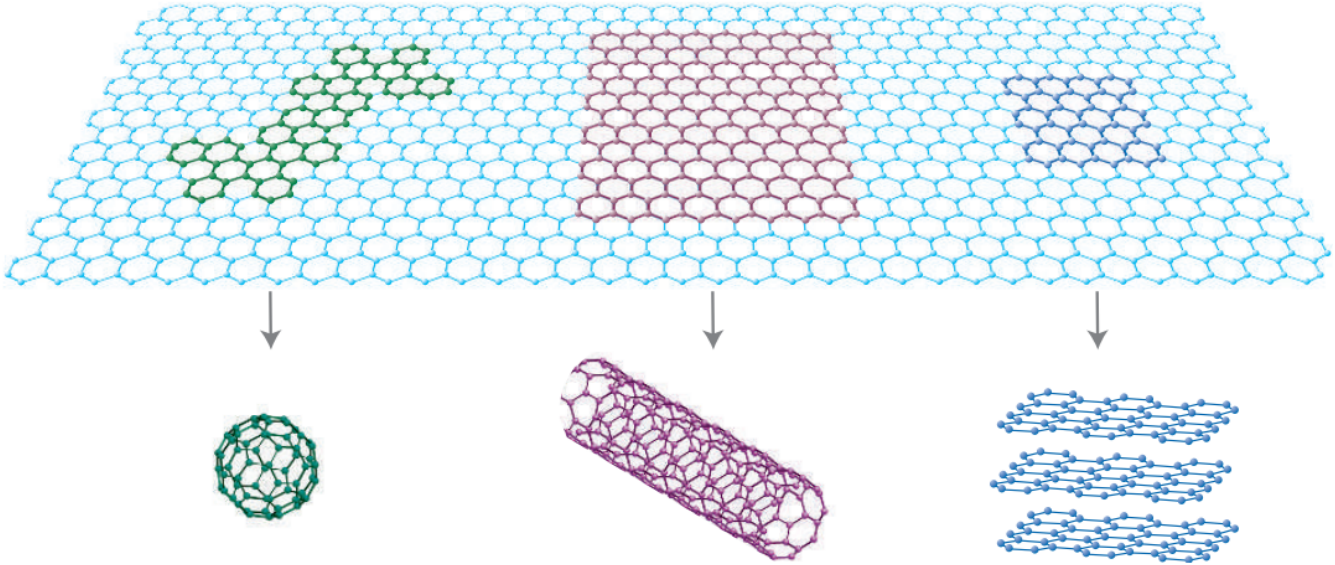
Face to Face GRAPHENE Transfer

Alex An, Srivatsan Balakrishnan, Yang Bai

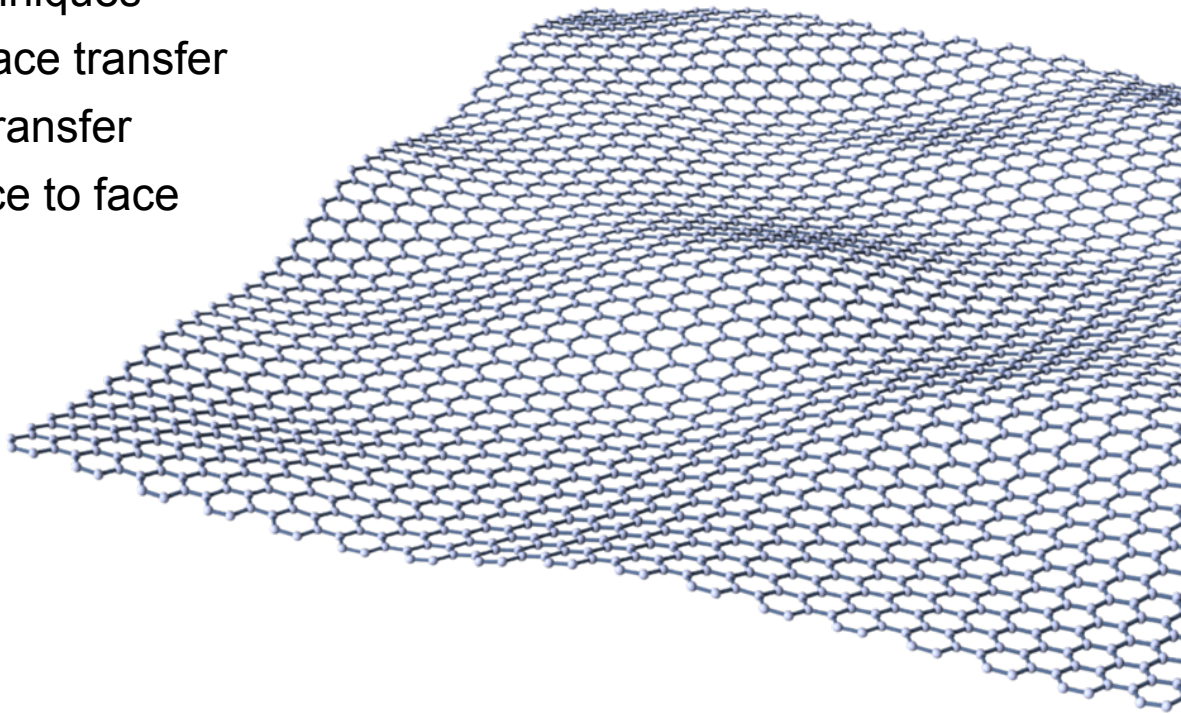
L. Gao *et al*. Face-to-face transfer of wafer-scale graphene films. *Nature* **505**, 190-194 (2014).



Adapted from A.K. Geim & K.S. Novoselov, The Rise of Graphene. *Nature Materials* **6**, 183-191 (2007).

Outline

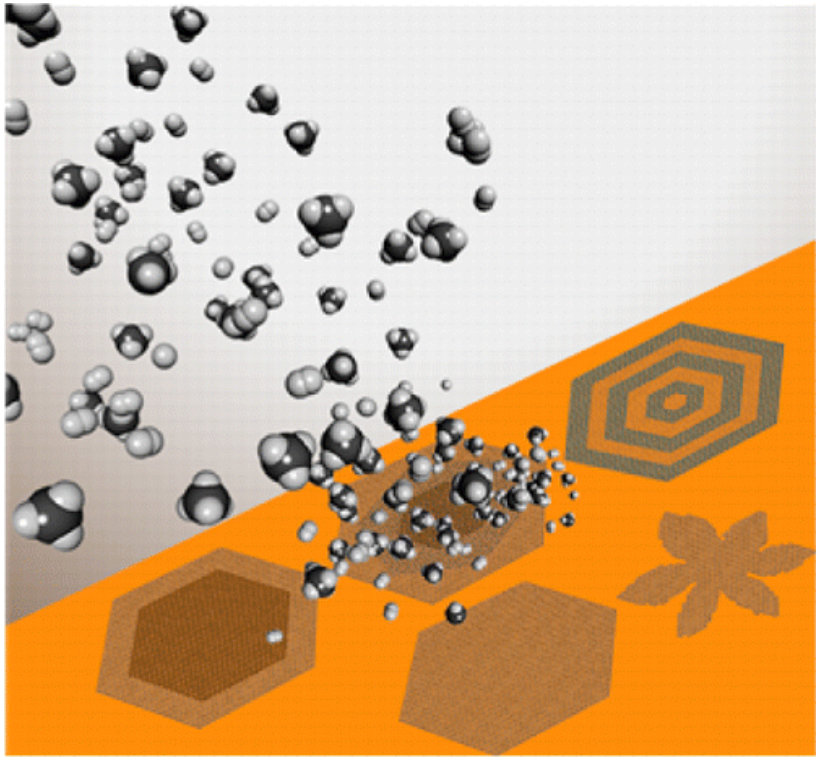
- Why care about graphene transfer?
- Conventional transfer techniques
- A better method: face to face transfer
- Faster etching than float transfer
- Improved properties of face to face transferred graphene
- Conclusion
- Evaluation
- Praise from critics



http://jameshedberg.com

Why is Transfer Useful?

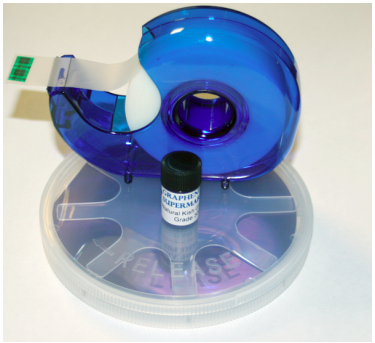
- Graphene can be grown on Copper substrates by chemical vapor deposition (CVD)
- Many applications require graphene on other substrates like Silicon
- Transfer between the substrates is necessary
- Better transfer techniques can improve quality of graphene



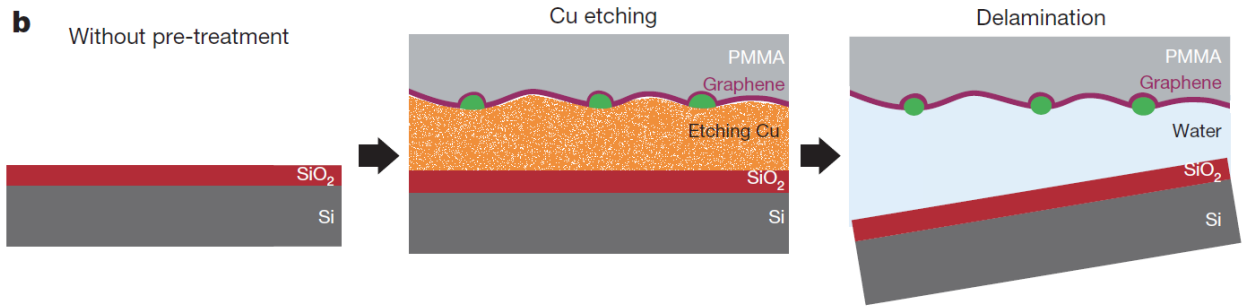
Z.Yan, Z.Peng, & J.M. Tour, Chemical Vapor Deposition of Graphene Single Crystals. *Acc. Chem. Res.* **47**, 1327-1337 (2014)

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



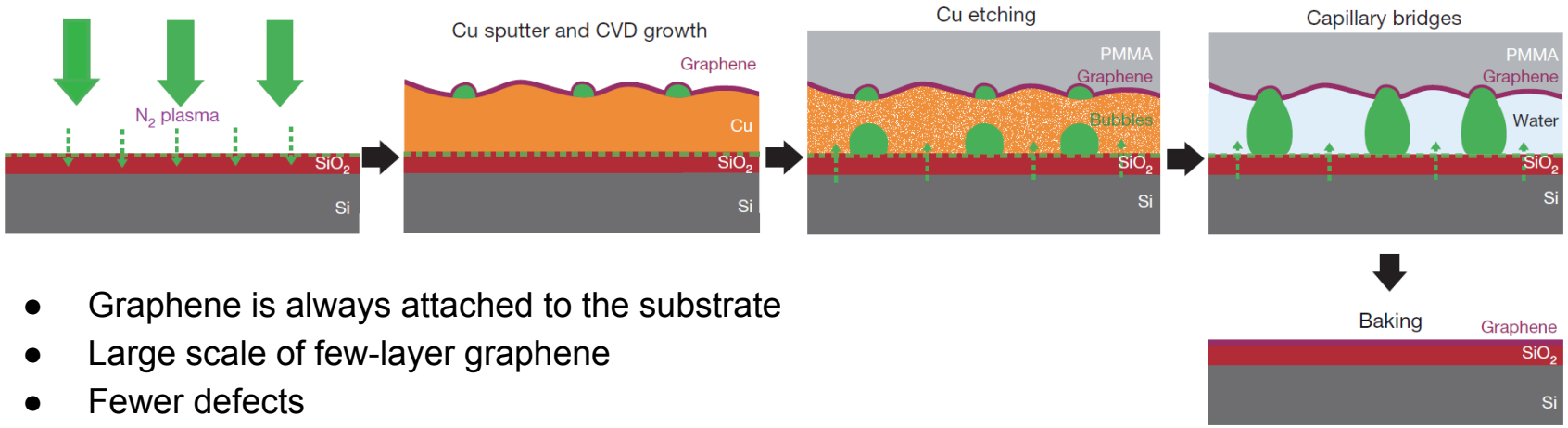
http://graphene-supermarket.com



Nature Provides the Motivation for Face to Face Transfer

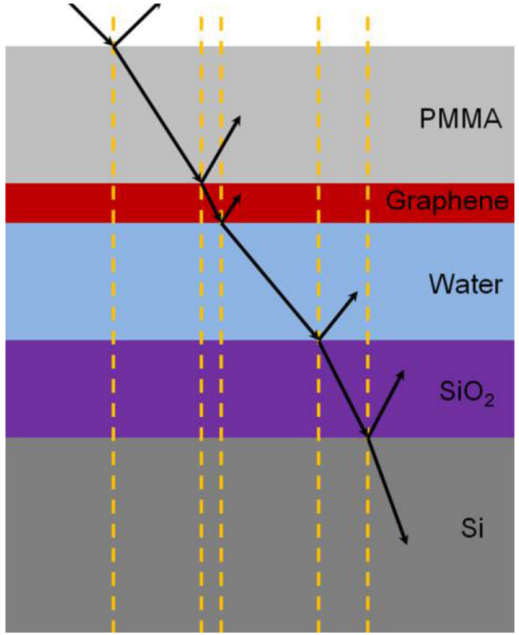
http://avaxnews.net/pictures/61162

The Face to Face Transfer Technique

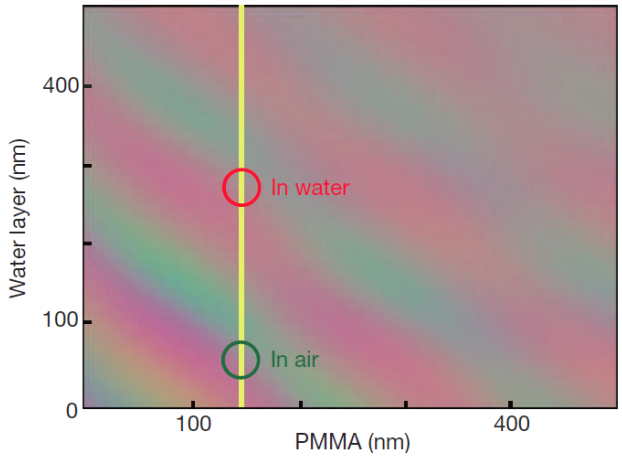


- Graphene is always attached to the substrate
- Large scale of few-layer graphene
- Fewer defects
- Faster fabrication
- Amenable to batch processing in a semiconductor production line

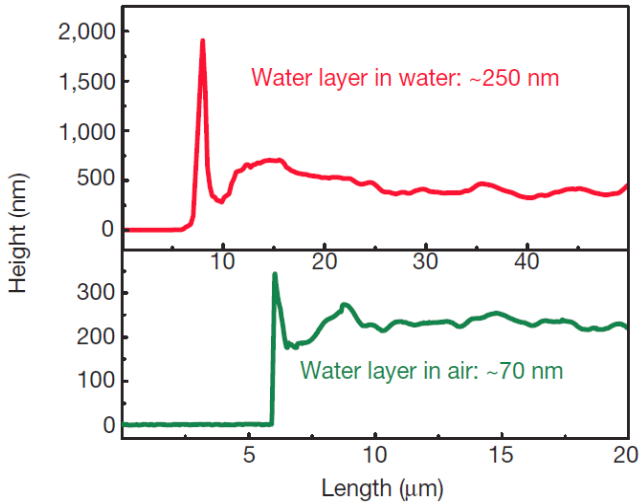
Detecting the Water Layer



Refracted and reflected paths in sample

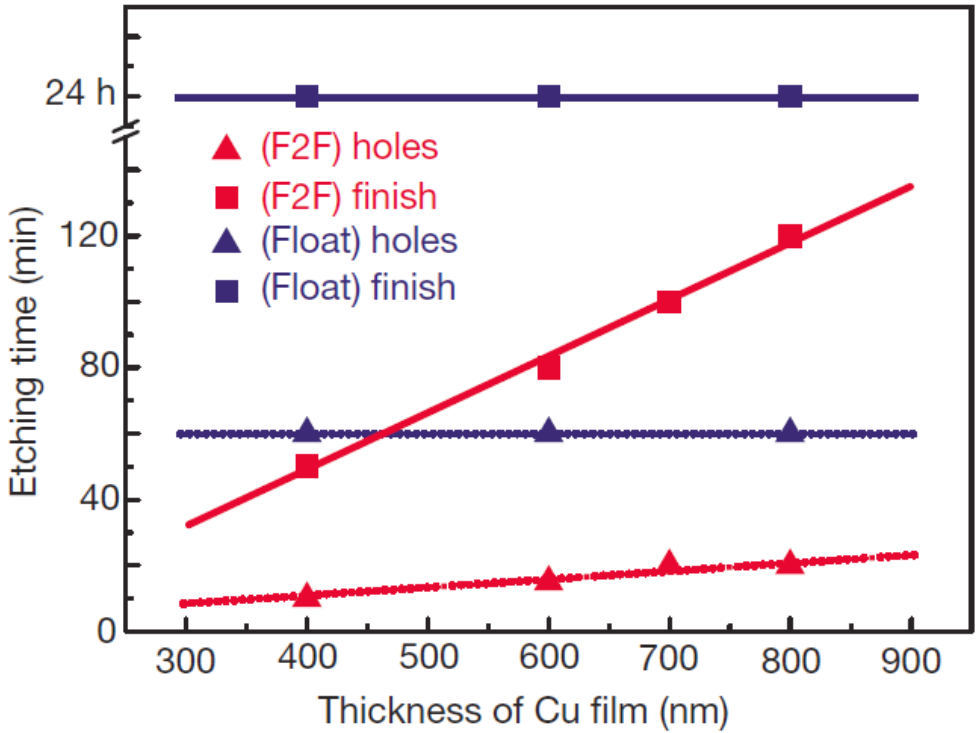


Simulated color change

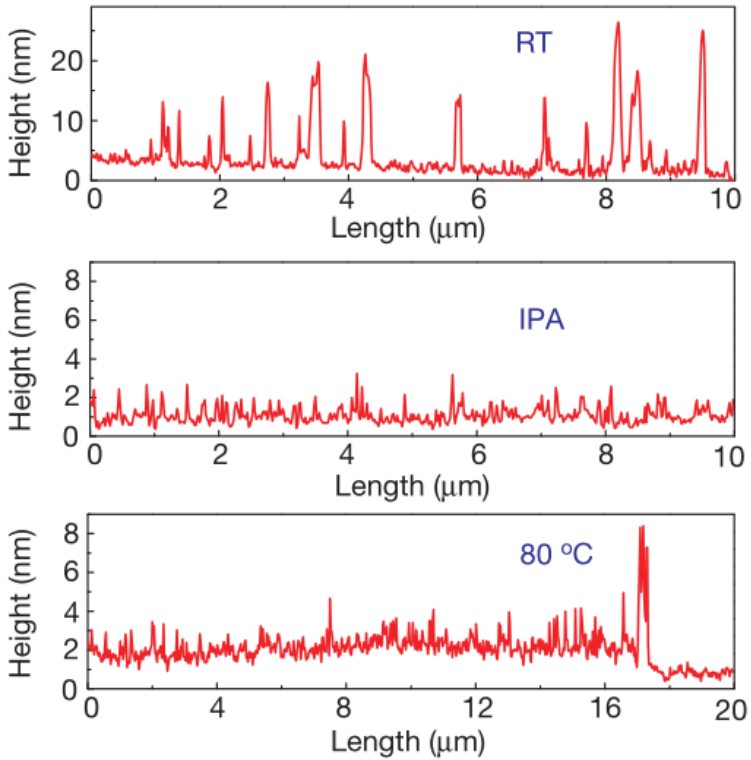


AFM scans of water layer thickness

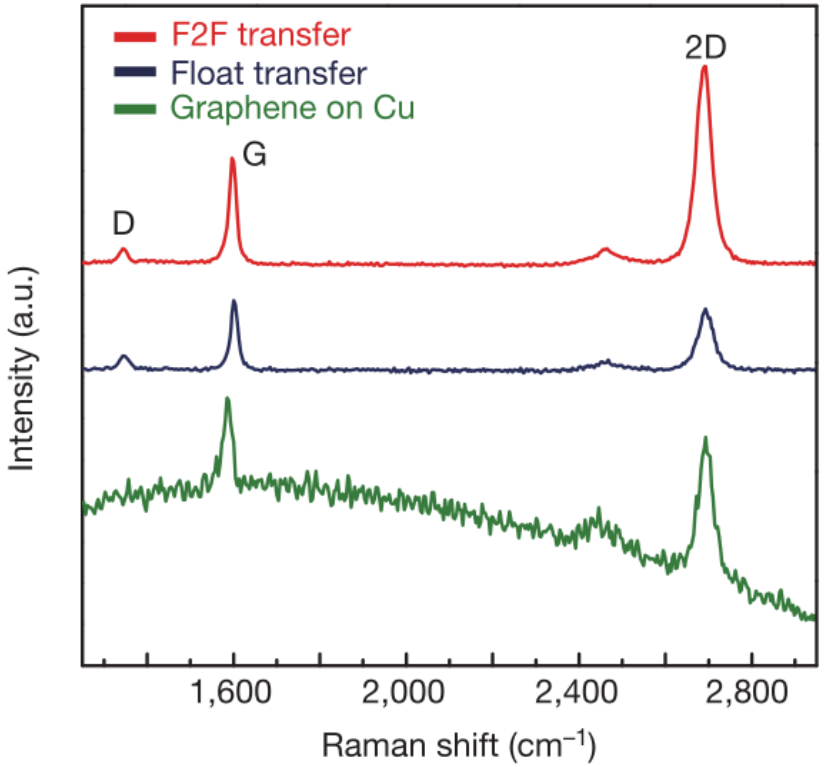
Face to Face Transfer Offers Faster Etching Times



Face to Face Transfer Maintains Structure of Graphene



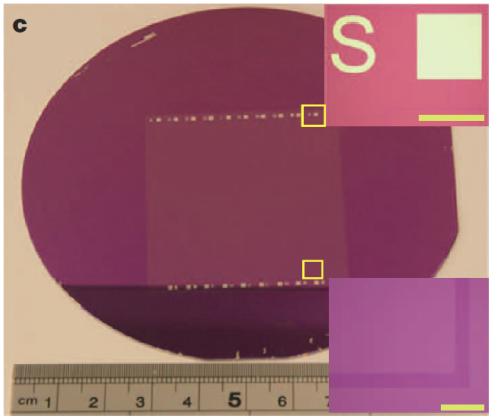
AFM height profiles showing uniformity of fabricated graphene

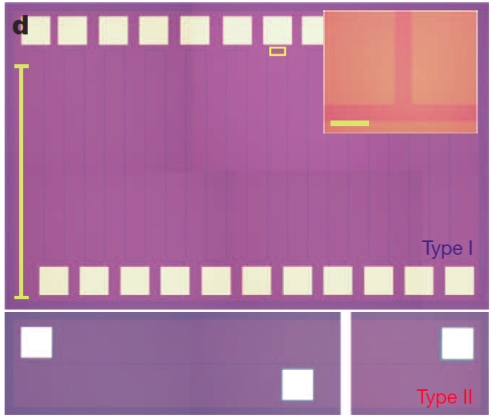


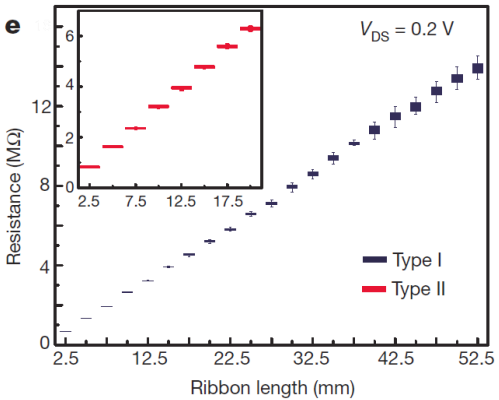
Raman spectra showing long range order

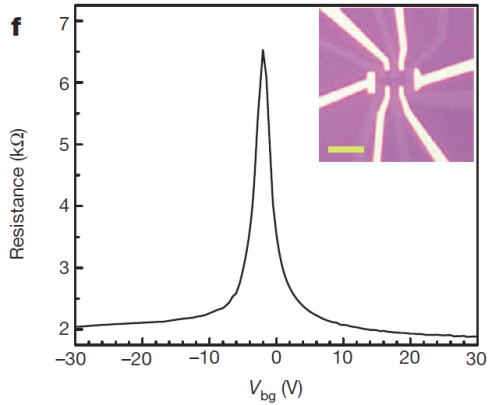
Transferred Graphene Exhibits Good Electrical Properties

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.

http://medicine.yale.edu/lab/mccormick/Images/full694_167672ppt3slide15a.jpg

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 an novel idea.
- This is a potentially breakthrough attempt at automated production of graphene.

http://wegotthiscovered.com/tv/couch-critics/

Praise from Critics

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]

[1] J.A. Torres, R.B. Kaner, *Nature Materials* (2014).
[2] H.P. Cong, J.F. Chen, S.H. Yu, *Chem. Soc. Rev.* (2014).
[3] X. Wan, K. Chen, J. Xu, *Small* (2014).
[4] M.A.N. Dewapriya, R.K.N.D. Rajapakse, *Journal of Applied Mechanics,*(2014)
[5] H. Tian, H.Y. Chen, T.L. Ren *et al*., *Nano Letters*,(2014)