Face to Face GRAPhene Transfer

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Outline

- Why care about graphene transfer?
- Conventional transfer techniques
- A better method: face to face transfer
- Faster etching than float transfer
- Improved properties of face to face transferred graphene
- Conclusion
- Evaluation
- Praise from critics
Why is Transfer Useful?

- Graphene can be grown on Copper substrates by chemical vapor deposition (CVD)
- Many applications require graphene on other substrates like Silicon
- Transfer between the substrates is necessary
- Better transfer techniques can improve quality of graphene

Conventional Techniques for Graphene Transfer

- **Dry Transfer**
  - Infamous Scotch Tape
  - High quality, but small pieces

- **Wet Transfer**
  - “Float transfer” separates the growth from the transfer
  - Low quality, but large pieces

http://graphene-supermarket.com
Nature Provides the Motivation for Face to Face Transfer

http://avaxnews.net/pictures/61162
The Face to Face Transfer Technique

- Graphene is always attached to the substrate
- Large scale of few-layer graphene
- Fewer defects
- Faster fabrication
- Amenable to batch processing in a semiconductor production line
Detecting the Water Layer

Simulated color change

AFM scans of water layer thickness

Water layer in water: ~250 nm

Water layer in air: ~70 nm

Refracted and reflected paths in sample

PMMA
Graphene
Water
SiO₂
Si
Face to Face Transfer Offers Faster Etching Times

![Graph showing etching time vs. thickness of Cu film]
Face to Face Transfer Maintains Structure of Graphene

AFM height profiles showing uniformity of fabricated graphene

Raman spectra showing long range order
Transferred Graphene Exhibits Good Electrical Properties

Conductivity: 4000 S cm\(^{-1}\)

Carrier mobility: 3800 cm\(^2\) V\(^{-1}\) s\(^{-1}\)
Conclusion

- Gas bubbles can effectively decrease transfer defects.
- Face-to-face transfer is compatible with any size and shape of substrate.
- Face-to-face transfer can accomplish both the growth and transfer steps on one wafer.
- Face-to-face nature of the transfer eliminates the manual fishing of floating Graphene.
- Graphene transferred by face-to-face is structurally better than by float transfer and offers good carrier mobility.
Evaluation

- The water layer and carrier mobility graphs are presented without much context.
- Constant etching time for float transfer needs explanation.
- Treatment of the substrate with the Nitrogen plasma for bubble seeding is a novel idea.
- This is a potentially breakthrough attempt at automated production of graphene.
Cited 32 times since November 2013.

- “A potential breakthrough”\(^1\)
- “Has brought great promise for CVD-grown graphene films in industrially scalable devices”\(^2\)
- “The greatest advantage of the technique is that it is automatically compatible and industrially scalable”\(^3\)
- “Excellent progress toward synthesizing defects free graphene sheets”\(^4\)
- “The face to face transfer method has demonstrated the transfer of 8 inches wafer-scale graphene onto silicon substrate successfully”\(^5\)