

# Attività di ricerca sul grafene

## Angelo Armano

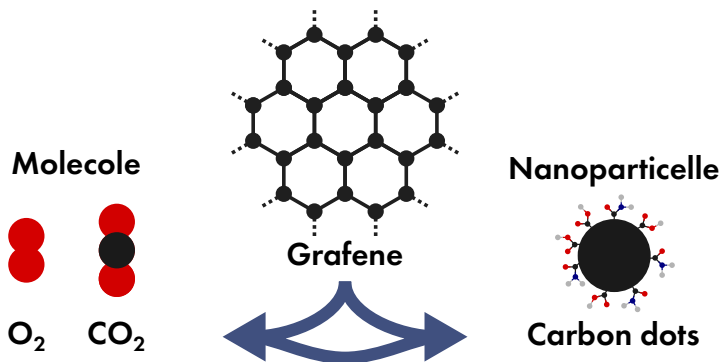


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di CATANIA

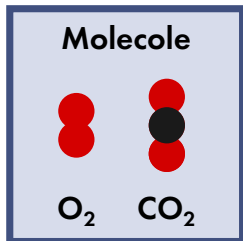


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DI PALERMO

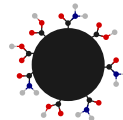
## Processi di trasferimento di carica



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**Nanoparticelle**



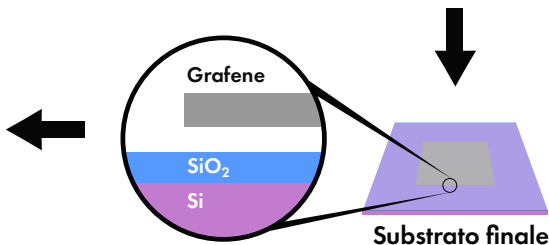
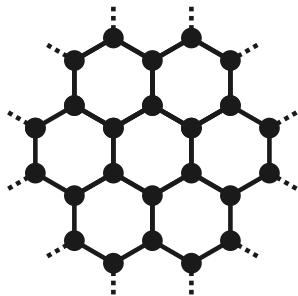
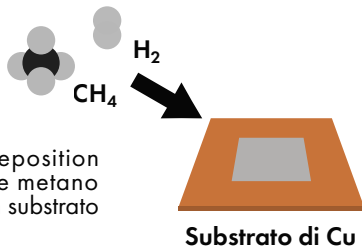
**Carbon dots**

## Struttura

Materiale 2D composto da atomi di C  $sp^2$  disposti in un reticolo esagonale

## Sintesi

Grafene cresciuto tramite Chemical Vapor Deposition su un substrato di rame utilizzando idrogeno e metano come precursori. Successivamente trasferito su un substrato finale, tipicamente  $SiO_2/Si$ .



## Trattamenti Termici in Atmosfera controllata

Esposizione selettiva del grafene a differenti gas: azoto, ossigeno, anidride carbonica e acqua in questo intervallo di parametri:



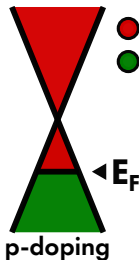
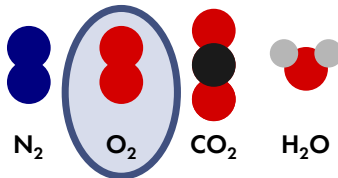
Temperatura · 150–400°C



Pressione · 2 bar



Tempo · 5 min → 2 h



- Stati disponibili
- Stati occupati

## Effetti

**Strain** dovuto alla tensione o compressione meccanica del grafene termicamente indotti dall'interazione col substrato

**Tensione (+)**

**Compressione (-)**

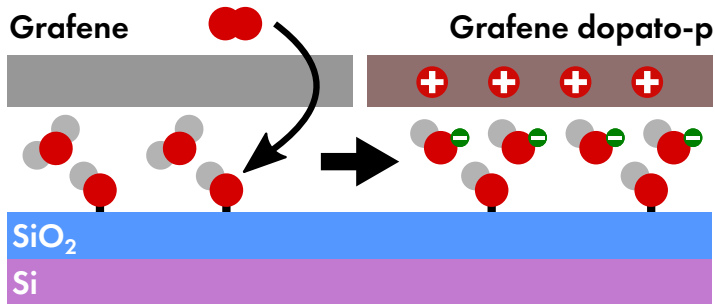


**Doping** indotto dal trasferimento di elettroni verso molecole adsorbite

## Reazione di riduzione dell'ossigeno

Processo multi-step:

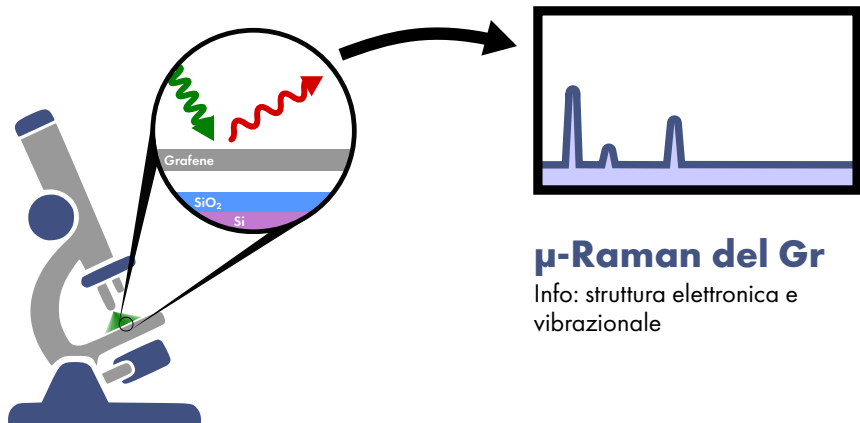
- 1 • **Diffusione** di  $O_2$  nello spazio interstiziale tra grafene e substrato
- 2 • **Adsorbimento** di  $O_2$  in siti specifici del grafene
- 3 • **Reazione** attivata termicamente con l'acqua presente sul substrato



## Spettrometro + Microscopio

Lunghezza d'onda di eccitazione:

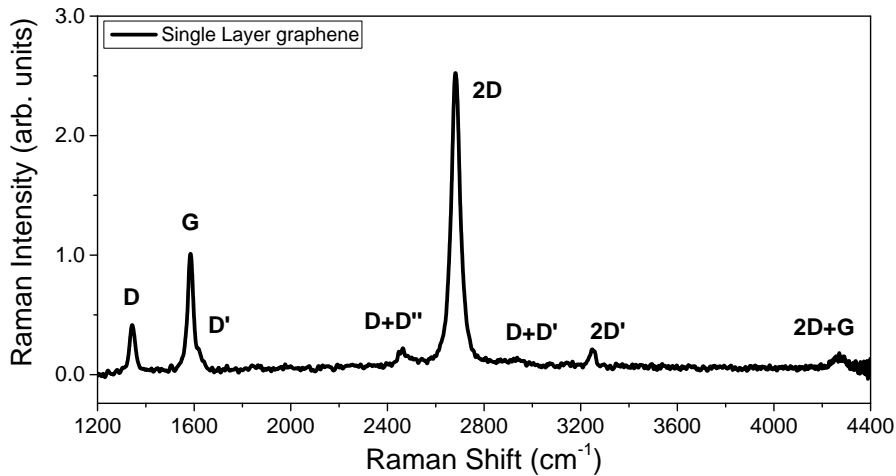
Laser: **532 nm** · **633 nm**



## $\mu$ -Raman del Gr

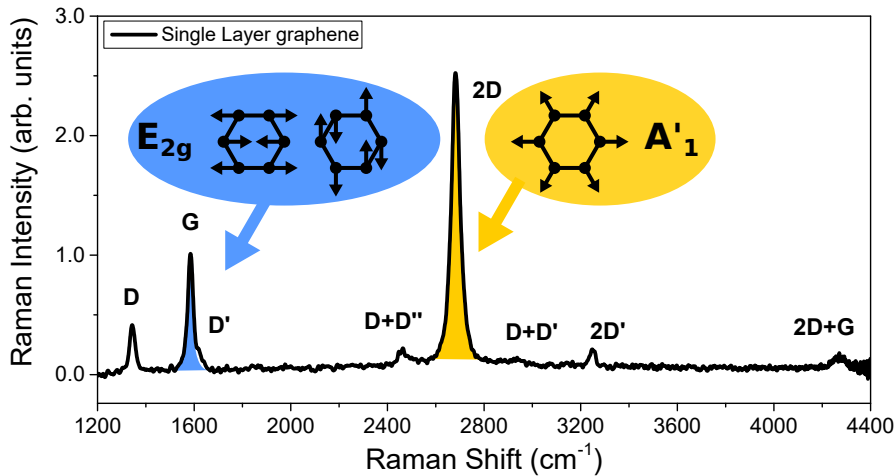
Info: struttura elettronica e  
vibrazionale

# Spettro Raman del grafene

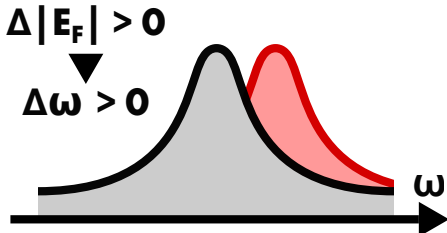
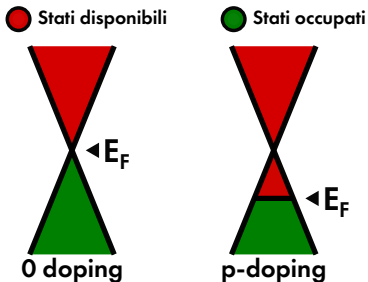




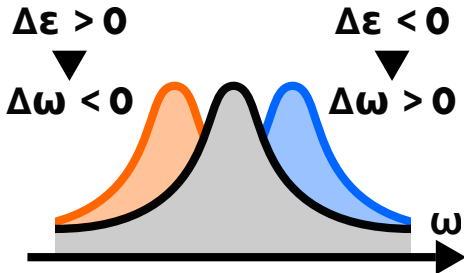
# Spettro Raman del grafene



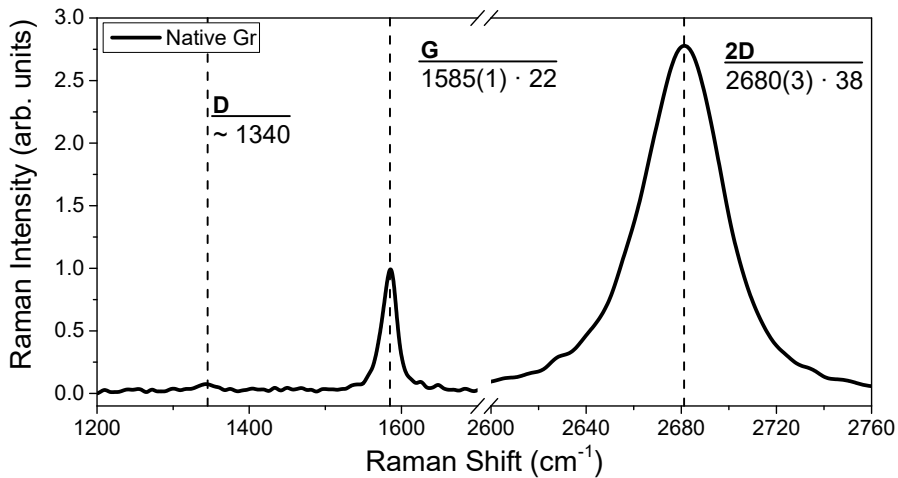
## Doping



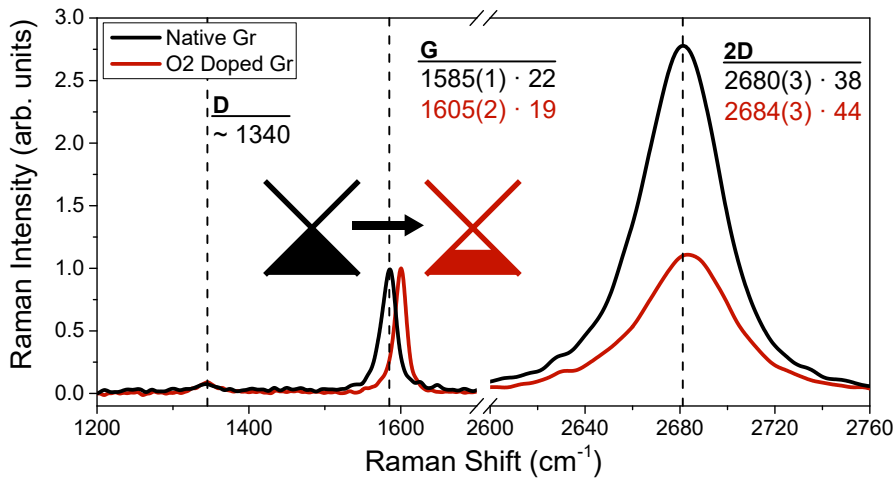
## Strain



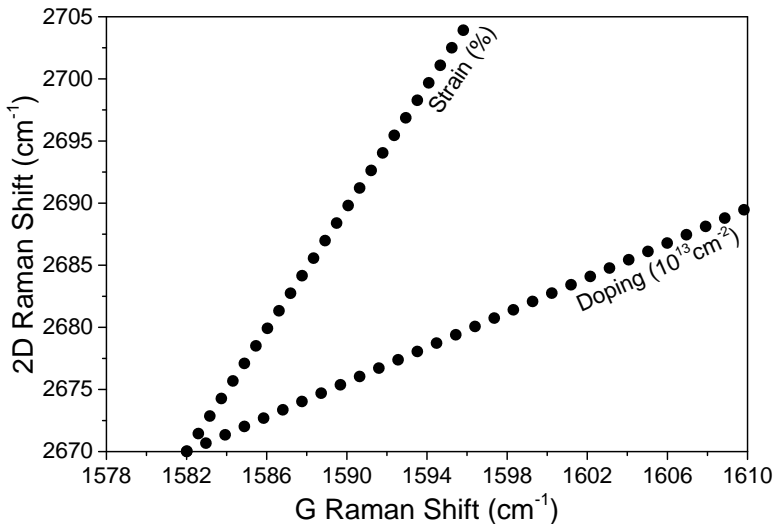
# Spettro Raman del p-Gr



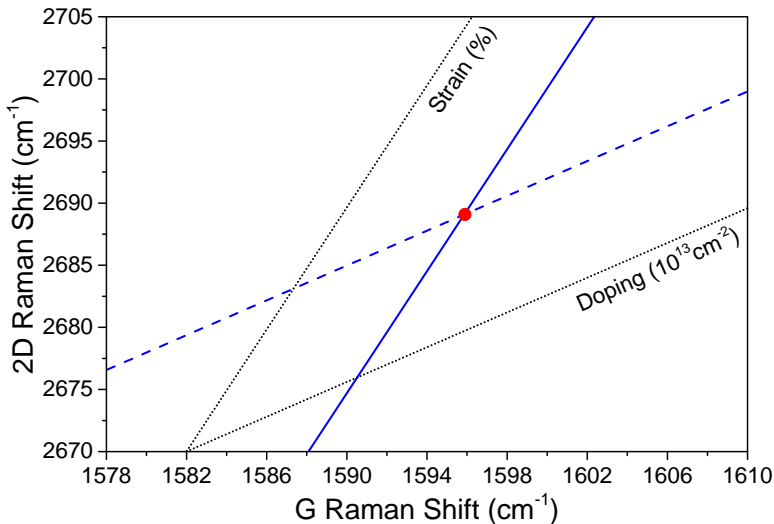
# Spettro Raman del p-Gr



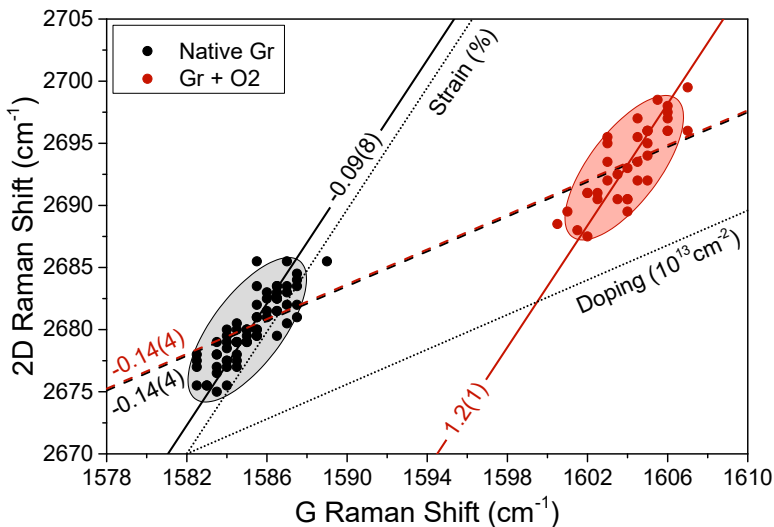
# Mapa di correlazione G-2D



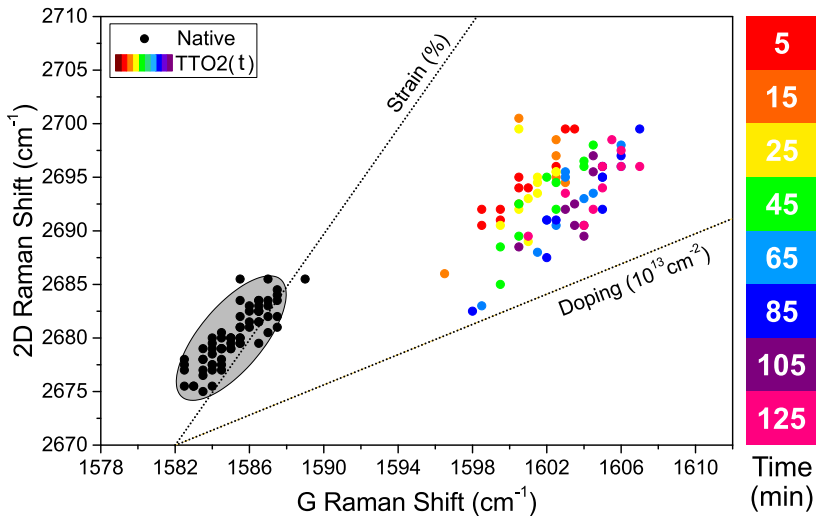
# Mappa di correlazione G-2D



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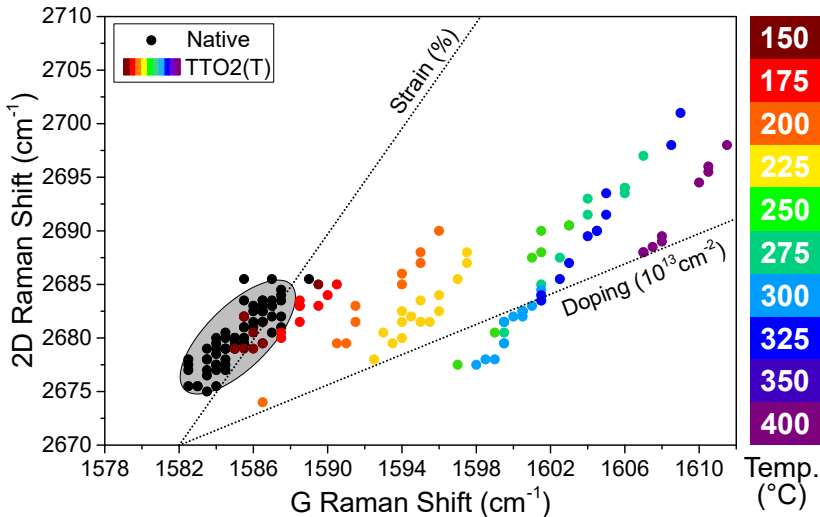


# Tempo e Temperatura

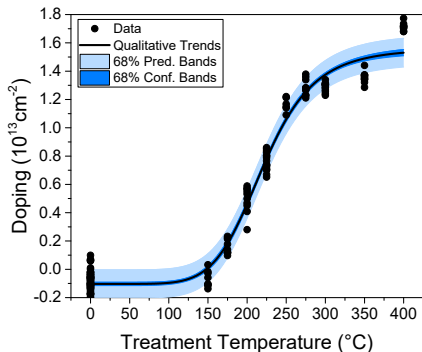




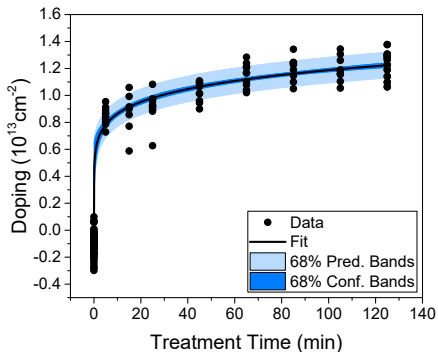
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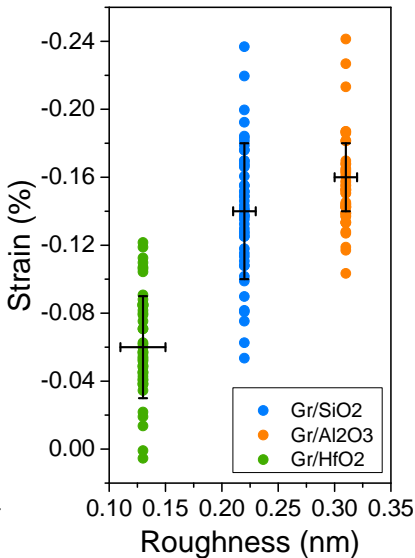
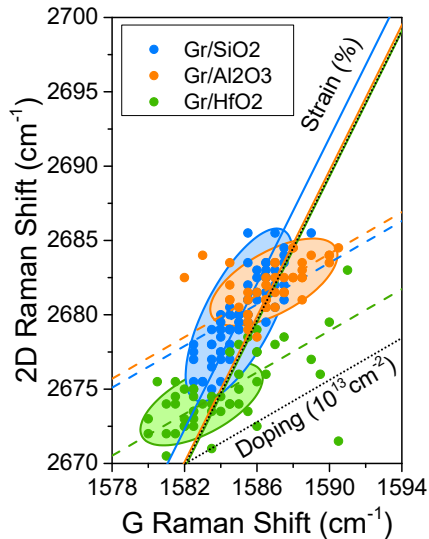


**D(T)** 

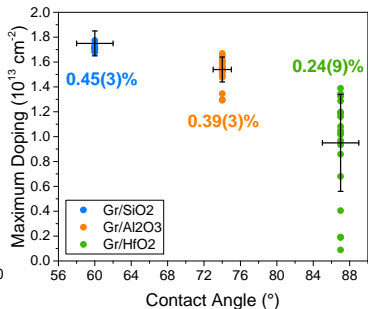
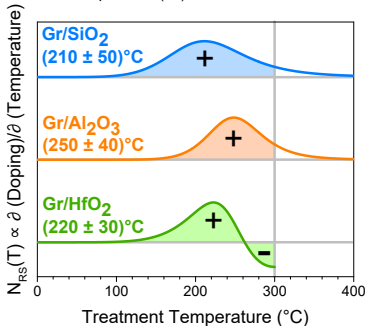
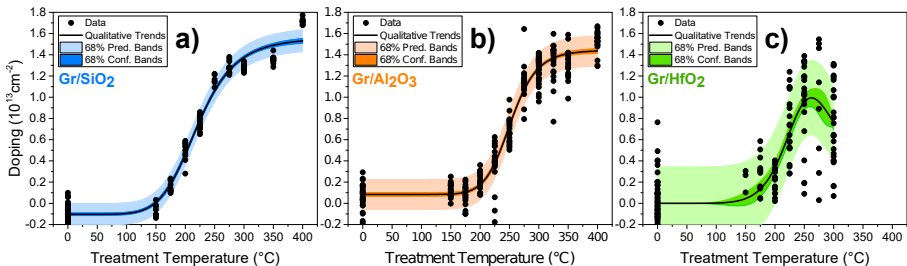


**D(t)** 

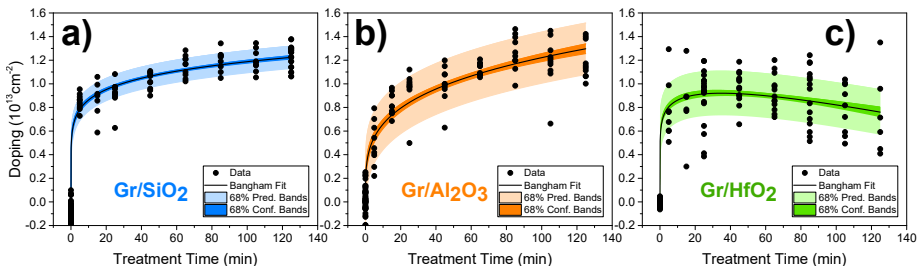




# Influencia del sustrato • Temperatura



# Influenza del substrato • Tempo



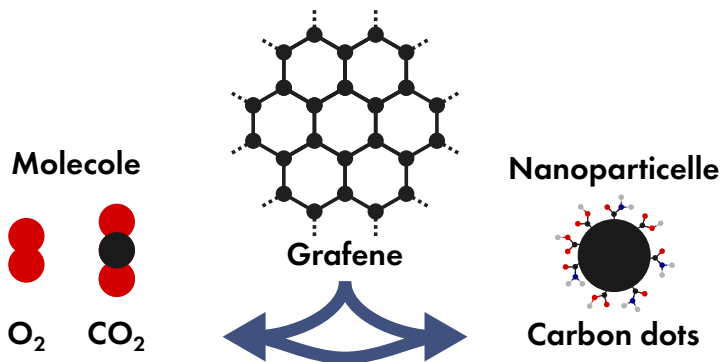
Termine di perdita

$$D(t) = c \cdot \left( \underbrace{kt^\vartheta}_{\text{Modello di Bangham}} + \underbrace{st}_{\text{Termine di perdita}} \right), \quad c = 10^{13} \text{cm}^{-2}$$

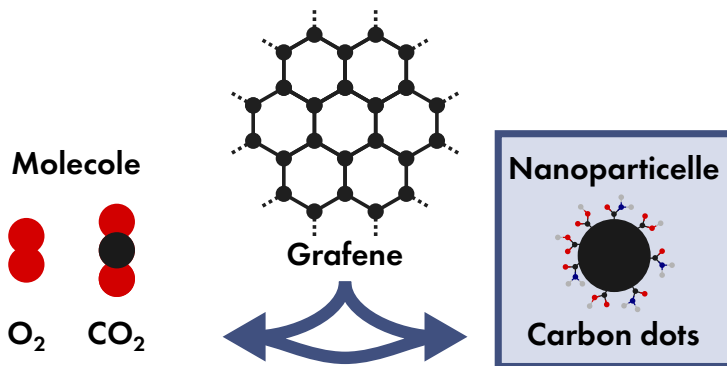
Modello di Bangham

Sample	k (min <sup>-1</sup> )	ϑ	s (min <sup>-1</sup> )
Gr/SiO <sub>2</sub>	0.72(3)	0.13(1)	–
Gr/Al <sub>2</sub> O <sub>3</sub>	0.36(5)	0.27(3)	–
Gr/HfO <sub>2</sub>	0.67(3)	0.13(1)	-0.004(6)

## Processi di trasferimento di carica

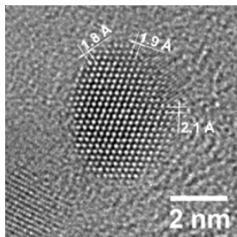


## Processi di trasferimento di carica



## Struttura

Nanoparticelle a base di carbonio di dimensione compresa fra i 1 e 10 nm

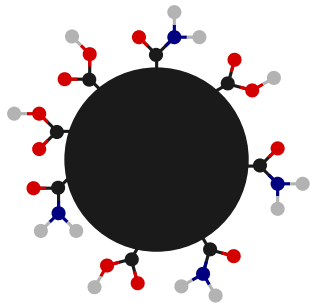


## Core

Costituito da atomi di carbonio e azoto in fase cristallina secondo la struttura  $\beta$ - $C_3N_4$

## Superficie

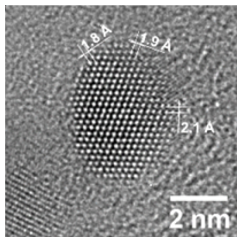
Passivata da gruppi molecolari semplici:  
-CH, -COOH, -CONH<sub>2</sub>





## Struttura

Nanoparticelle a base di carbonio di dimensione compresa fra i 1 e 10 nm

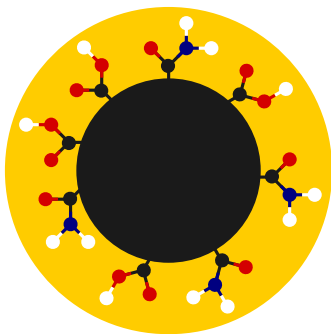


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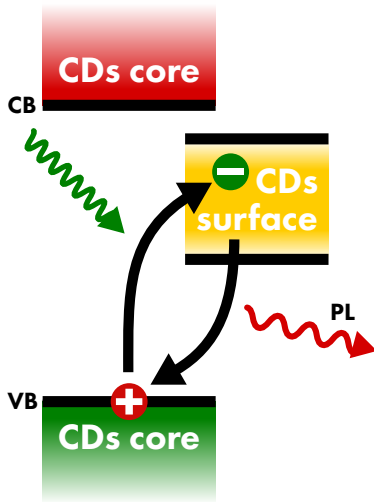
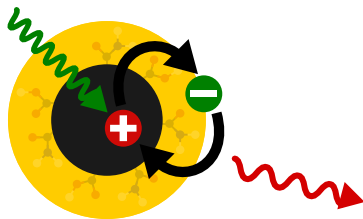
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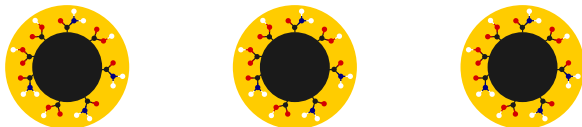


## Meccanismo di emissione

Coinvolge sia il core che la superficie dei CDs mediante la promozione foto-indotta di un elettrone dalla banda di valenza del core agli stati esposti in superficie



## CDs depositati su grafene

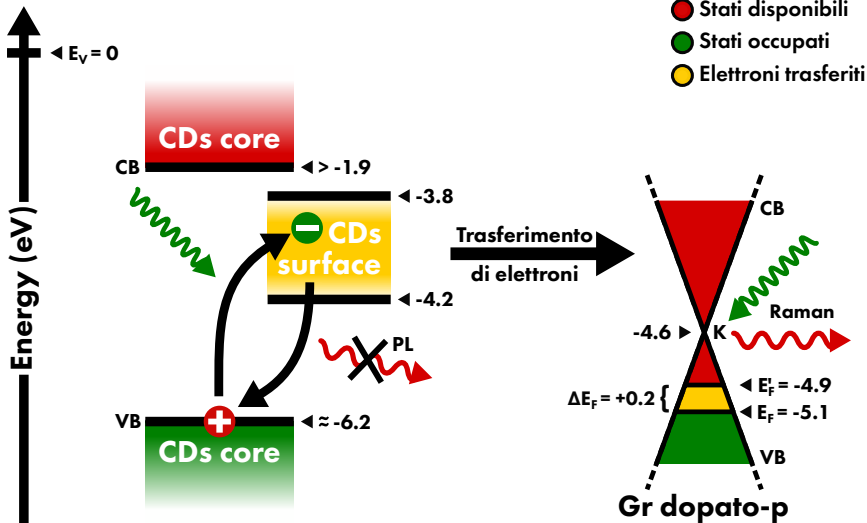


Grafene

$\text{SiO}_2$

Si

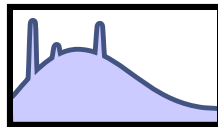
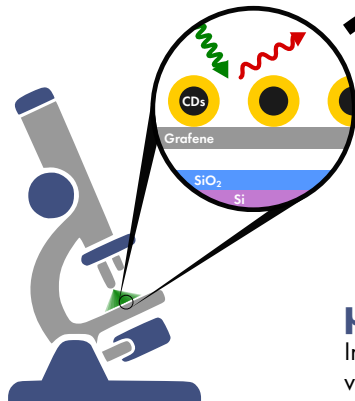
# Modello Trasferimento di carica • da CDs a Gr



## Spettrometro + Microscopio

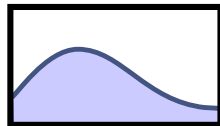
Lunghezza d'onda di eccitazione:

Laser: **532 nm** · **633 nm**



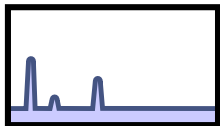
### $\mu$ -PL dei CDs

Info: struttura elettronica



### $\mu$ -Raman del Gr

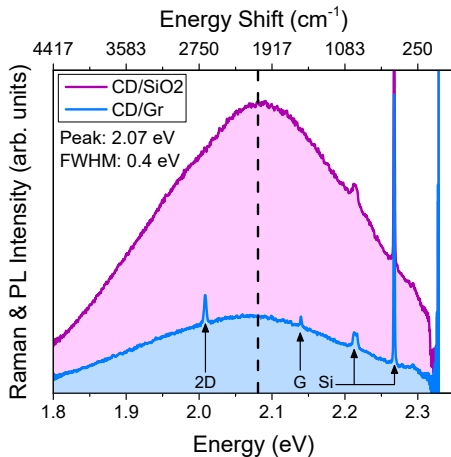
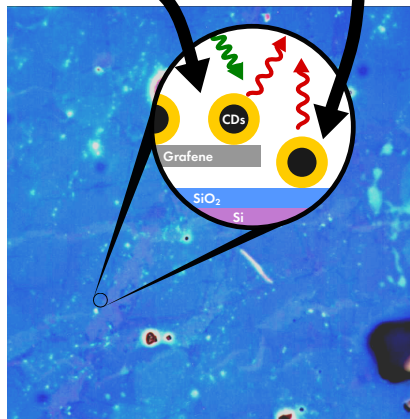
Info: struttura elettronica e vibrazionale



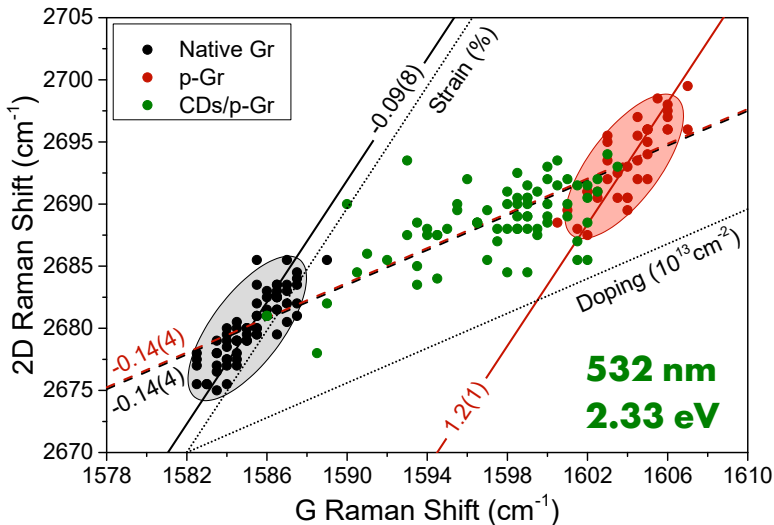
## Riduzione dell'efficienza di emissione

CDs/Gr

CDs/SiO<sub>2</sub>



## Riduzione del doping per effetto dei CDs •



## Riduzione del doping per effetto dei CDs • ✘

