

# Graphene Nanostructures Integration in Nanophotonic Biosensors

*Catalan Institute of Nanoscience and Nanotechnology (ICN2)*

Bárbara Diego Lisboa

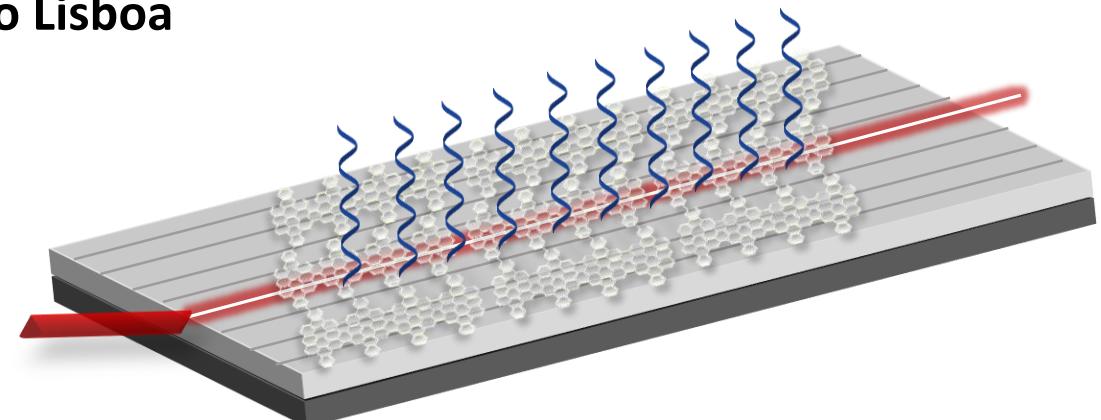


Centro Singular de Investigación  
en Química Biológica e  
Materiais Moleculares

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*Dr. Diego Peña*

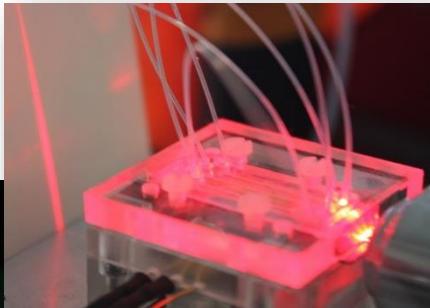
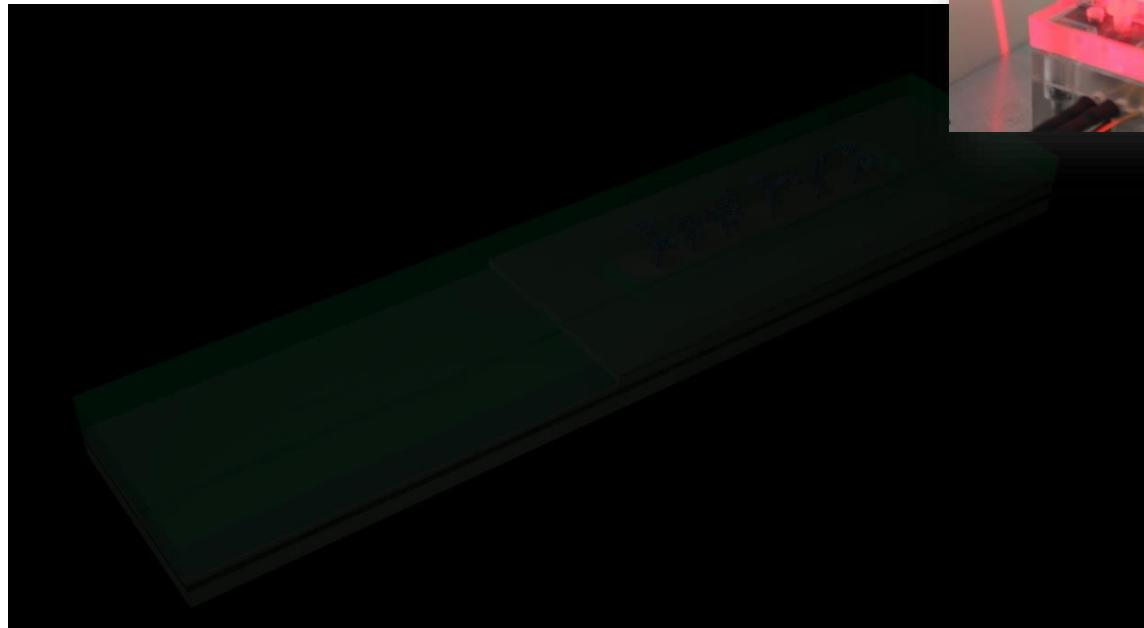


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*Dra. Maria Soler (NanoB2A)*  
*Prof. Aitor Mugarza (AMS)*  
*Dr. César Moreno (AMS)*

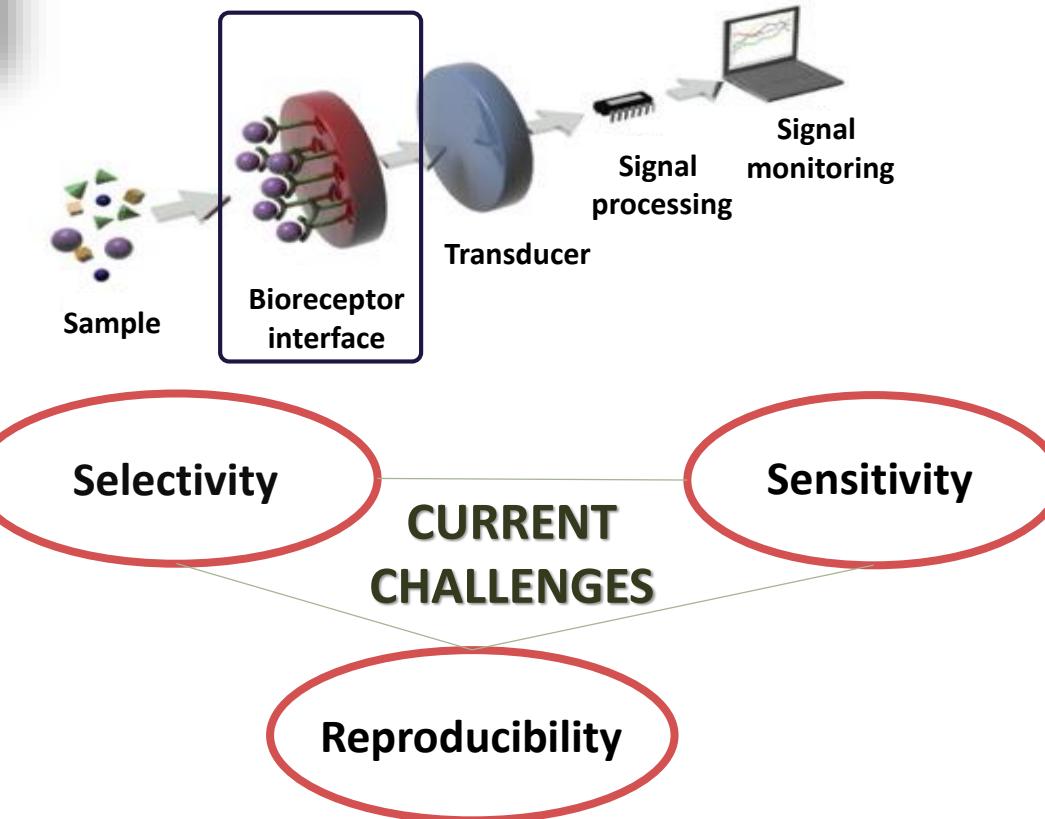


# Interferometric BiModal Waveguide (BiMW) biosensor

Evanescence wave working principle: highly sensitive label-free detection



- Sensitivity (pM-fM)
- Label-free, direct and real-time analysis
- Wafer scale fabrication (Miniaturised size)
- Capacity integration Lab-On-Chip



# Silanization

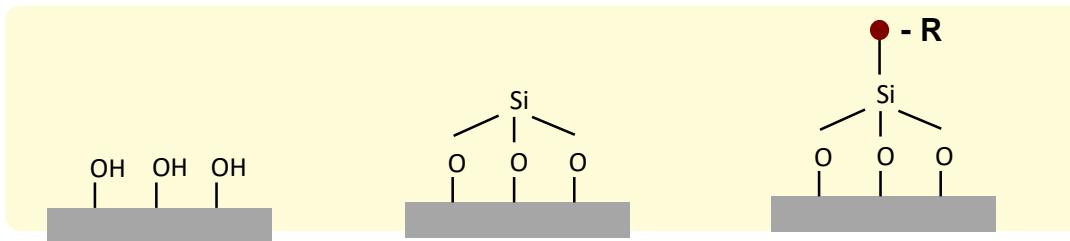


## Biosensor substrate activation

Different protocol for every silicon surface



## No control over the distribution of the biofunctional interface layer



- Depends on material's choice, surface roughness, porosity and even purity
- Lack of reproducibility



**Need for optimized protocol!**

# Graphene Nanostructures



## Transfer of graphene nanostructures

Different type of materials



## Intrinsic functionalization

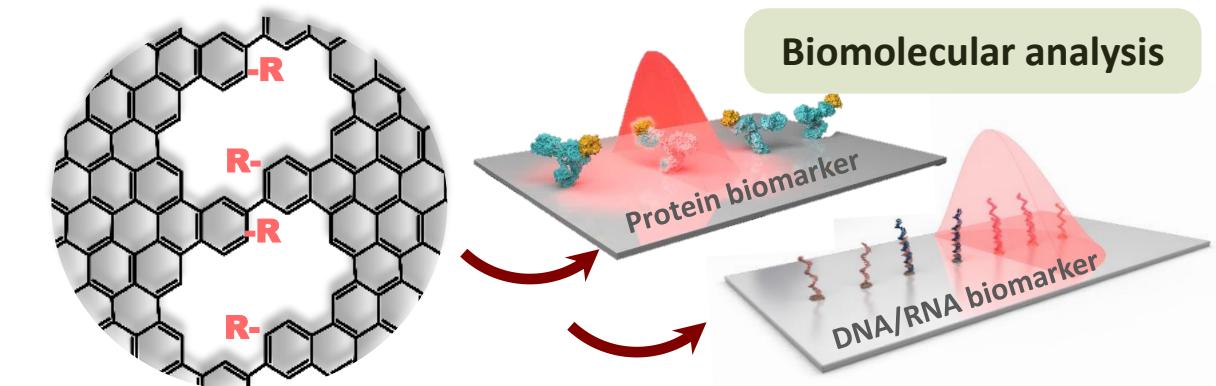
Create specific pinning centers in the graphene template



## Imaging graphene with atomic resolution

Visual characterization of the graphene porosity

Develop a **universal** biofunctionalization protocol



# Main Properties

**Atomic control of the anchoring points**

Bottom-up synthesis of atomically design functionalized monomers

**Specific functional groups on surface**  
(-NH<sub>2</sub>, -COOH)

Compatible with current silanization protocols

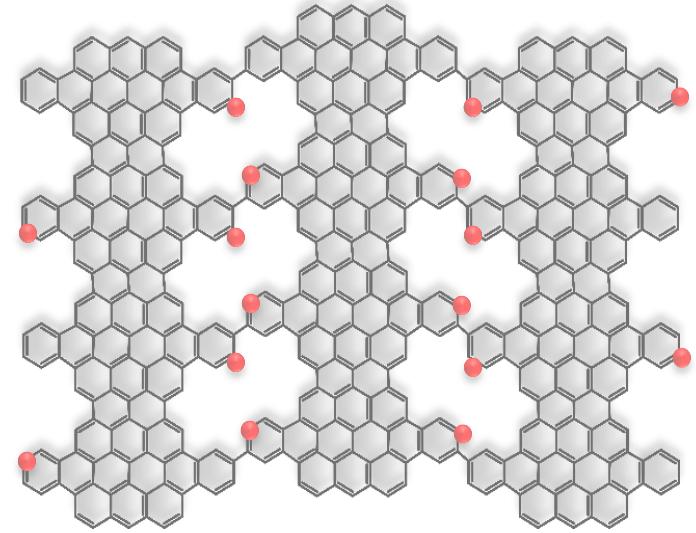
**2D Material**

Long-range ordered material enables the 3D arrangement of bioreceptors

**Graphene nanoarchitectures template**

**Surface - area contact**

Increase sensitivity towards the target species  
(DNA, proteins, virus)

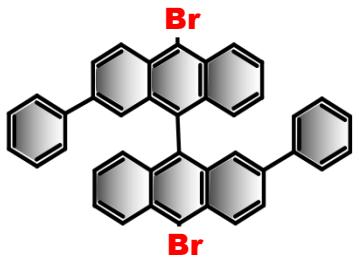


# Bottom-up strategy of 2D graphene nanostructures

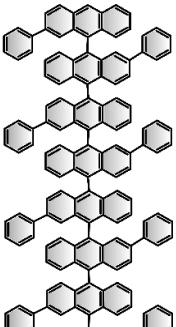
C. Moreno et al., Science 2018

Li et al., ACS Nano 2020

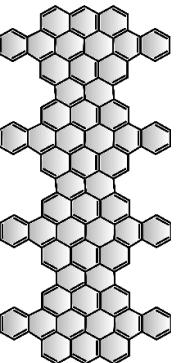
## Monomers



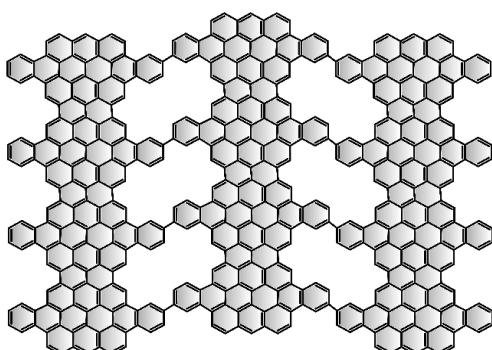
## Polymers



## Nanoribbons



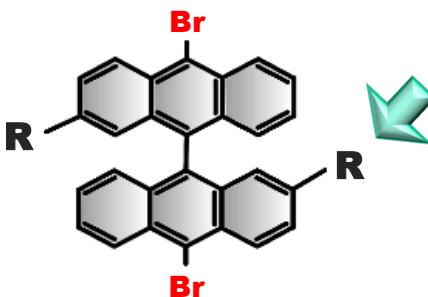
## Nanoporous Graphene



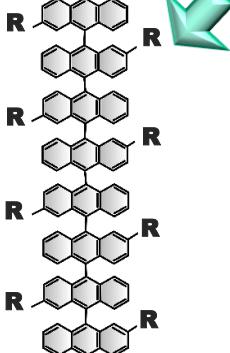
Synthesis condition  
 $P \leq 10^{-10}$  mbar

Extrinsic  
functionalization  
approach

RT



T1

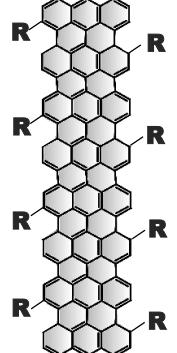


## Monomers

## Polymers

## Nanoribbons

T2

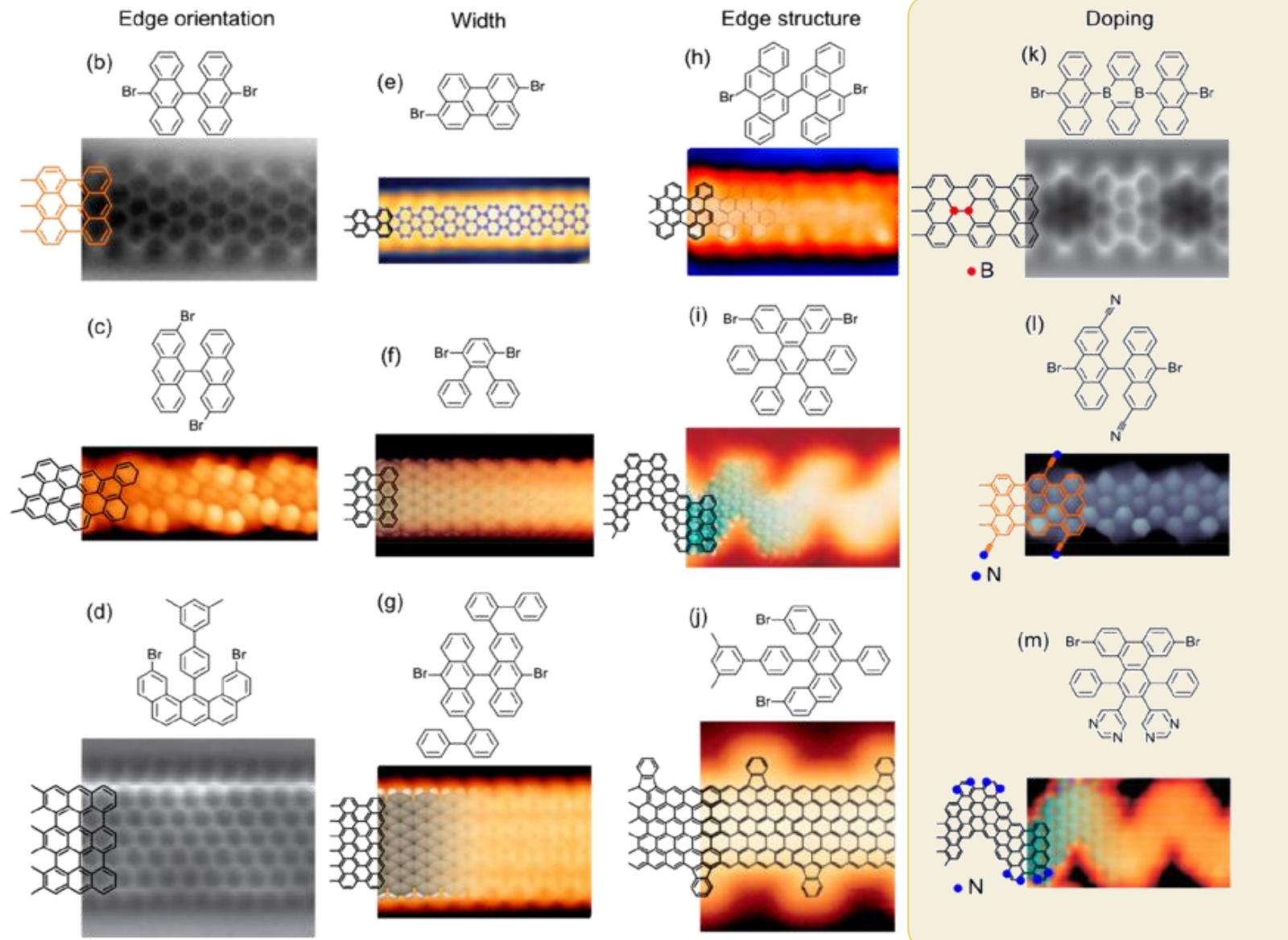


T3

Intrinsic  
functionalization  
approach

Higher control of the  
functional groups on the  
graphene surface

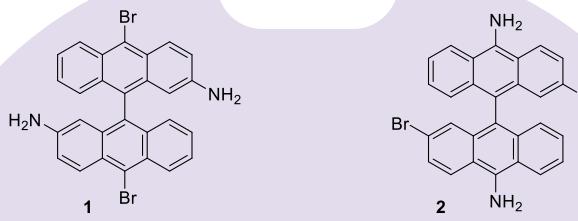
# On-surface synthesis of Graphene Nanoribbons



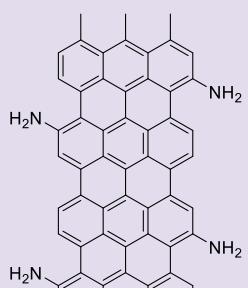
**Different functional groups**  
can be introduced at  
**specific positions** of the  
monomers.

# Intrinsic functionalization approach

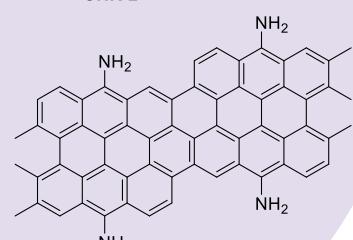
Amino



GNR-1

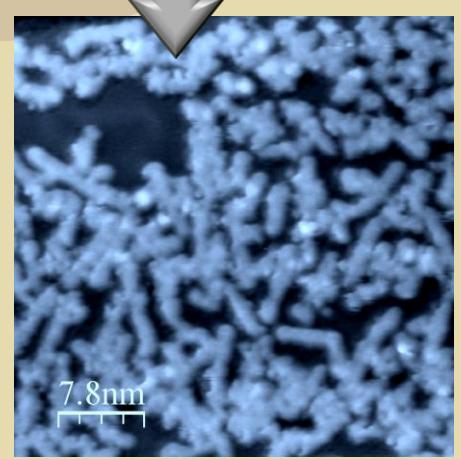
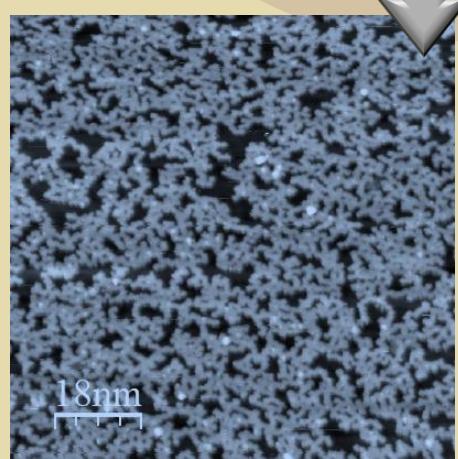


GNR-2



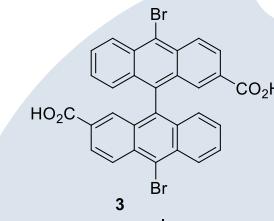
Coverage of the nanostructures  
can be controlled

The functional group will be  
selected for the desired  
sensing application

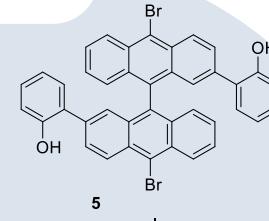
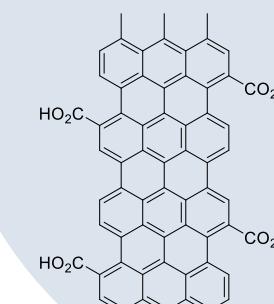


Scanning Tunneling  
Microscopy

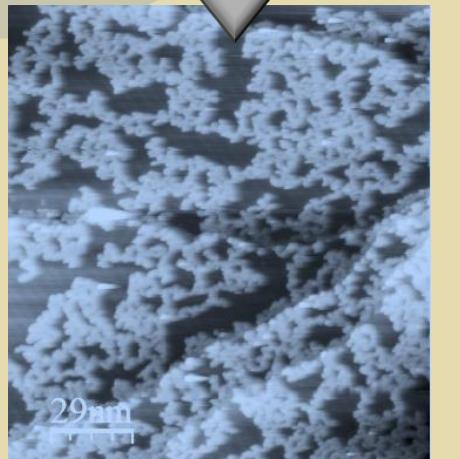
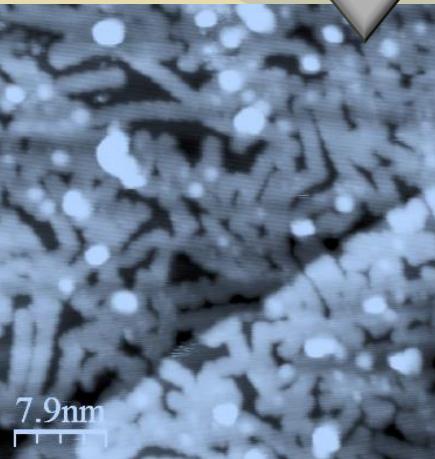
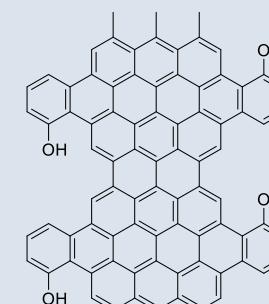
Carboxyl



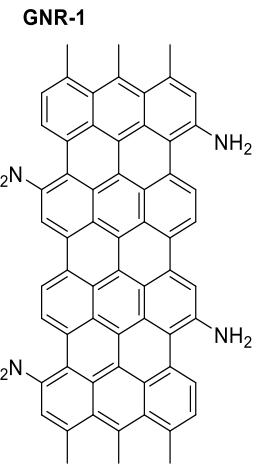
GNR-3



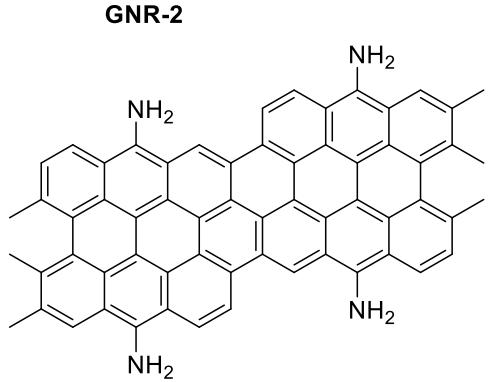
5



# Surface characterization X-ray Spectroscopy

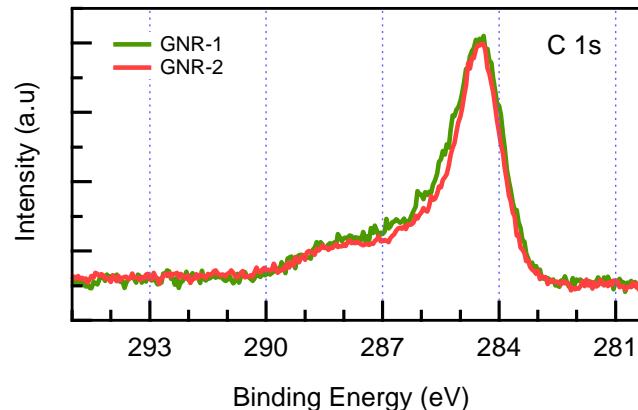


Armchair edge orientation

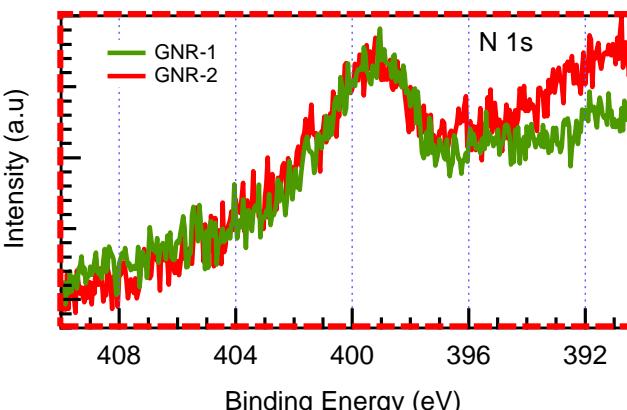
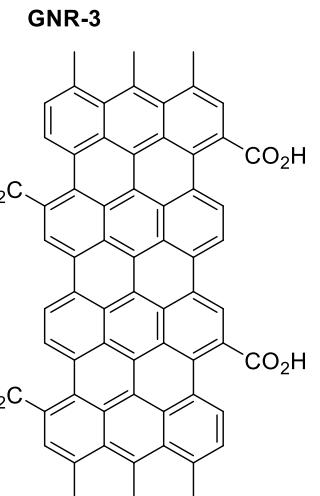
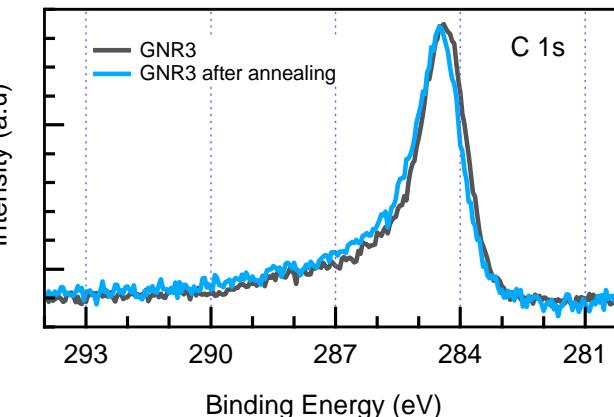


Chiral edge orientation

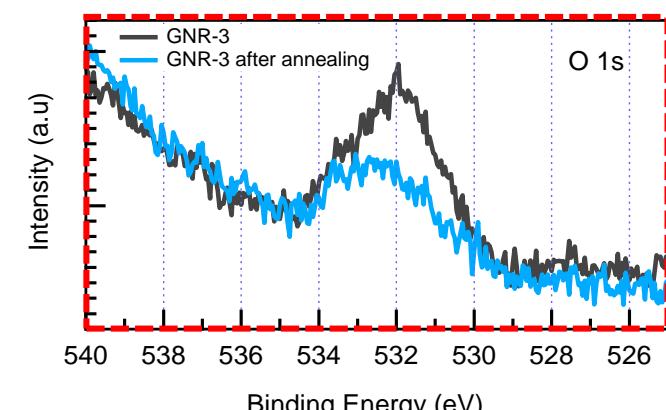
## Amino functionalized groups



## Carboxyl functionalized groups



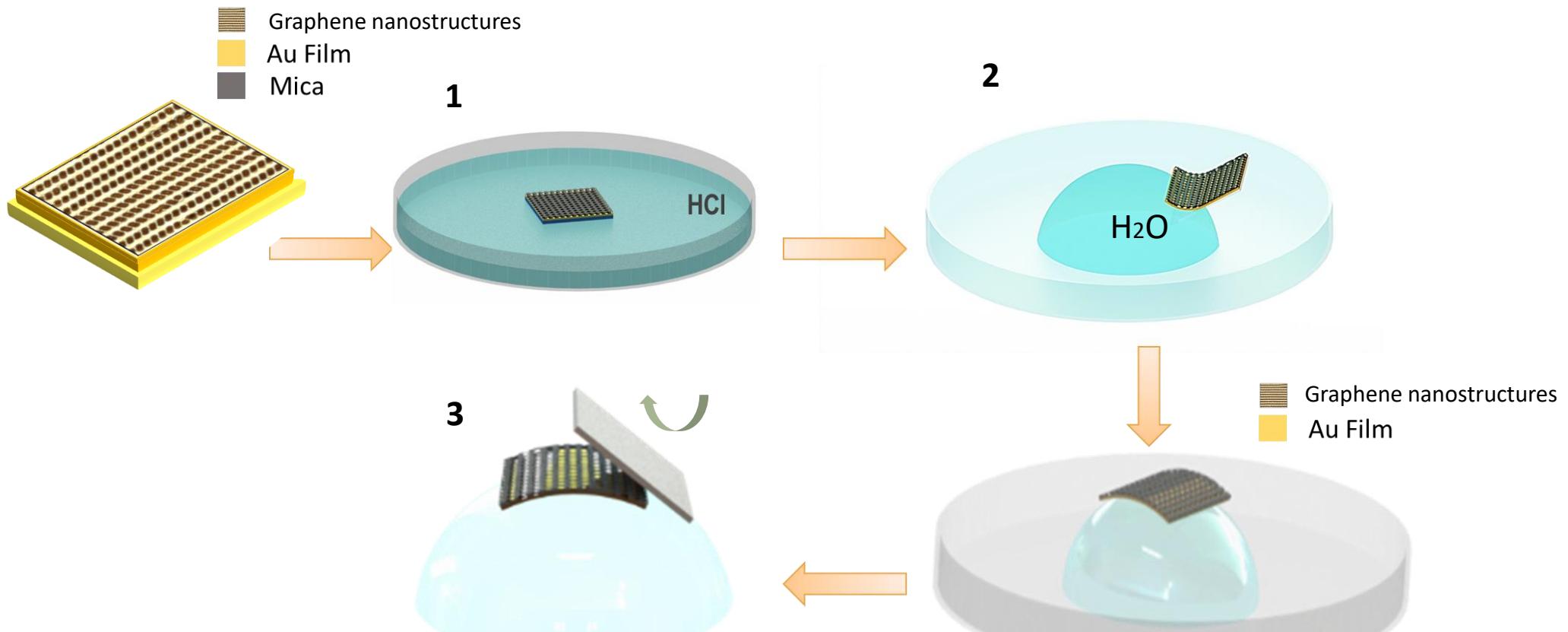
Amino groups are equally stable at atmosphere conditions



Oxygen from atmosphere removed and functional groups remain intact

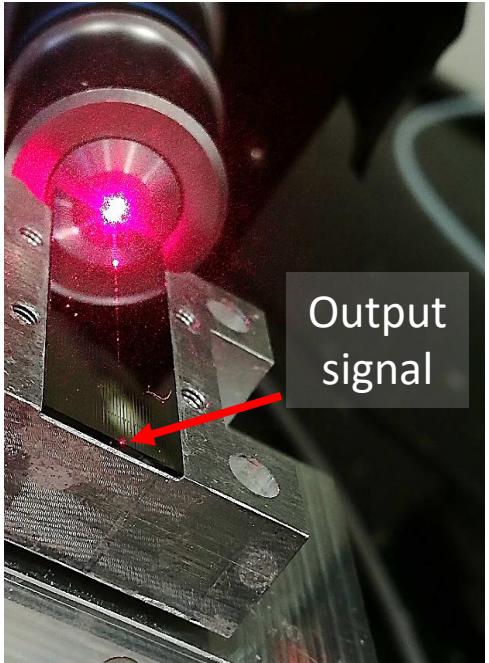
# Graphene transfer onto the biosensor area

C. Moreno et al., Science 2018



Wet and polymer-free transfer route of samples  
until 1x1 cm<sup>2</sup> size by gold etching

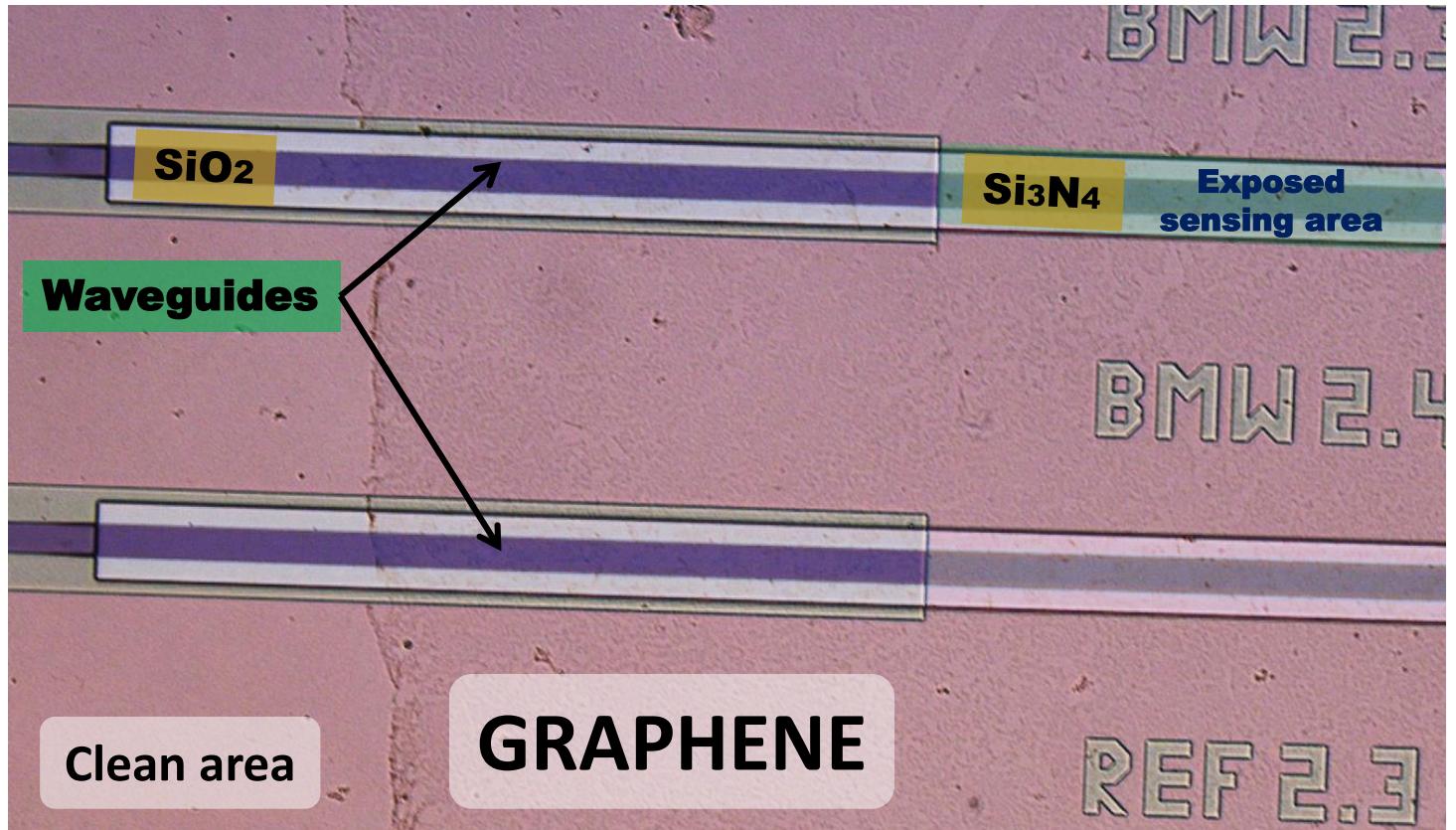
# Graphene transfer onto the biosensor area



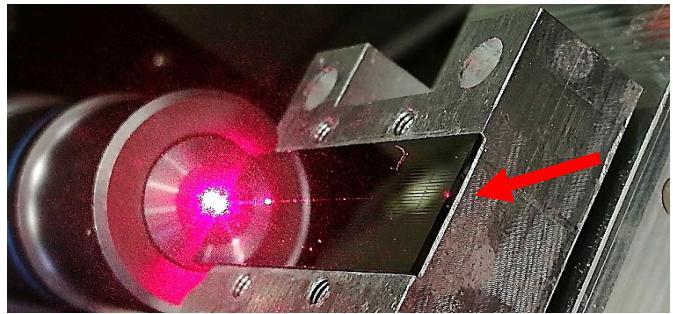
Bimodal Waveguide (BiMW)  
Interferometer



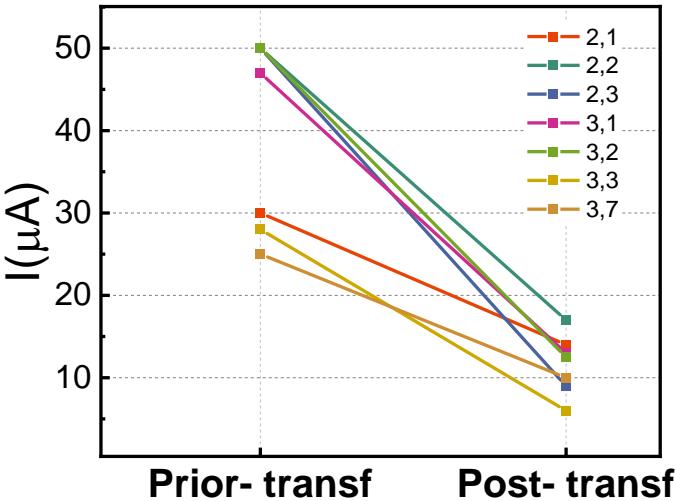
SENSING  
AREA



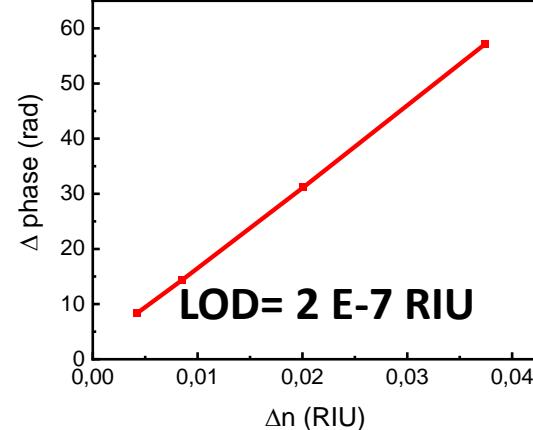
# Preliminary tests: Immobilization of antibodies



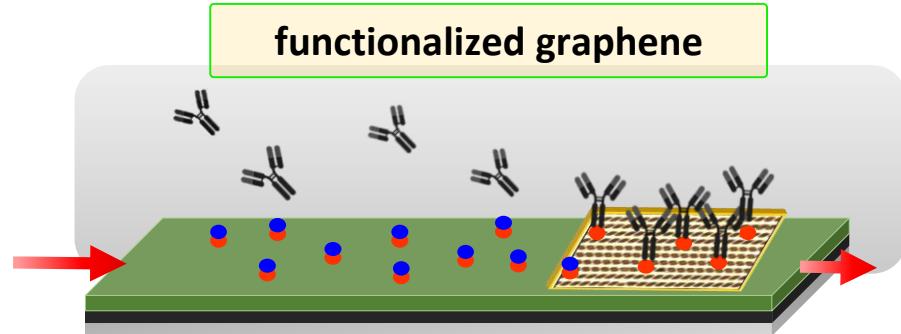
Coupling intensity values



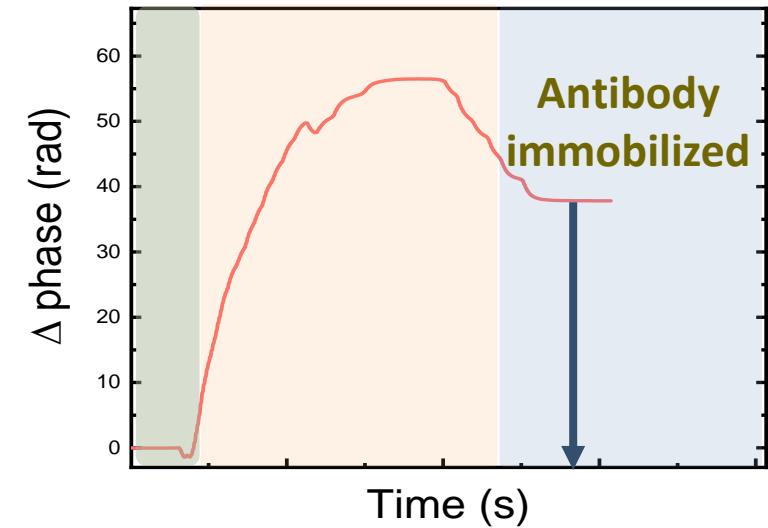
Post-transfer calibration  
waveguide 3.2



Graphene nanoribbons cover 20% of sensing area

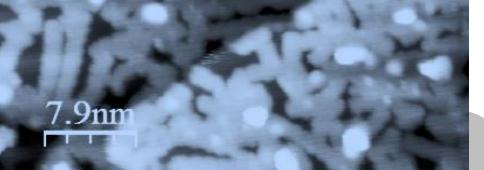
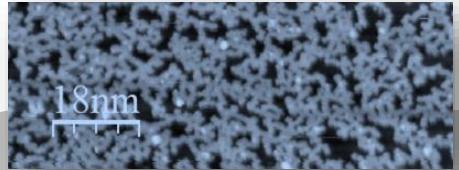


$\text{H}_2\text{O}$  in flow      Antibody in flow       $\text{H}_2\text{O}$  in flow

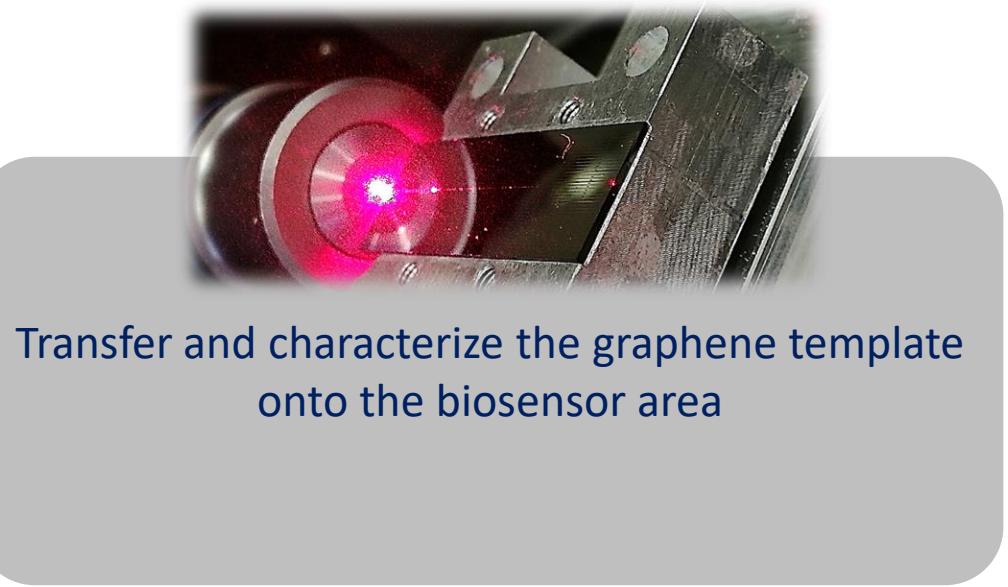


On-going work!!

# Conclusions

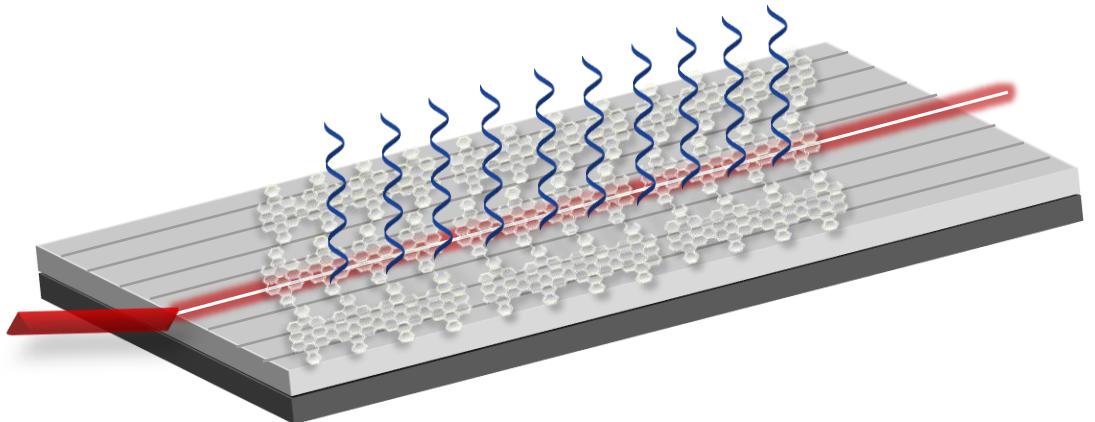


Synthesize Graphene nanoribbons with intrinsically modified functional groups in a bottom-up method



Transfer and characterize the graphene template onto the biosensor area

Further on:  
The graphene nanostructures will be evaluated in-situ as a promising and innovative universal biofunctionalization approach



# Thank you for your attention!



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