

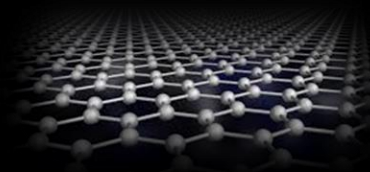
Fabrication of free-standing graphene and derivatives via a microwave plasma-based method

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Plasma Enabled and Graphene Allowed Synthesis of Unique nanoStructures

The project's ambitious purpose is

- *to translate the unique properties of plasmas into extraordinary material characteristics*
- *to create novel forms of matter*

by using a multitude of specific plasma mechanisms

- to control the energy
- matter transfer processes at nanoscale



4M € Project → 2.5M € for Portugal

<https://www.ipfn.tecnico.ulisboa.pt/PEGASUS/>

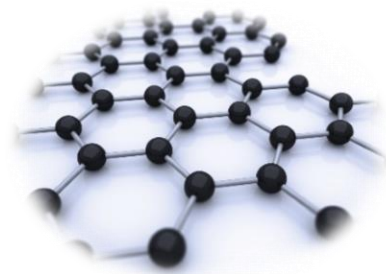
Goal

FSG and derivatives synthesis

Carbon
precursors

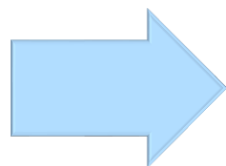


- Graphene
- N-graphene
- Fulerenes
- Nanodiamonds
- CNTs



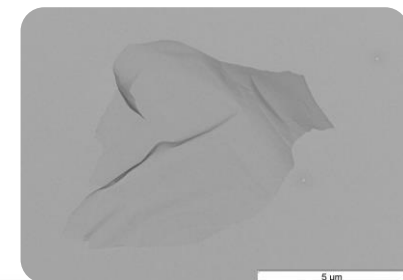
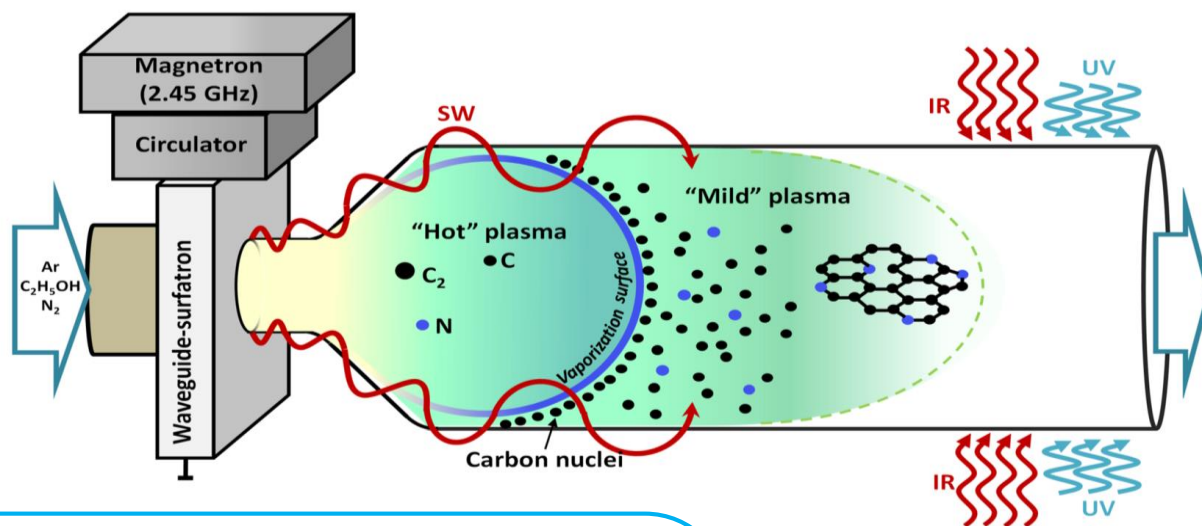
- Strong mechanical strength
- Excellent thermal and electrical conductivity
- Fast charge carriers' mobility
- Ultrahigh specific surface area

→ Graphene
→ N-graphene



Energy storage and conversion devices
Eg. Supercapacitors

Microwave plasma-based method for FSG and N-doped graphene synthesis

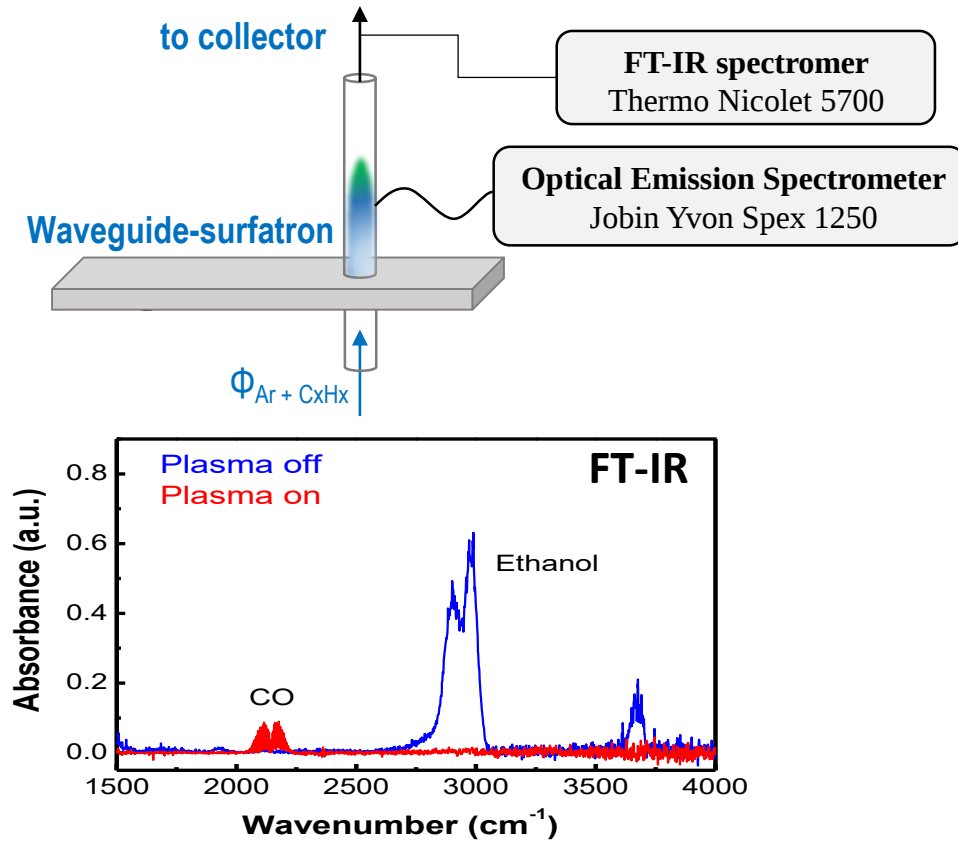


- ✓ **Control at atomic scale level of**
 - energy and matter fluxes
- ✓ **Controlled self-organization of**
 - free-standing carbon nanostructures
- ✓ **Selective synthesis**
tailoring the plasma environment
- ✓ **Scalable**

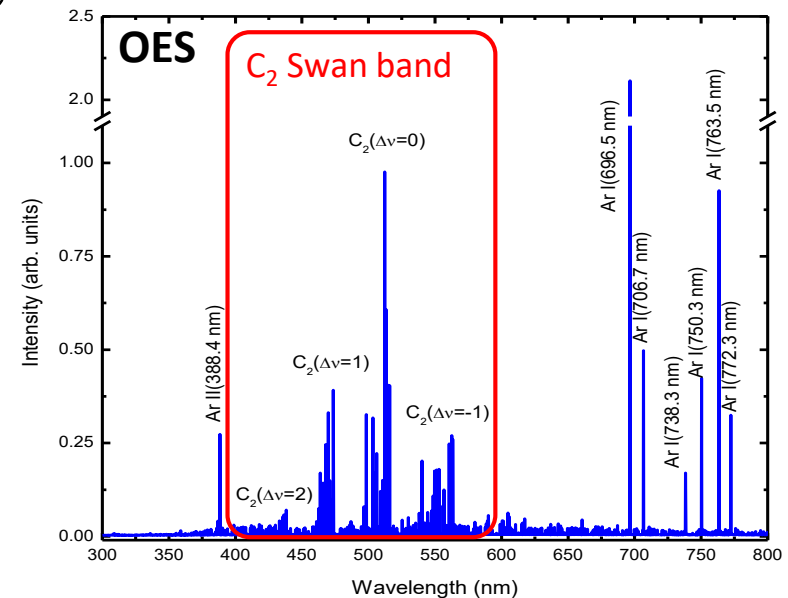


Decomposition process

Tayloring plasma conditions

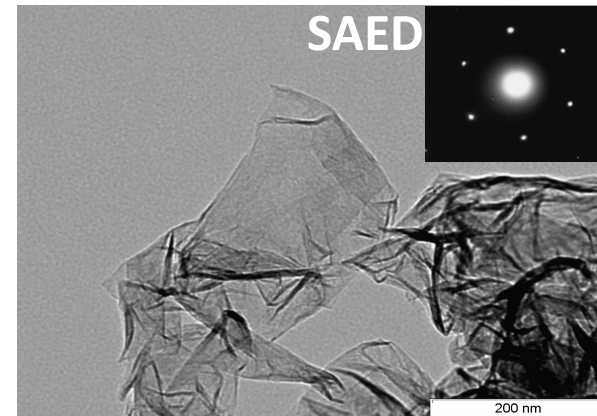
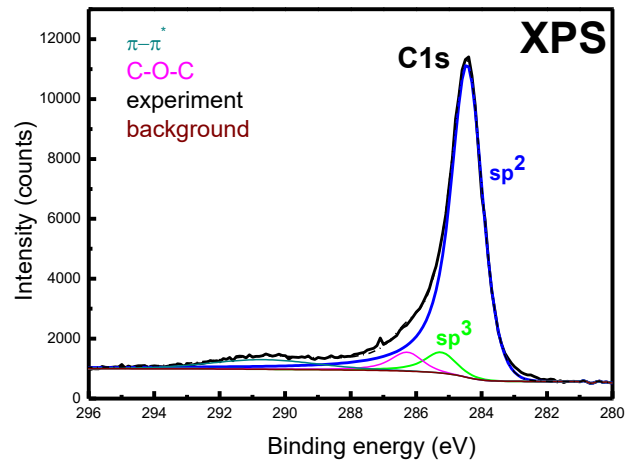


Radiative decay of $C_2^*(A_3\Pi_g)$ level



More C_2 radicals in plasma $\rightarrow$ more planar sp^2 carbons on graphene sheets

Control over the synthesis process and improve the structural quality



Without thermodynamic control

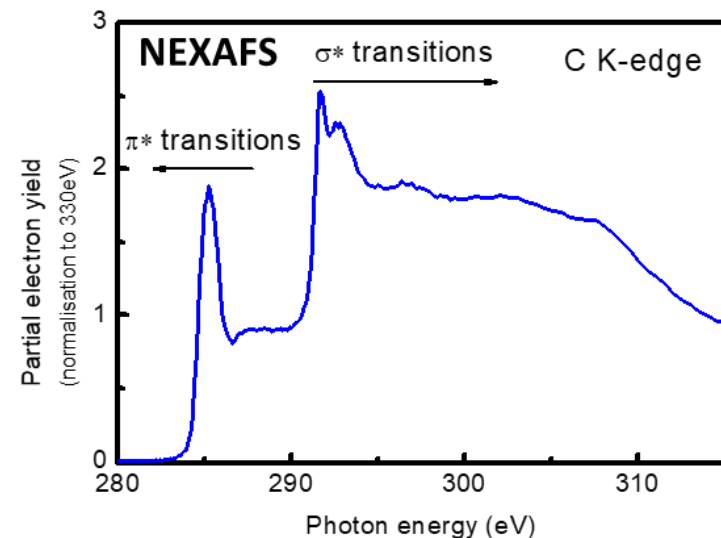
- $sp^2/sp^3 \sim 10$
- [O] ~ 2.3 %

IR

- $sp^2/sp^3 \sim 15$

+UV

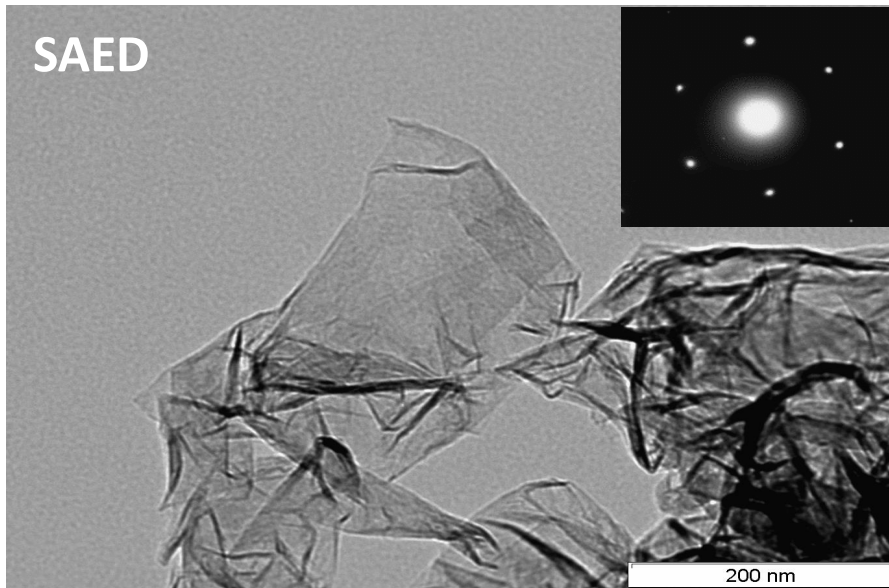
- [O] ~ 1.1 %



HESGM beam-line at BESSY II synchrotron, Berlin

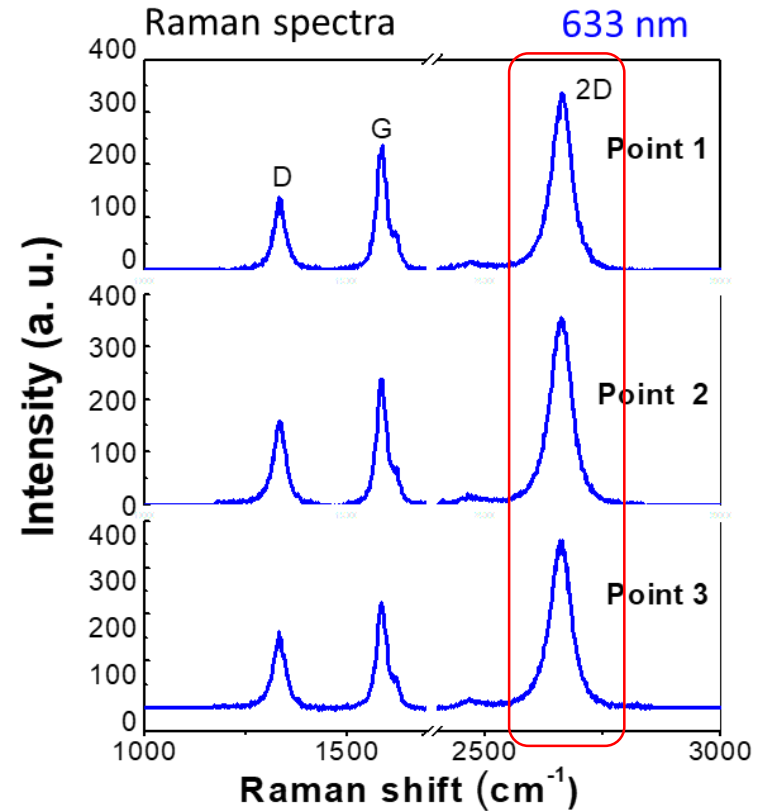
Quality of graphene sheets

Raman spectroscopy analysis



Plasma tailoring

- $\uparrow$ 2D/G → $\downarrow$ Number of mono-layers
- $\downarrow$ D/G → $\downarrow$ Defects, sp^3 carbons
- **homogeneity**

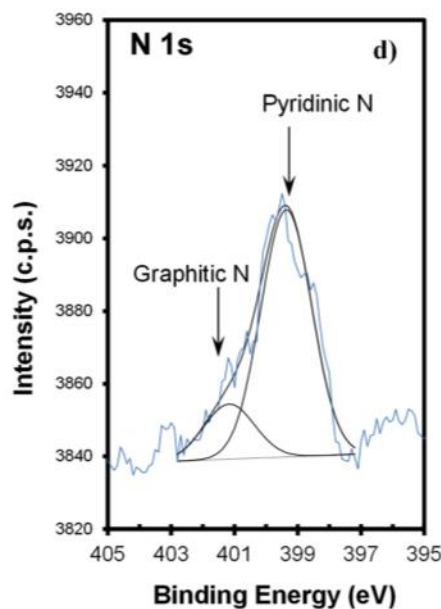
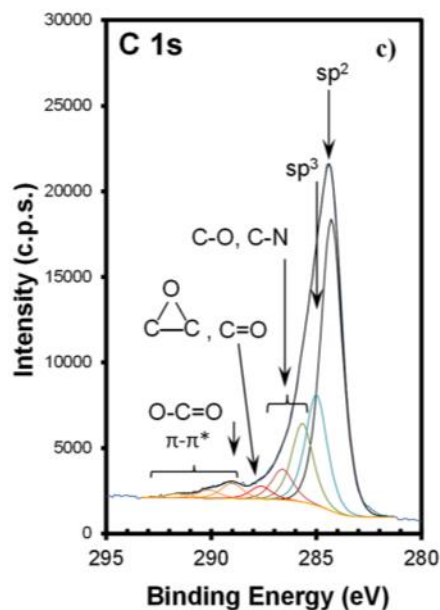


LabRam HR Visible (Horiba Jobin Yvon)

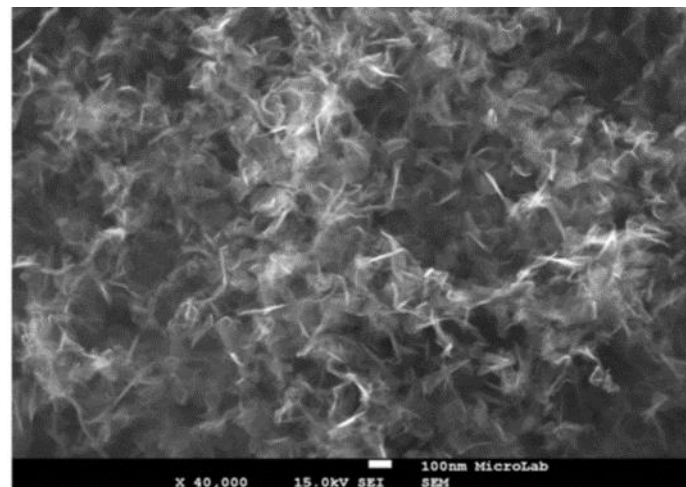
N-graphene

XPS to determine the elemental composition

XPS



SEM

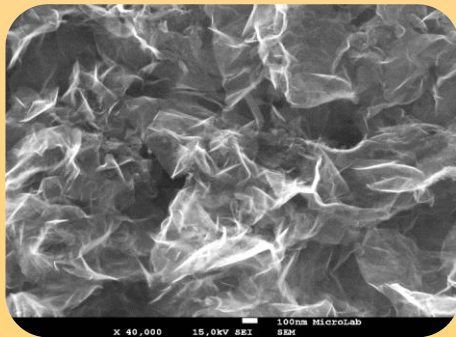


SEM images from: JEOL, JSM-7001F

Doping level:

- $N_2 \rightarrow 0.2\% \text{ N/C}$
- Other nitrogen content precursor $\rightarrow 5.6\% \text{ N/C}$

PEGASUS shows



- ✓ Very high potential for controllable single step large-scale fabrication at atmospheric pressure of:
 - ✓ Free-standing graphene & N-graphene (without expensive catalysts & hazardous chemicals)
- ✓ Scalability ($> 3\text{mg/min}$)
- ✓ Promotes microwave plasmas as
 - ✓ Green
 - ✓ Competitive
 - ✓ Cost-effective alternative to the chemical methods used today

Aknowledgements

- **Plasma Engineering Laboratory**

N-Prime/IPFN/IST/ULisboa, PORTUGAL

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Sofia University, Bulgaria



Synchrotron BESSY II, HZB, Berlin, Germany



C2C New Cap, Portugal



Centro de Química-Física Molecular/ IST, Portugal

CeFEMA/IST, Portugal



Thank you!!

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€30 billion is still
available in the 2018-2020
Work Programme!

#InvestEUresearch

  **European
Commission**

**Microwave plasmas
meet graphene**

Dr Elena Tatarova presents the primary advantages of using microwave plasmas as a disruptive 'green' alternative for the production of high quality graphene and its derivative h-graphene at a large scale

Graphene, a new two-dimensional material, has attracted significant attention in the scientific community and industry alike. It is a single layer of carbon atoms arranged in a hexagonal lattice, which gives it unique properties such as high strength, high conductivity, and high transparency. Graphene is considered a promising material for a wide range of applications, from electronics to energy storage. However, the production of high-quality graphene at a large scale has been a challenge. Dr Elena Tatarova, a researcher at the Institute of Materials and Nanotechnology, presents the primary advantages of using microwave plasmas as a disruptive 'green' alternative for the production of high-quality graphene and its derivative h-graphene at a large scale. She highlights the benefits of this method, including its simplicity, scalability, and environmental friendliness. The research is part of the PEGASUS project, which aims to develop a sustainable and efficient process for the production of graphene and its derivatives.

4M € Project → 2.5M € for Portugal

PEGASUS is Horizon2020 FET-OPEN Grant Number: 766894

<https://www.ipfn.tecnico.ulisboa.pt/PEGASUS/>

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