

# Preparation of Graphene

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Selected Topics in Physics: Physics of Nanoscale Carbon  
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# Outline

## Introduction

## Exfoliation

Micromechanical Exfoliation

Liquid-phase Exfoliation

Substrat Preparation

## Growth on Surfaces

Epitaxial Growth

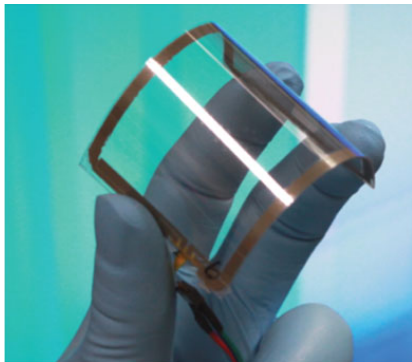
Chemical Vapor Deposition

## Summery

# Why Graphene?

## Advantages:

- Transparent
- Conducting
- Very strong
- Flexible



Source: *Bae, S. et al.; Nature Nanotech. 5, 574-578 (2010)*

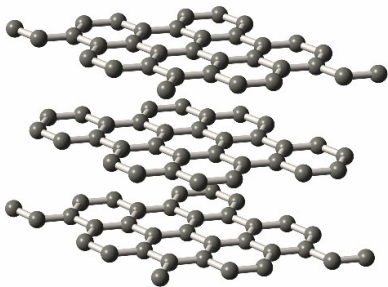
# Summary Table

Method	Qual.	Size	Amount	Complex.	Control.

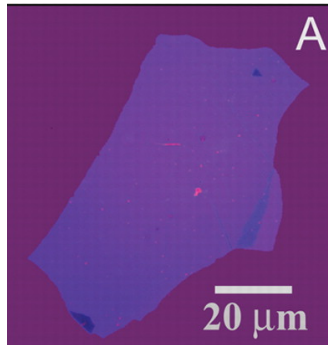


## The “Scotch Tape Method”

- Cleavage by adhesive tape
- Well prepared wafer necessary



Source: [www.idw-online.de](http://www.idw-online.de)



Source: Novoselov KS *et al.*; *Science* 306, (2004)



## Summary Table

Method	Qual.	Size	Amount	Complex.	Control.
Tape	✓	×	×	(✓)	×



## Dispersion of Graphite

- Dispersion of graphit in organic solvents
- Surface energies approximately equal



Source: Coleman JN *et al.*; *ACS Nano* 4, 3155-3162 (2010)



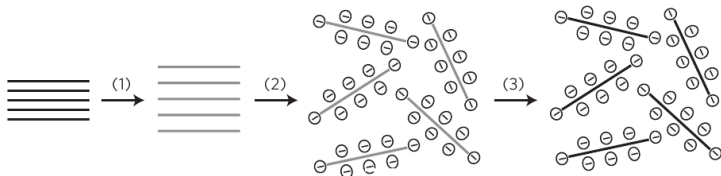
## Summary Table

Method	Qual.	Size	Amount	Complex.	Control.
Tape	✓	×	×	(✓)	×
Fluid	✓	×	✓	✓	×



# Graphite Oxide Exfoliation

- Hydrophilic graphite oxide
- Reduction of graphene oxide
- Atomic C/O ratio:  $\sim 10$

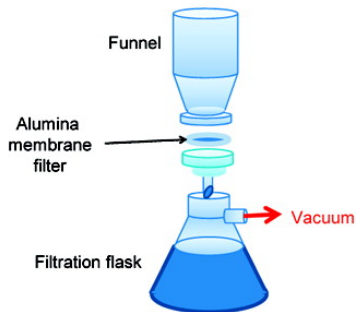


Source: Park S, Ruoff RS; *Nature Nanotech.* 4, 217-224 (2009)

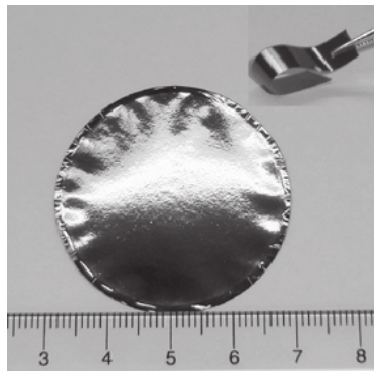


# Substrat Preparation

- Vacuum filtration



Source: Kong BS *et al.*, *Langmuir* 25, 11008-11013 (2009)



Source: Li D *et al.*, *Nature Nano.* 3, 101-105 (2008)

# Substrat Preparation

- Drop-casting
- Spin coating
- Spray-coating



Source: Pham VH *et al.*, *Carbon* 48, 1945-1951 (2010)

## Summary Table

Method	Qual.	Size	Amount	Complex.	Control.
Adhesive tape	✓	×	×	(✓)	×
Liquid phase	✓	×	✓	✓	×
Graphite oxide	—	×	✓	×	×

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## Exfoliation

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Liquid-phase Exfoliation

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Epitaxial Growth

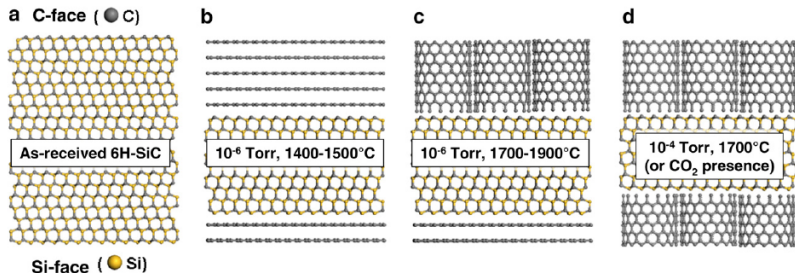
Chemical Vapor Deposition

## Summery



# Epitaxial Growth on SiC

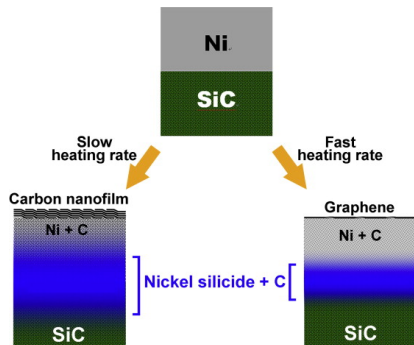
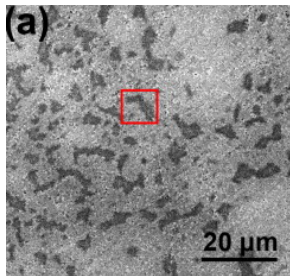
- Evaporation of Si by heating



Source: Gambaz ZG *et al.*, *Carbon* 46, 841-849 (2008)

# Epitaxial Growth by Nickel Diffusion

- Ni grown on SiC



Source: Juang ZY *et al.*, *Carbon* 47, 2026-2031 (2009)

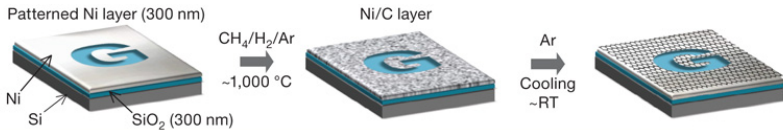
## Summary Table

Method	Qual.	Size	Amount	Complex.	Control.
Adhesive tape	✓	×	×	(✓)	×
Liquid phase	✓	×	✓	✓	×
Graphite oxide	—	×	✓	×	×
Epi. growth	×	(✓)	×	✓	✓

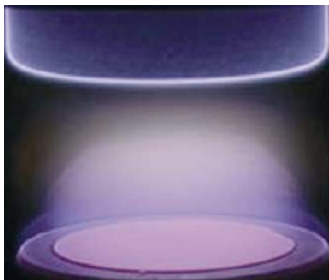




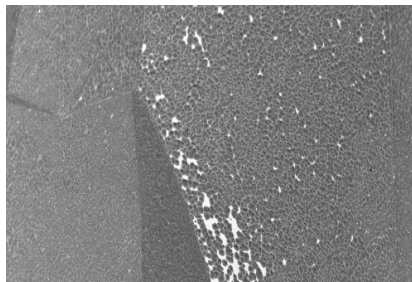
# Chemical Vapor Deposition



Source: Kim KS *et al.*, *Nature* 457, 706-710 (2009)



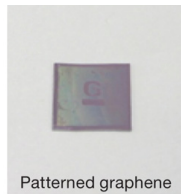
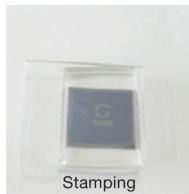
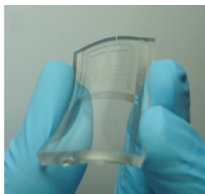
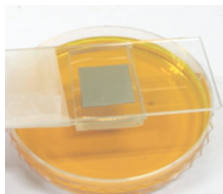
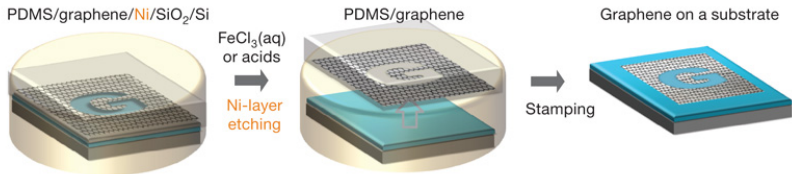
Source: Obratsov AN *et al.*, *Carbon* 41, (2003)



Source: Robertson AW, Warner JH

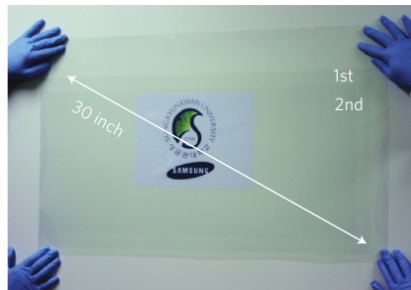
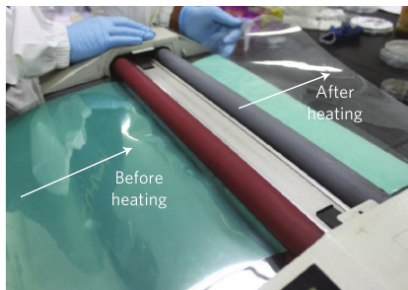
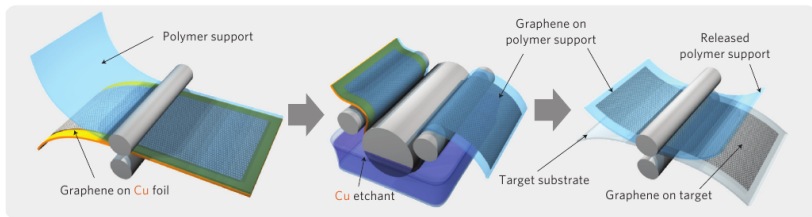


# Transfer



Source: Kim KS *et al.*, *Nature* 457, 706-710 (2009)

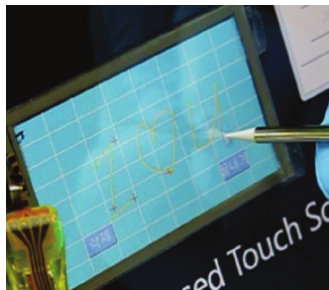
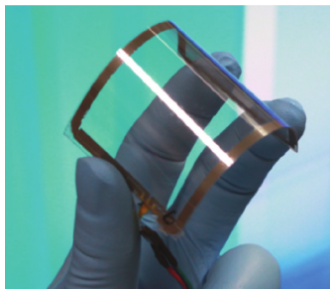
# Roll-to-Roll Production of 30-inch Graphene



Source: Bae, S. et al.; *Nature Nanotech.* 5, 574-578 (2010)

## Roll-to-Roll Production of 30-inch Graphene

- Doped with  $\text{HNO}_3$   
→ decreased resistance
- Fully functional touch-screen panel



Source: Bae, S. et al.; *Nature Nanotech.* 5, 574-578 (2010)

## Summary Table

Method	Qual.	Size	Amount	Complex.	Control.
Adhesive tape	✓	×	×	(✓)	×
Liquid phase	✓	×	✓	✓	×
Graphite oxide	—	×	✓	×	×
Epi. growth	×	(✓)	×	✓	✓
CVD	×	✓	✓	✓	✓

Thanks for your attention