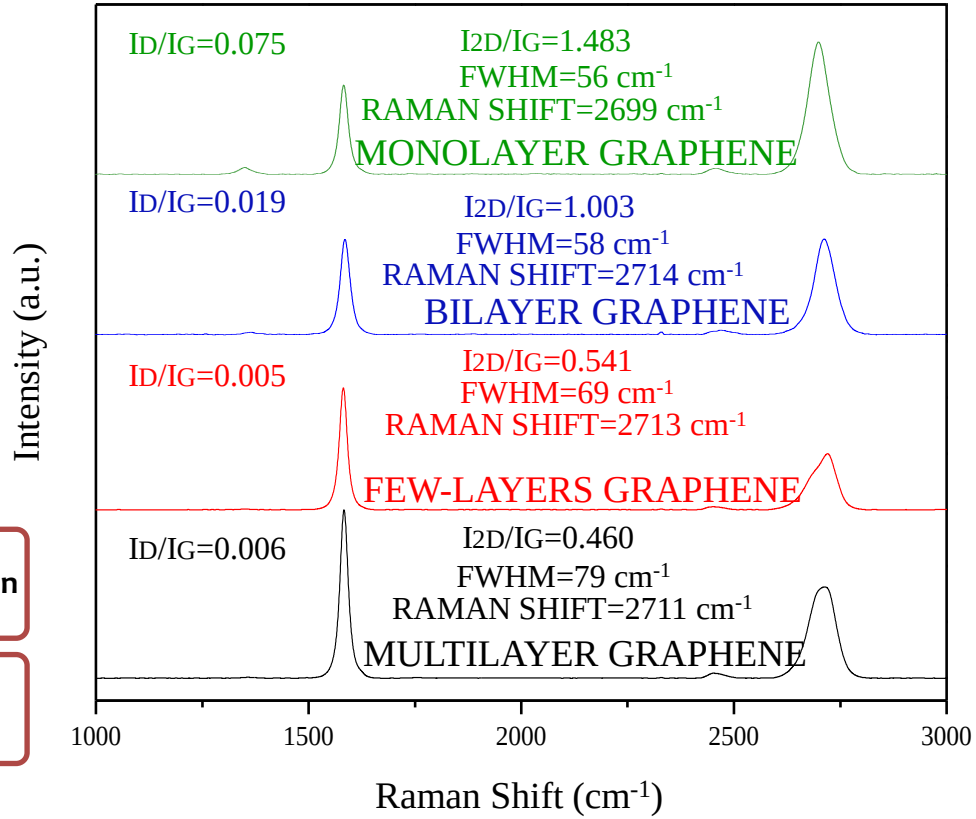
NICKEL

OPTIMUM CONDITIONS

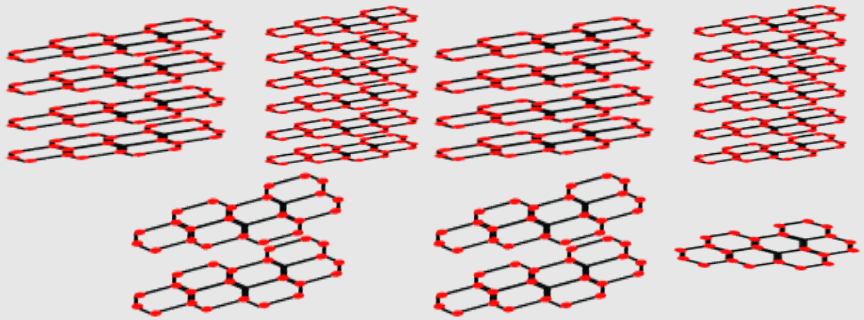
- Q_T=80Nml/min
- Time=1 min

$T^a_{reaction}$=980°C, CH_4/H_2=0.07 v/v, $time_{reaction}$=1 min, Q_T=80 Nml/min

% MULTILAYER GRAPHENE	% FEW-LAYERS GRAPHENE	% BILAYER GRAPHENE	% MONOLAYER GRAPHENE	QUALITY
0.33	11.15	8.41	80.12	810



CONCLUSIONS

VARIABLE	COPPER	NICKEL
REACTION Tª	1050 ºC	980 ºC
CH_4/H_2 FLOW RATE RATIO	0.07 v/v	0.07 v/v
Q_T DURING REACTION STEP	60 Nml/min	80 Nml/min
REACTION TIME	10 min	1 min
GRAPHENE		
QUALITY	59	810

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