Synthesis and Clean Transfer of Atomically Thin Materials

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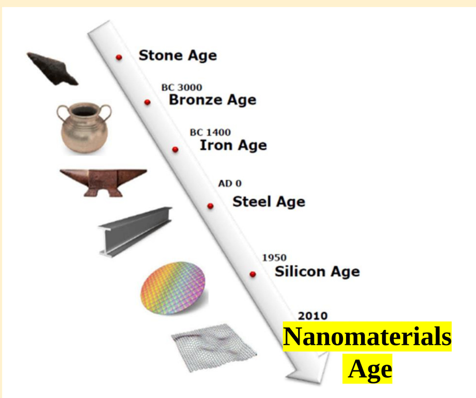
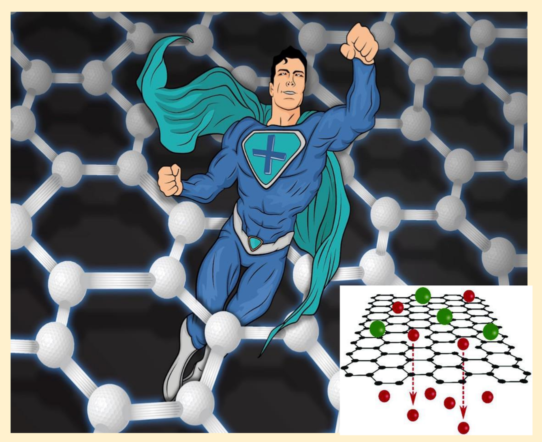
Introduction

Atomically Thin Materials



- Atomically thin 2D materials offer new possibilities for ultrathin barrier and membrane applications

- Graphene is commonly grown using chemical vapor deposition and transferred using a polymethyl methacrylate support layer



Motivation

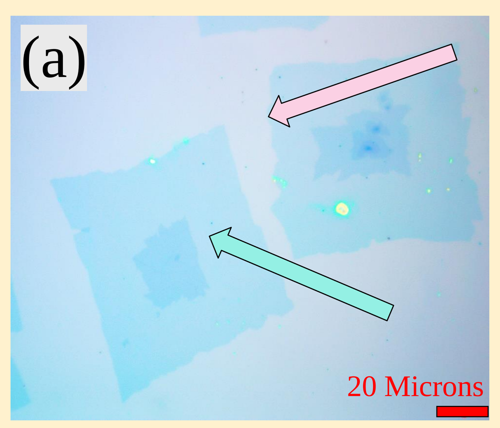
Primary Goals:

1. Grow a uniform monolayer of graphene
2. Transfer clean, pristine graphene from growth substrate to target substrate

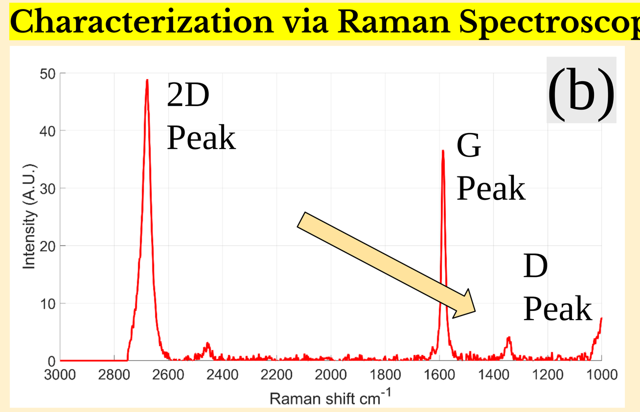
Common Growth Issues:

1. Graphene adlayers
2. Discontinuity
3. Intrinsic defects (I_D:I_G>0.05)

Fig 1. a) Graphene adlayers (blue arrow), discontinuous growth (pink arrow), and b) Raman spectra depicting defective graphene (yellow arrow)



Characterization via Raman Spectroscopy



Common Transfer Issues:

- PMMA often leaves residue
- PMMA transfer requires skill
- Wet etching method is expensive and limits scalability

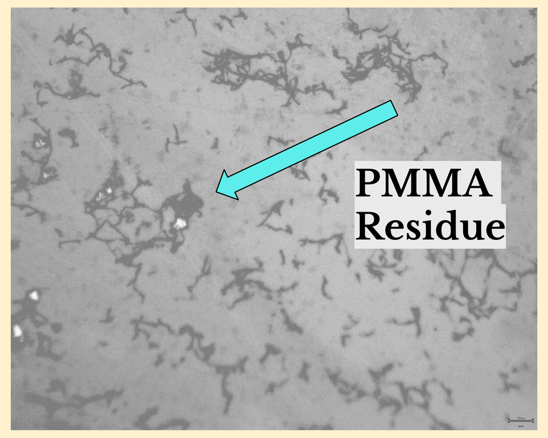


Fig 2. Optical image of graphene transferred via PMMA

Graphene Growth

Growth via Chemical Vapor Deposition

- **Goal:** grow a uniform monolayer of graphene
- Variables: gas volume, pressure, temperature, time, pre-treatment
- Possible methods: - 2 Step Growth
  - Liquid Copper Growth

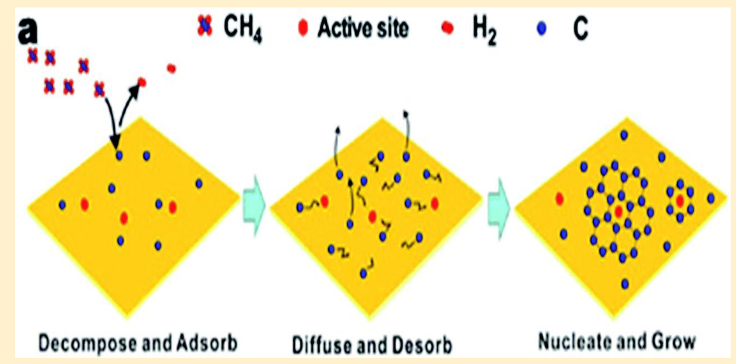


Fig 3. The diagram illustrates the process of chemical vapor deposition and how gas molecules break down to form 2D materials
Image retrieved from https://pubs.rsc.org/en/content/articlehtml/2015/sc/c5sc01941a

Results: 2 Step CVD Growth

- Grow at
  - 100:1 H_2:CH_4 ratio for 30 minutes
  - 100:2 H_2:CH_4 ratio for 30 minutes
- Continuous graphene layer
- Minimal defects

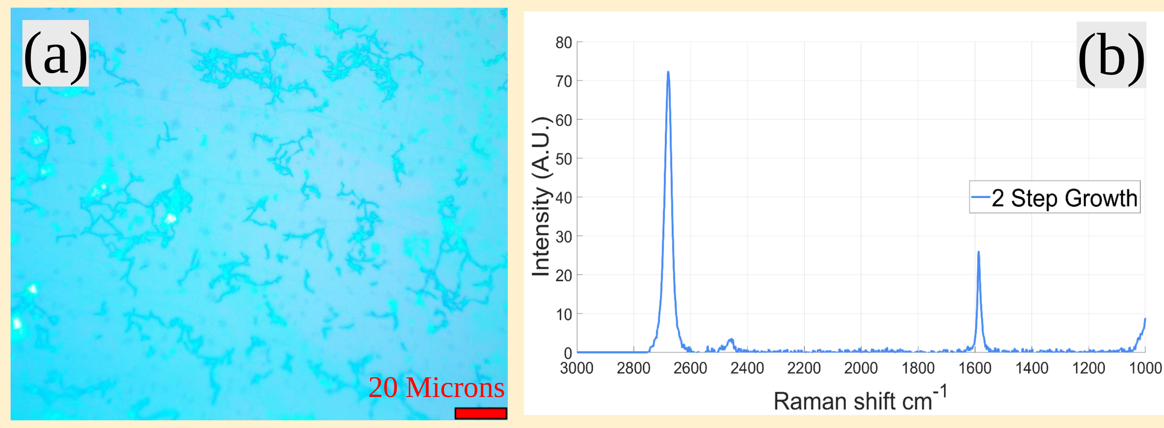


Fig 4. a) Optical image of graphene grown using 2 step growth transferred onto SiO_2 wafer b) Example of Raman spectra measured from 2 step growth sample

Results: Liquid Copper Growth

- Problem: 2 step CVD growth still produces multilayer graphene
- Solution: 1. Grow a continuous layer of graphene on solid copper
  2. Raise the temperature of the CVD reactor above the melting point of copper for 3 minutes
- Treatment on liquid copper reduces multilayer graphene regions

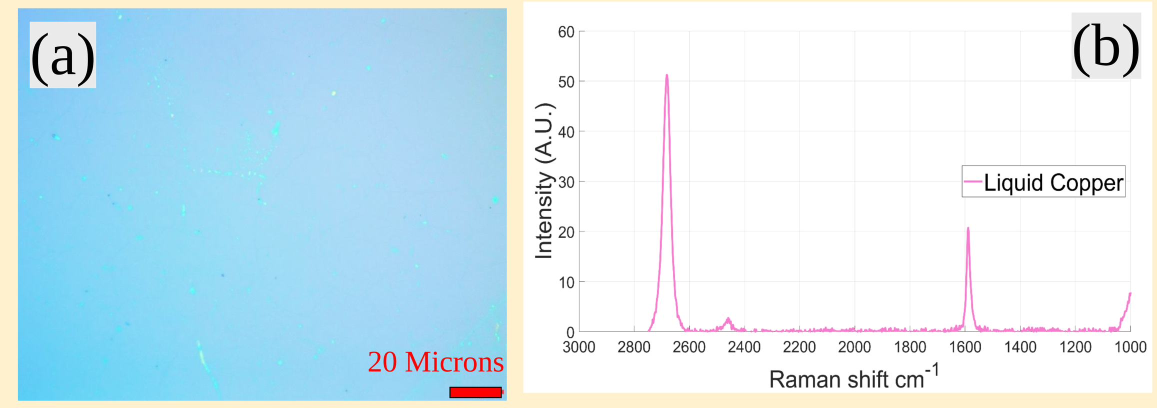


Fig 5. a) Optical image of graphene grown using liquid copper growth transferred onto SiO_2 wafer b) Example of Raman spectra measured from liquid copper growth sample

Graphene Transfer

Graphene Transfer via PMMA

- **Goal:** provide adequate support to prevent graphene defects and achieve clean transfer
- Possible alternatives: - Polyvinyl Alcohol
  - Rosin/PMMA Double Layer

Fig 6. The diagram illustrates the process of graphene transfer using PMMA as a support layer followed by wet etching of the copper

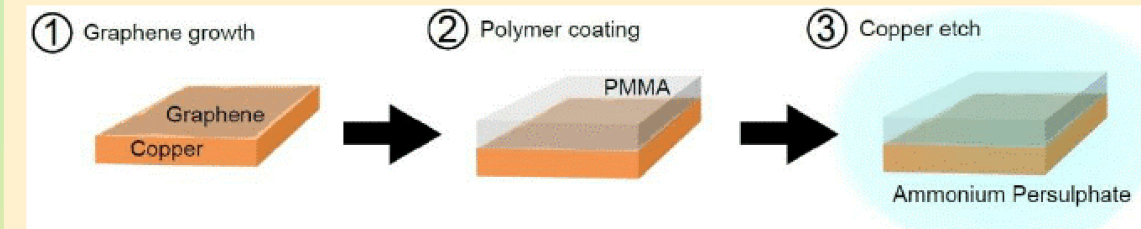


Image retrieved from https://www.researchgate.net/figure/A-simplified-drawing-of-the-wet-graphene-transfer-process-onto-substrates-for-both_fig3_283648313

Results: Graphene Transfer via PVA

Why polyvinyl alcohol?

- PVA transfer offers scalability of graphene production
- Inexpensive due to its preservation of the growth substrate
- Water soluble

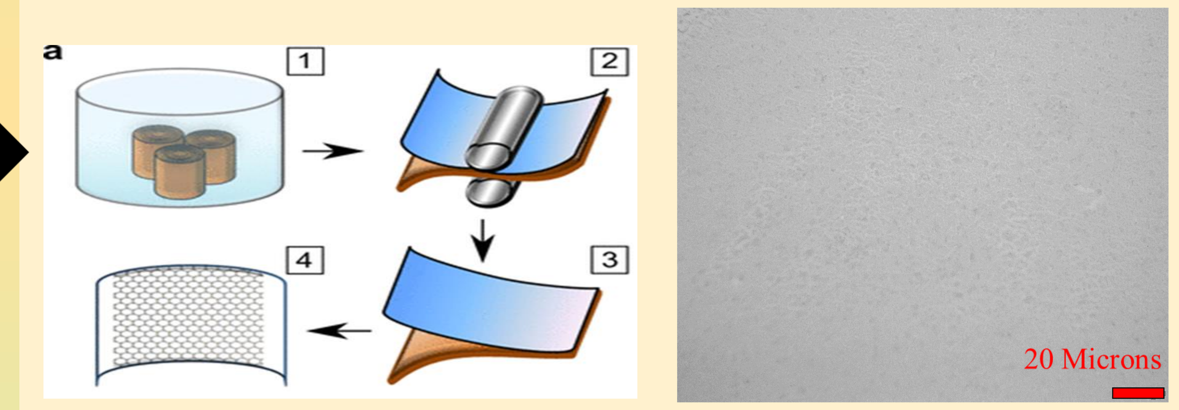


Fig 7. left) PVA transfer process, retrieved from ref 2. right) Optical image of graphene on SiO_2 wafer transferred via PVA

Results: Graphene Transfer via Rosin/PMMA double layer

Why rosin?

- Super-solubility in organic solvents and weak interaction with graphene
- Potential for electrochemical bubbling

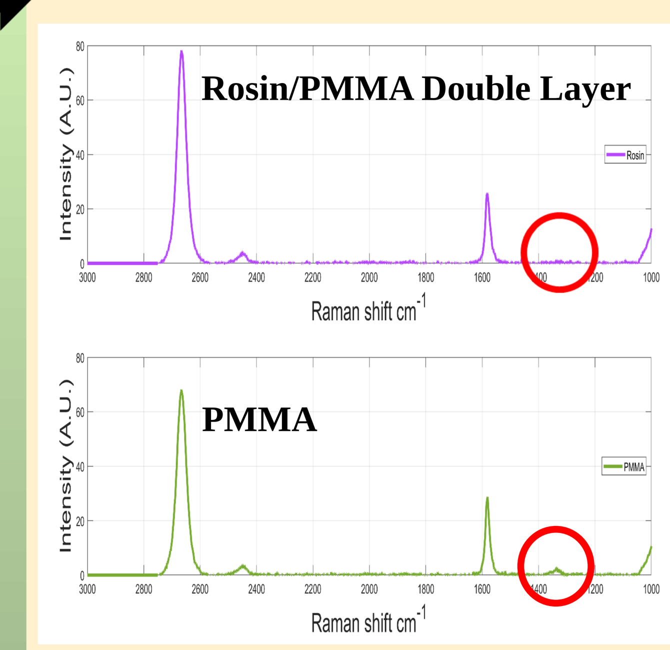


Fig 9. Raman spectra comparison between PMMA transferred graphene and Rosin/PMMA double layer transferred graphene

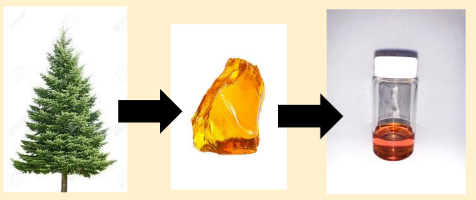
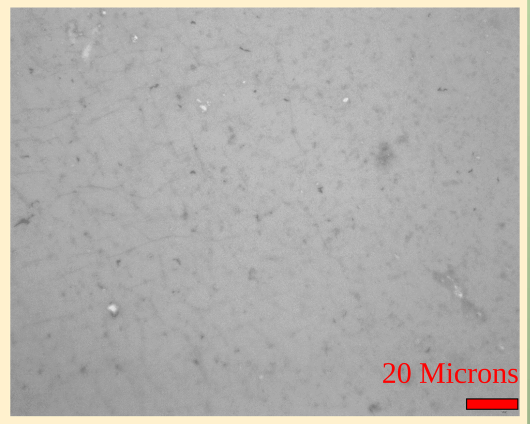


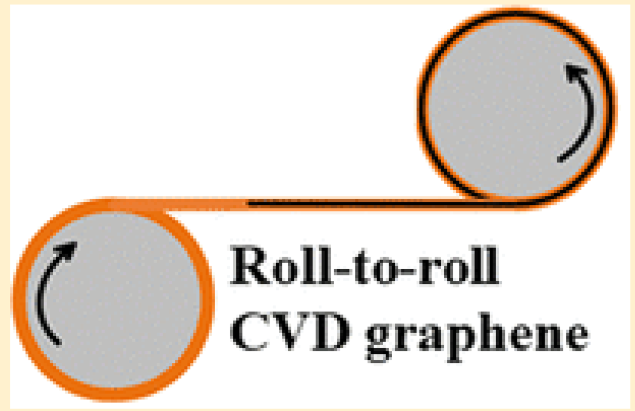
Fig 8. Optical image of graphene on SiO_2 wafer transferred via Rosin/PMMA double layer



Conclusion

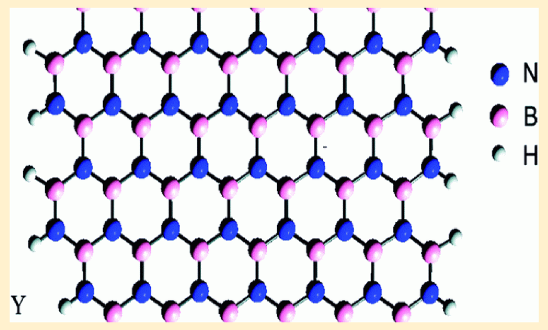
Implications of Results

- 2 step CVD growth is successful
- Liquid copper growth shows promise in decreasing areas of multilayer graphene
- **Short term:** Rosin is better than PMMA for the clean, defect free transfer of graphene
- **Long term:** PVA integration with roll-to-roll manufacturing



Future Work

- Proton transport and diffusion studies using new graphene
- Electrochemical bubbling with rosin support mechanism
- Apply transfer methods to few layer graphene and hBN



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