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

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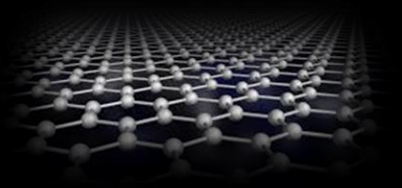


PEGASUS
Plasma Enabled and Graphene Allowed Synthesis of Unique nanoStructures

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

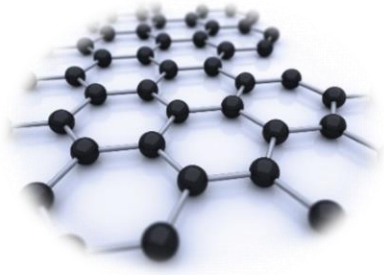
4M € Project → **2.5M** € for **Portugal**

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

Goal
FSG and derivatves synthesis

Carbon precursors

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

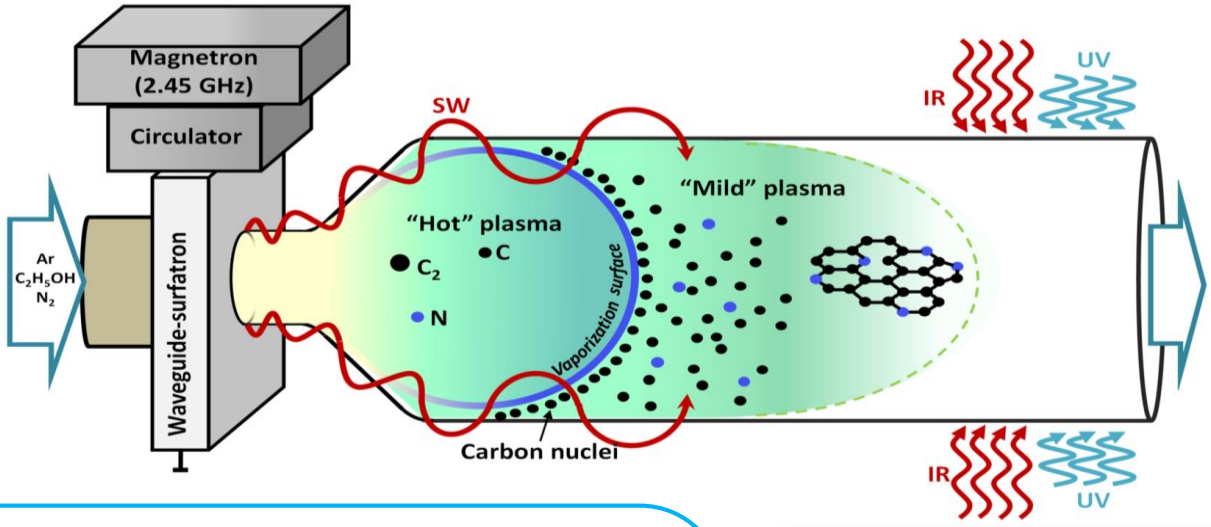


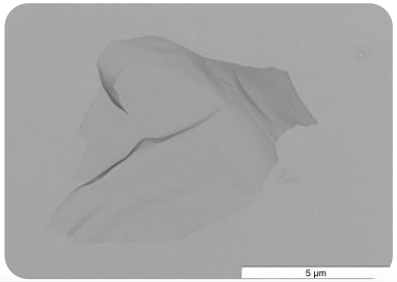
- Strong mechanical strength
- Excellent thermal and electrical conductivity
- Fast charge carriers' mobility
- Ultrahigh specific surface area

→ Graphene
→ N-graphene

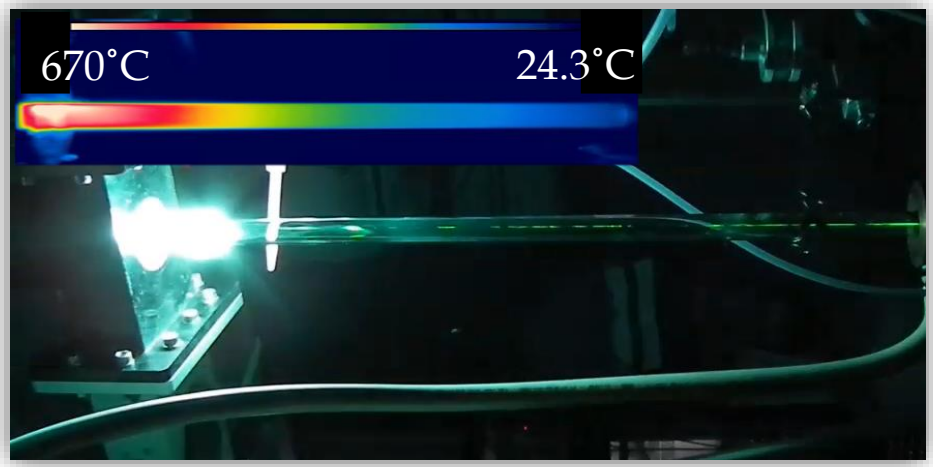
Energy storage and conversion devices
Eg. Supercapacitors

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

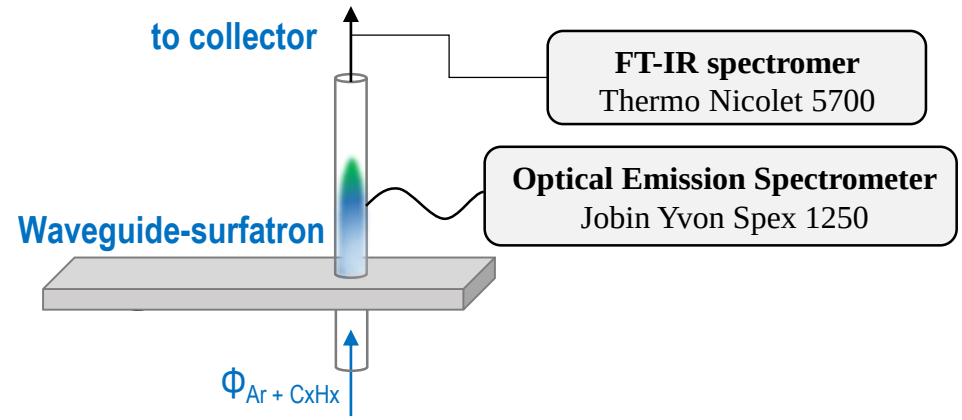


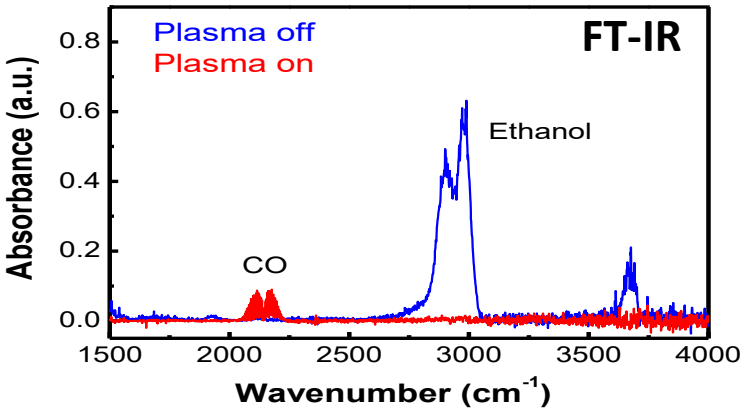


- ✓ **Control at atomic scale level of**
  - **– energy and matter fluxes**
- ✓ **Controlled self-organization of**
  - **– free-standing carbon nanostructures**
- ✓ **Selective synthesis**
  - **tailoring the plasma environment**
- ✓ **Scalable**

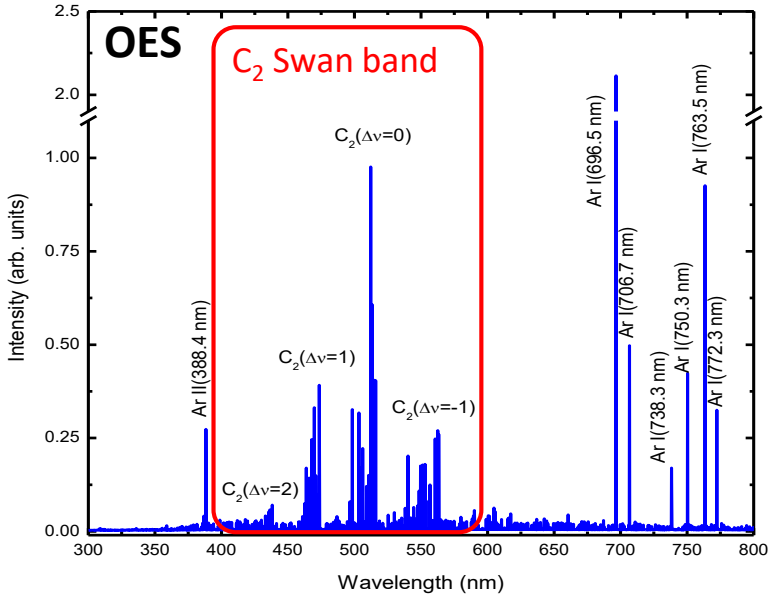


Decomposition process
Tayloring plasma conditions



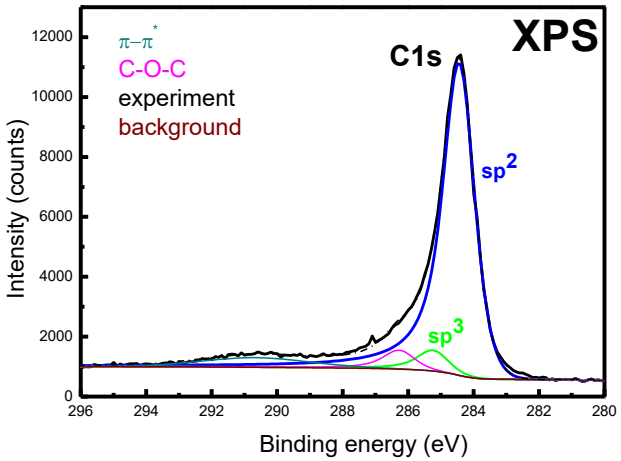


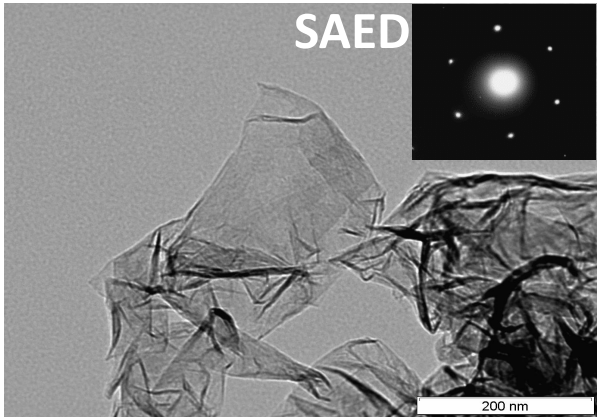
Radiative decay of $C_2^*(A_3\Pi_g)$ level



More C_2 radicals in plasma → more planar sp^2 carbons on graphene sheets

Control over the synthesis process and improve the structural quality





Without thermodinamic control

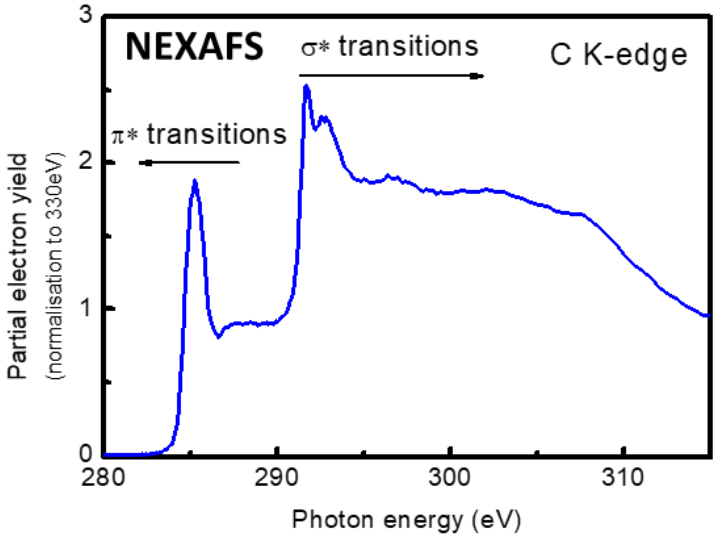
- $sp^2/sp^3 \sim 10$
- [O] ~ 2.3 %

IR

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

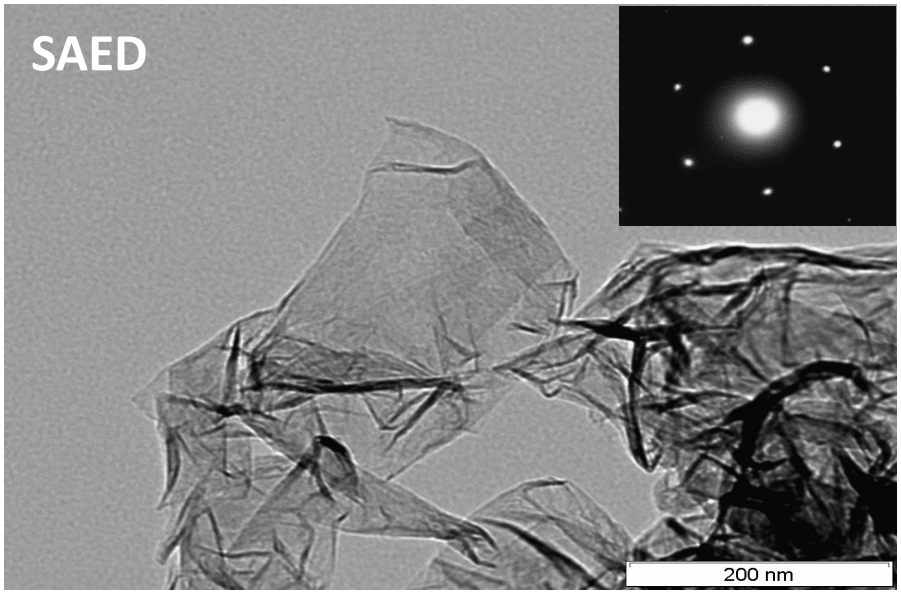
+UV

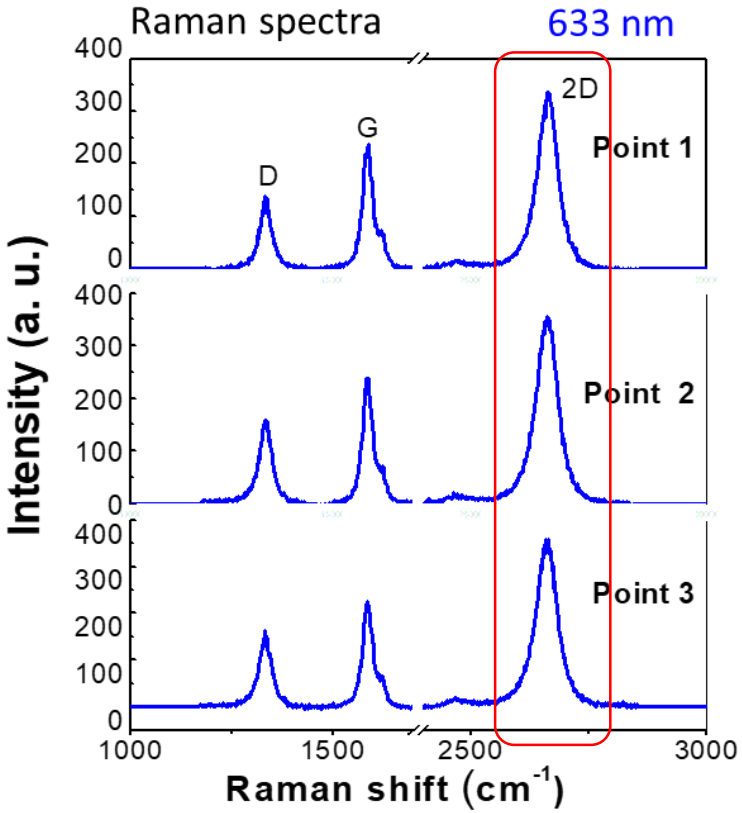
- [O] ~ 1.1 %



HESGM beam-line at BESSY II synchrotron, Berlin

Quality of graphene sheets
Raman spectroscopy analysis





Plasma tailoring

→ ↑ 2D/G → ↓ Number of mono-layers

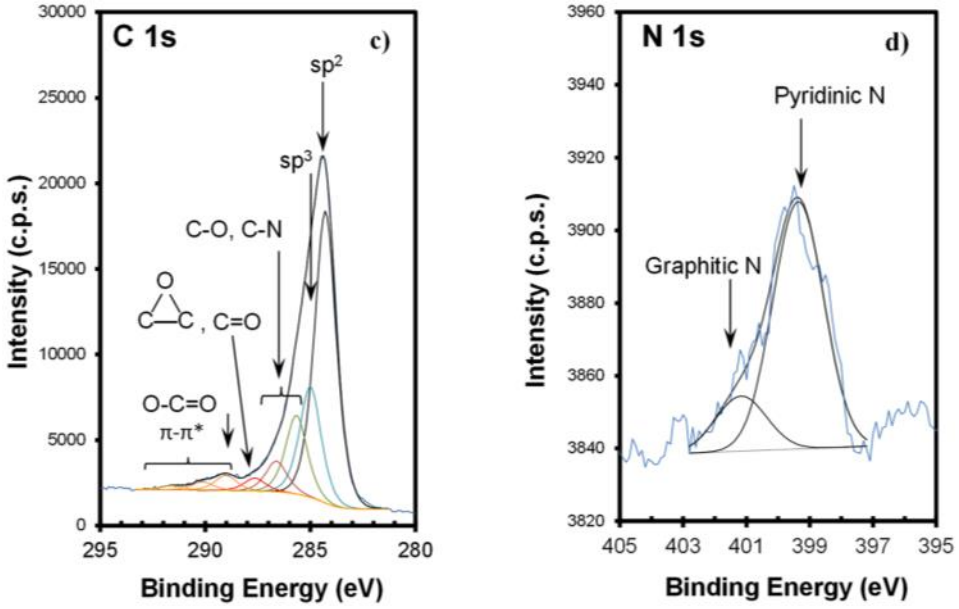
→ ↓ D/G → ↓ Defects, sp^3 carbons

→ homogeneity

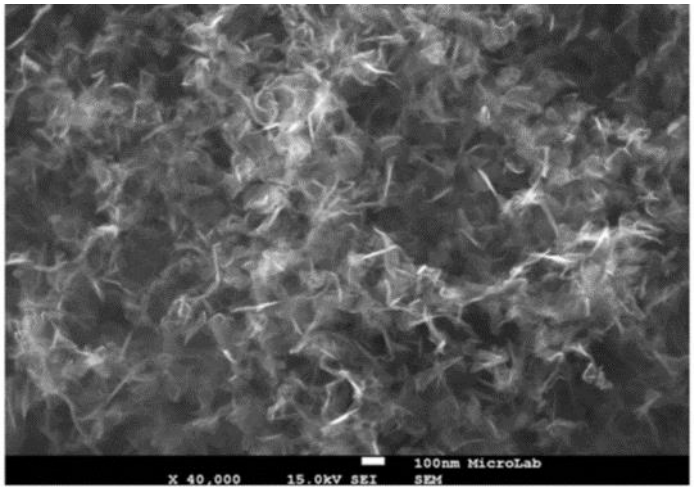
LabRam HR Visible (Horiba Jobin Yvon)

N-graphene
XPS to determine the elemental composition

XPS



SEM

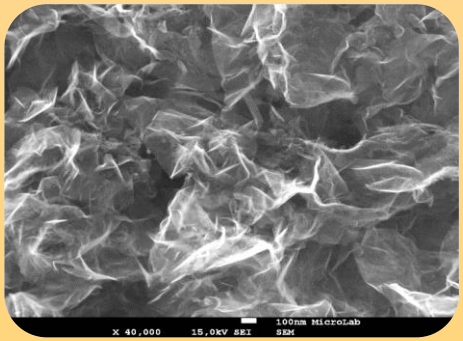


SEM images from: JEOL, JSM-7001F

Doping level:

- **N_2 → 0.2% N/C**
- **Other nitrogen content precursor → 5.6% 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** (> 3mg/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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C2C New Cap, Portugal
CeFEMA/IST, Portugal

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Thank you!!

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