# GRAPHENE FET DEVICE FABRICATION USING DIRECT WRITE LITHOGRAPHY

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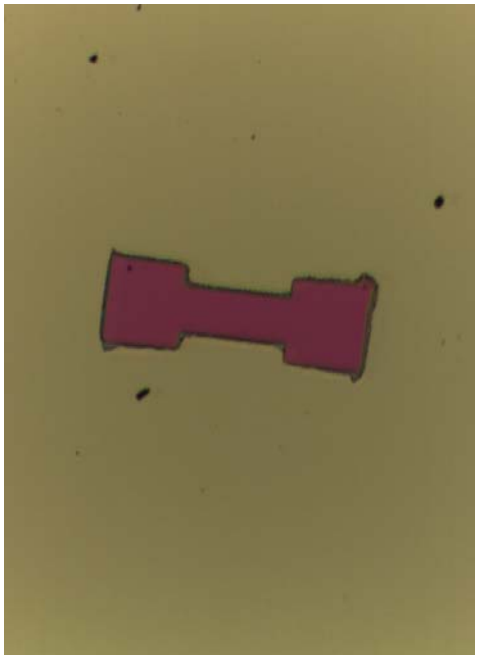
# OVERVIEW

I. Current Challenges with Computer Processors
II. Graphene
    I. Electronic quality
    II. production
III. FET Devices
IV. Direct-Write Lithography
    I. photolithography
V. Summary and Acknowledgments



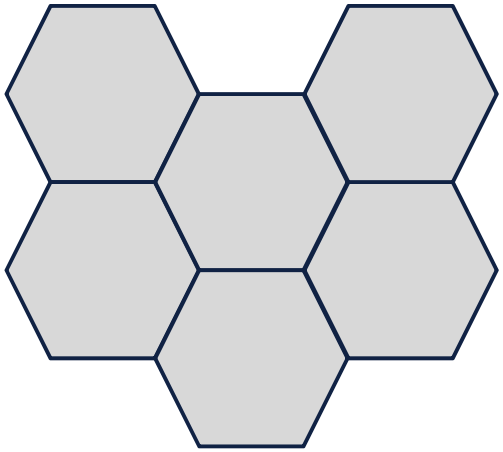
Device

# MOORE'S LAW: A REAL LIMIT?

- Moore's Law: number of transistor in a processor will double every two years
- Problematic because current materials in transistors become unreliable if they are scaled down any further
- Nano-size copper interconnects lose conductance and overheats[7]
- Semiconductor companies require a new material that is reliable and conductive at the nano-scale, which can be used for transistors and interconnects

# GRAPHENE

- 2-D honey-comb lattice carbon atoms[2]
- Zero-gap semiconductor
- Thin and strong, absorbs little light
- Can be cut down into true nm-size
- Popular because of its high electronic quality[4, 1, 6]



Hexagonal shape of graphene

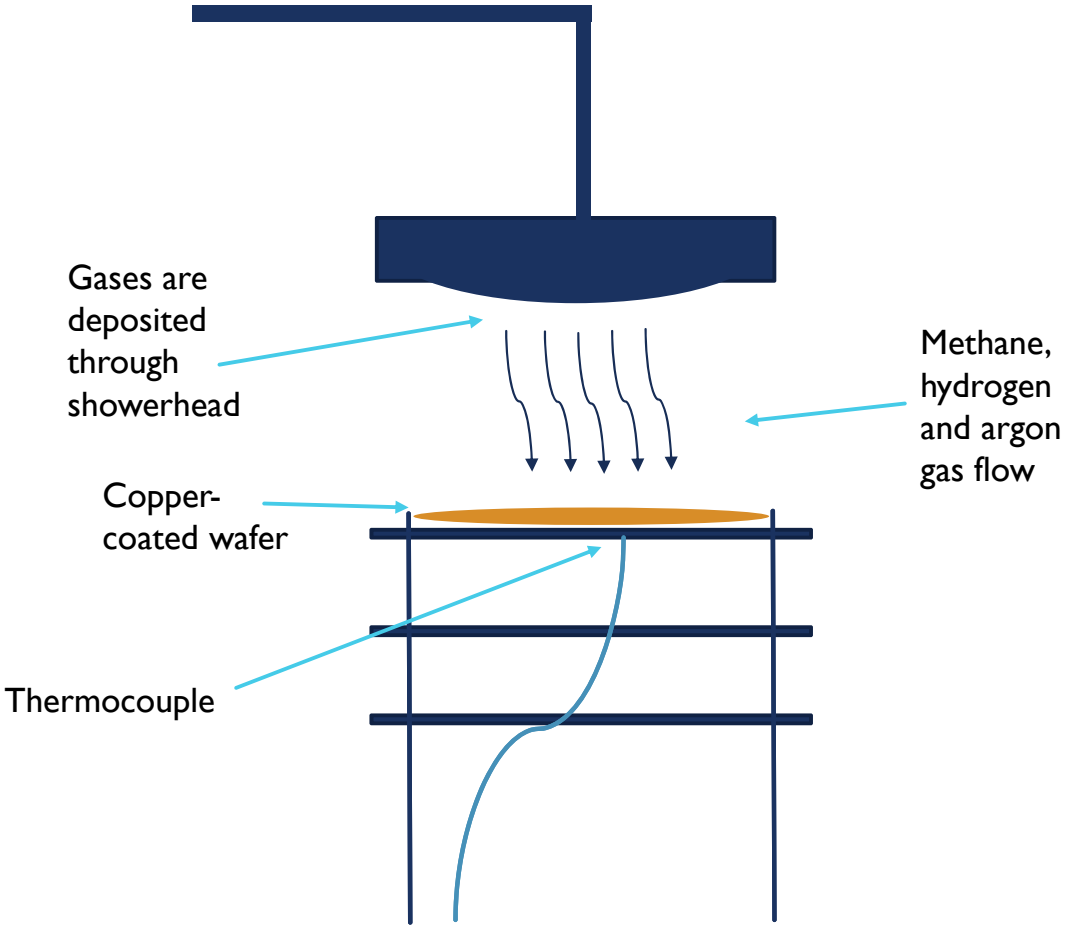
# ELECTRONIC QUALITY OF GRAPHENE

- Ballistic transport at submicron level
- High mean free path[2, 4]
- Immune to electro-migration
  - Electrons will not scatter when traveling on graphene

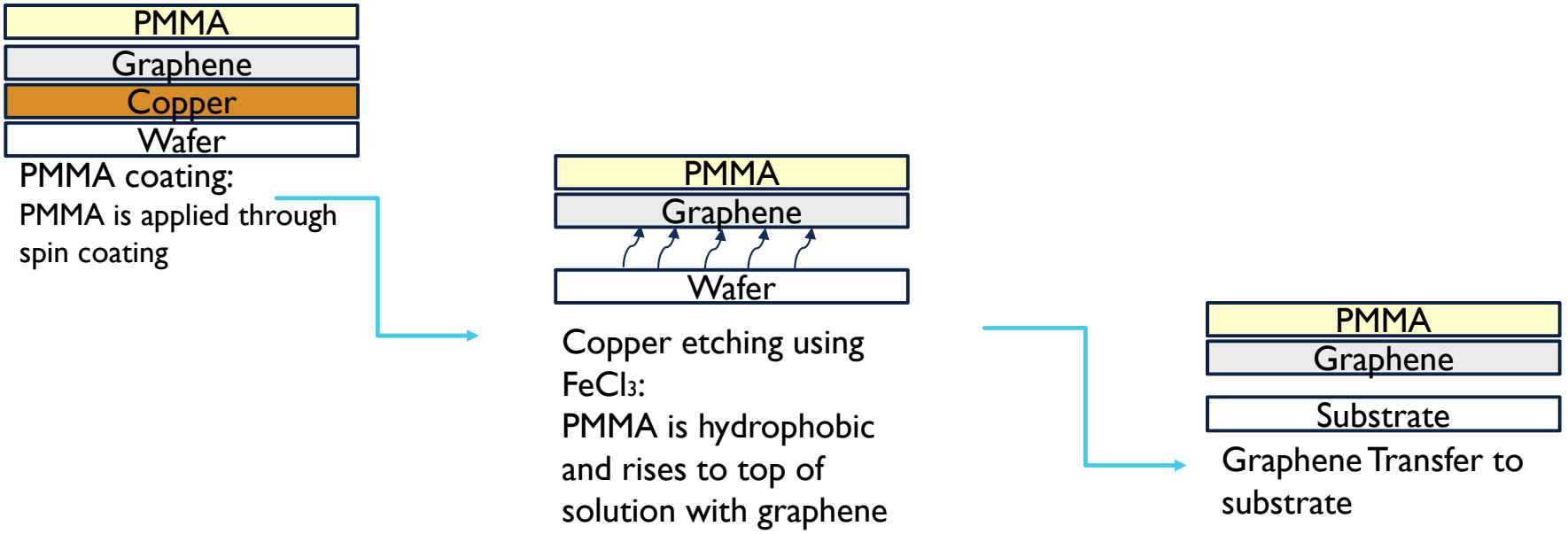
# GRAPHENE GROWTH

- Chemical Vapor Deposition
  - Copper catalyst: physical vapor deposition
  - Methane and hydrogen gas ratio
- Grown graphene is transferred to substrate using wet chemistry method[5]

Cold Wall Furnace

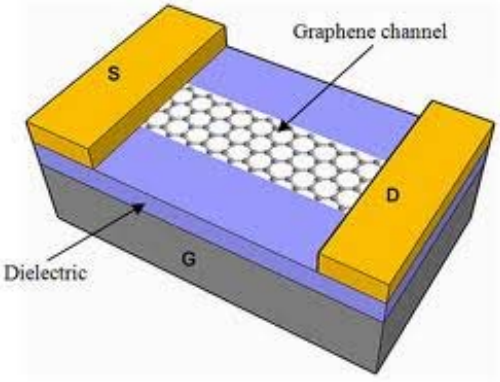


# Graphene Transfer Process

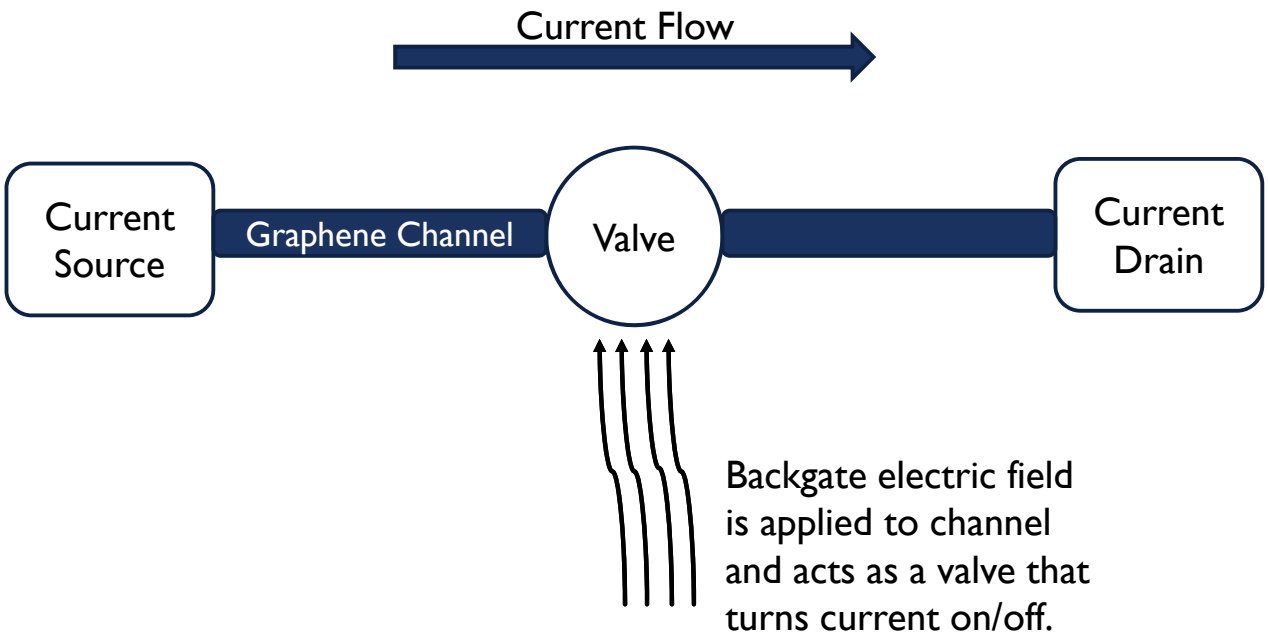


# FET DEVICES

- Field Effect Transistors controls the flow of electrons from source to drain
- Can control conductivity of a semiconductor



KT2


Current Flow
Current Source
Graphene Channel
Valve
Current Drain
Backgate electric field is applied to channel and acts as a valve that turns current on/off.

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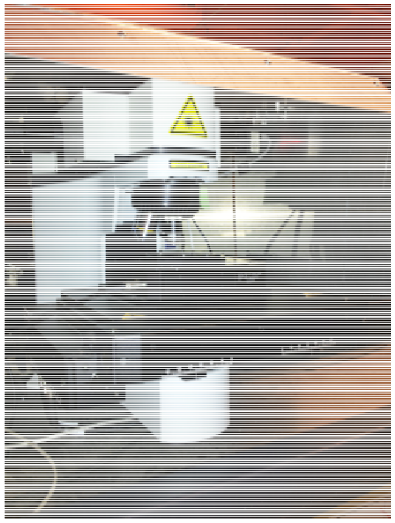
**KT2** Kathy Thach, 8/14/2014

# DIRECT-WRITE LITHOGRAPHY

- DWL is done using a modulated laser that exposes a photoresist-coated silicon wafer
  - Negative SU-8 photoresist
- Pattern is created in Paint or Autocad and info is put into Lab View Program
- Basic Procedures: focus on sample, collect a sample plane, start patterning

# BASIC PROCEDURES

Silicon Wafer is coated with SU-8 and is soft-baked at 95 C

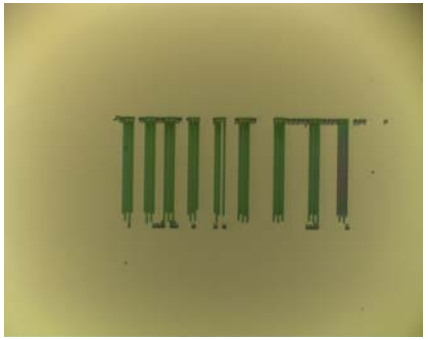


Laser exposure

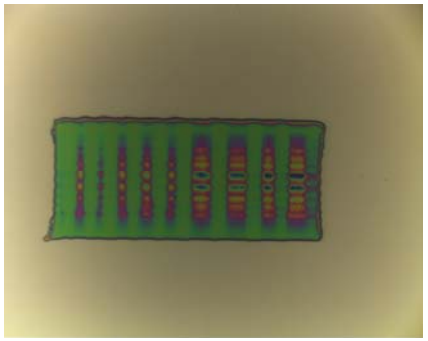

Post-exposure bake and development

# TEST PATTERNING

- Settings
  - Velocity
  - Resolution
  - Modulator
  - Purpose of tests: determine the best settings for devices
- Tests done on wafer combining a variety of resolution and velocities



Res.: 5 microns
Vel.: 2 rpm



Res.: 1 microns
Vel.: 2 rpm

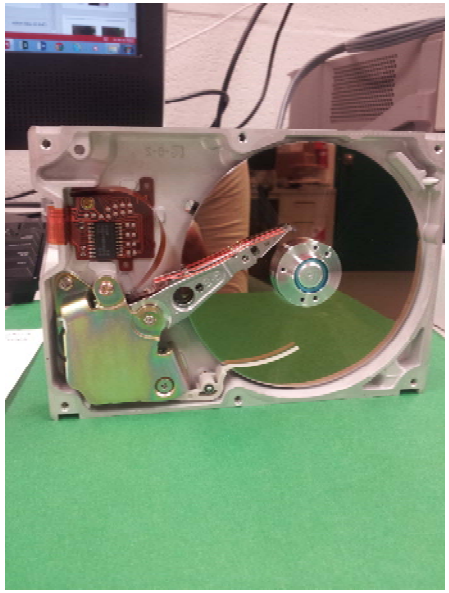
- Variety of tests were done to analyze the effects of each variable
- Trial 1 and 2 showed a smaller step size created better patter
- Trials 3 and 4 showed a lower velocity is best (.05-1 rpm)
- Trials 5 and 6 showed that a velocity closer to 0.50 works best, laser intensity primarily does not effect pattern
- Approximately 100 trials were using a combination of these settings

| Trial # | Wafer # | Resolutions (um) | Velocities x & y (rpm) | Modulator Setting |
|---|---|---|---|---|
| 1 | 1 | 20,10, 5, 1 | 0.05 | 1 |
| 2 | 2 | 20, 10, 5, 1 | 0.10 | 1 |
| 3 | 3 | 5, 1 | 7-10 | 1 |
| 4 | 4 | 5, 1 | 1-6 | 1 |
| 5 | 5 | 1 | .05-1 | 3 |
| 6 | 6 | 1 | .05-1 | 1 |

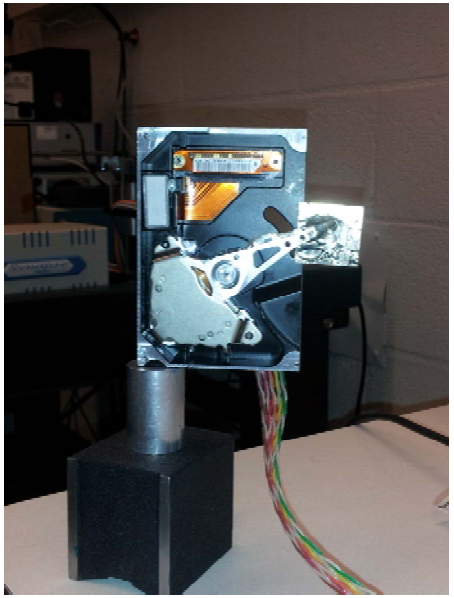
Test Patterning Matrix

# HIGH SPEED LASER SHUTTER

- Shutter is made from a recycled hard-drive
- Mechanics already available: voice coil controls pivot arm[3]
- Controlling amount of current that goes through voice coil and limiting swing length is crucial for a long-lasting shutter

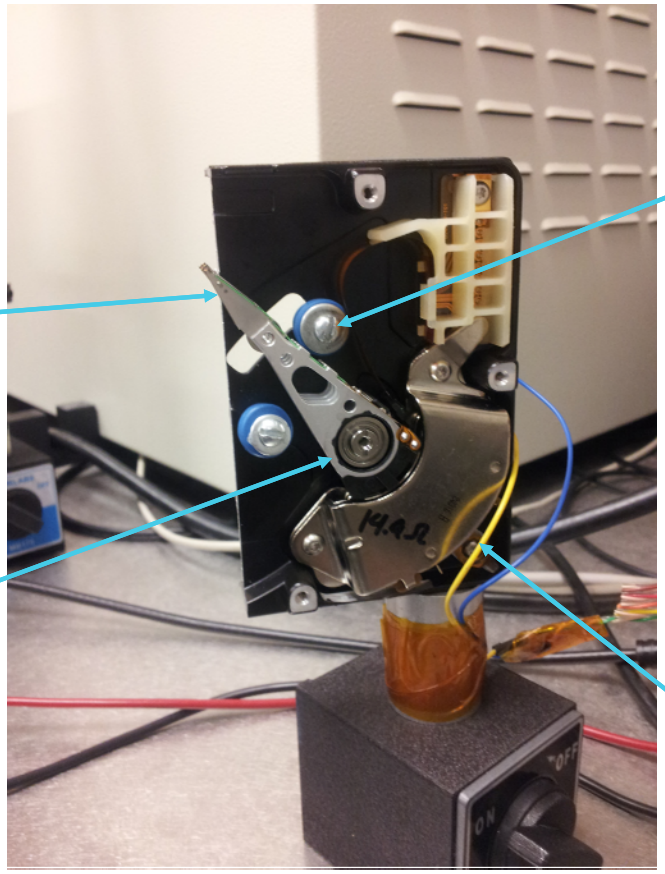


Hard Drive



Laser shutter version 1

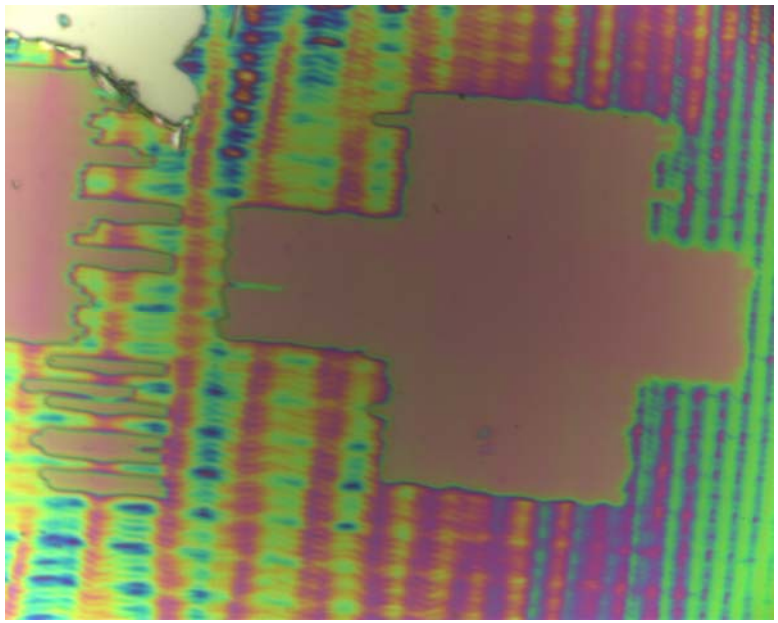
KT1



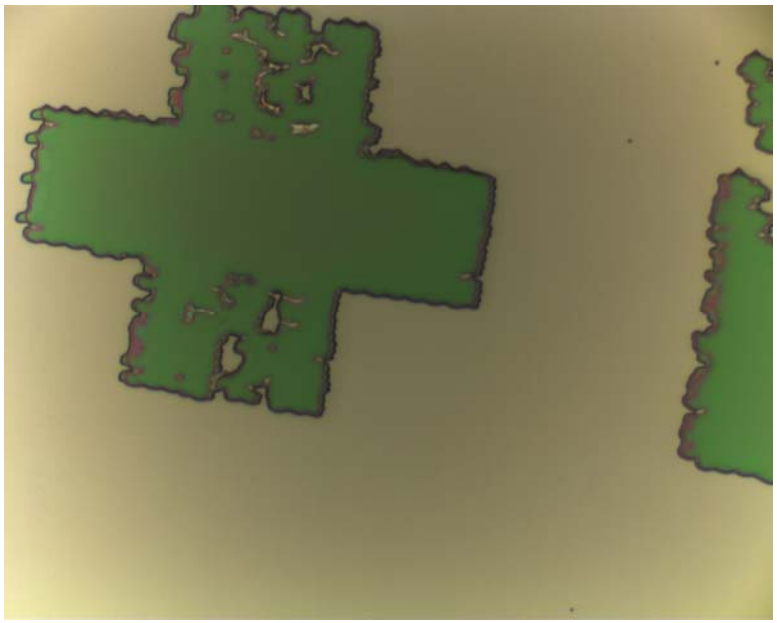

Laser Shutter Version 3

## Slide 16

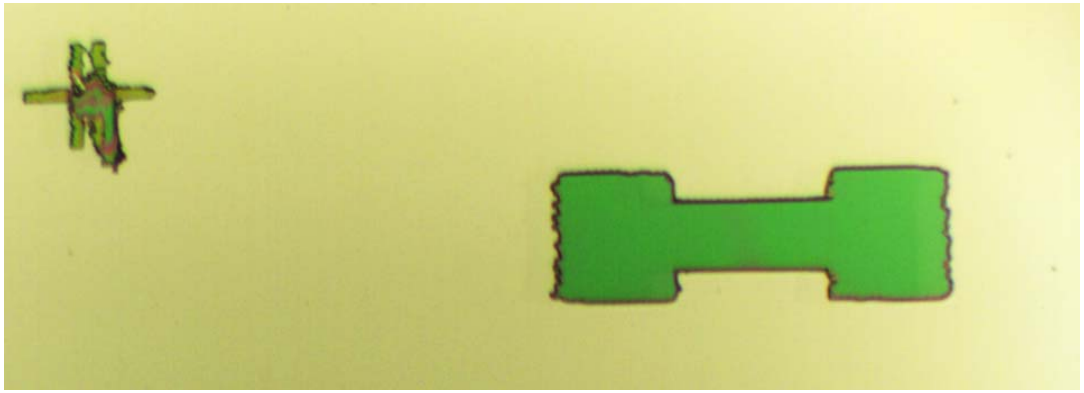
**KT1** Kathy Thach, 8/6/2014



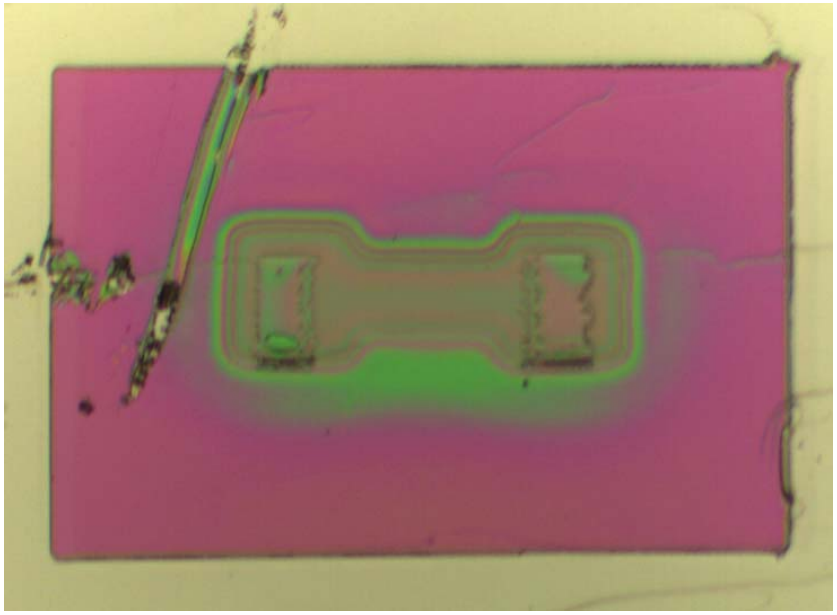
Pattern without laser shutter



Pattern with laser shutter



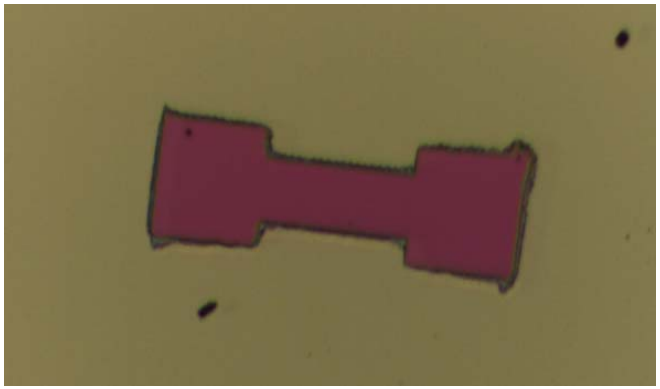
Stage 1



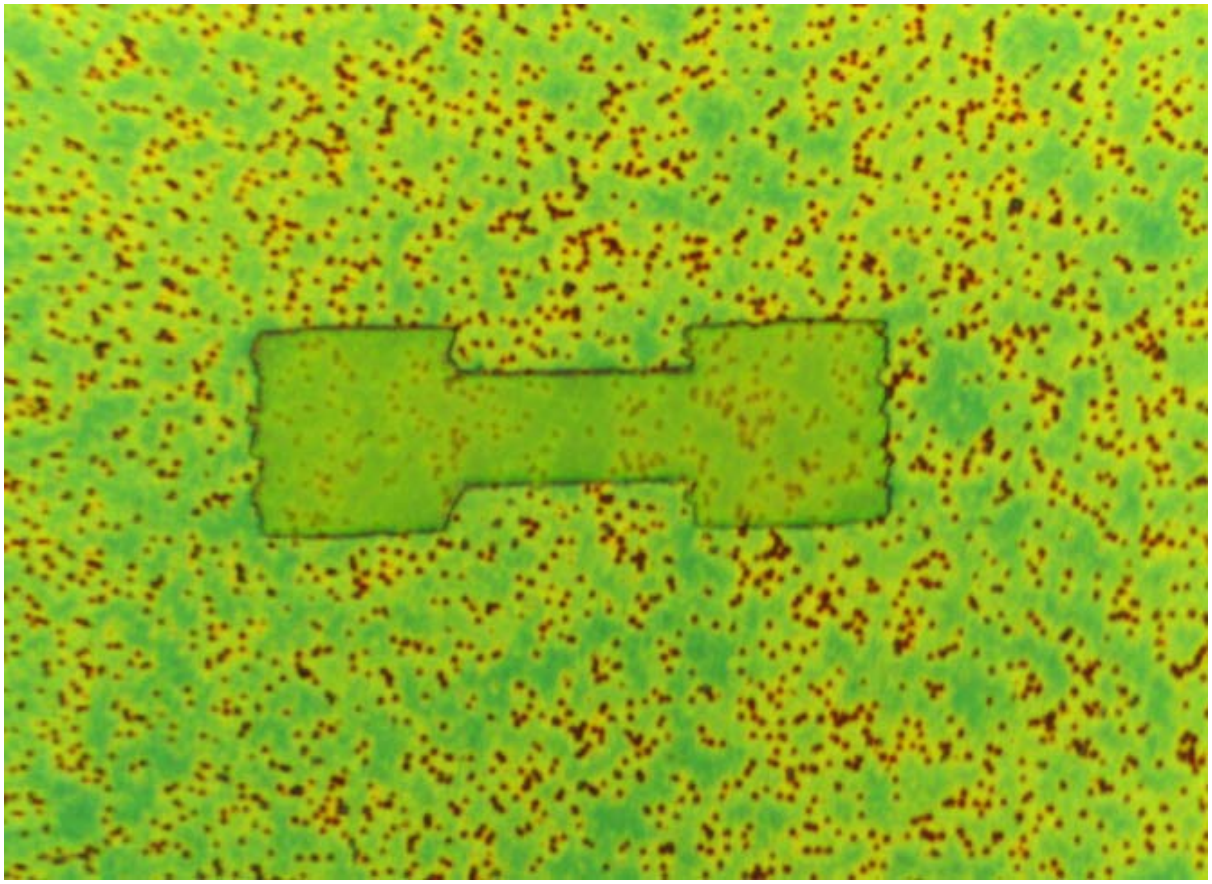
Stage 2

# DEVICE FABRICATION

- Devices will be fabricated out of graphene
- Graphene will be coated with resist, patterned, then remaining graphene will be removed using Oxygen plasma



Device Mask



Graphene FET Device

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Thank You for listening

Questions?