New FIB Processing Concept for Nanocarbons

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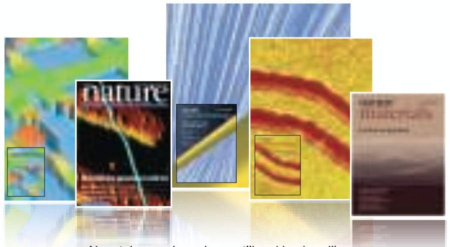
Nanocarbon Electronics

Background

Carbon nanotubes and single layer graphite (graphene) are exciting candidates for new electronics. Nanotubes are perfect metallic or semiconducting 1-dimensional wires and graphene exhibits record breaking electron mobility. Some of the hottest topics in nanocarbon research at the moment are:

- Carbon nanotube resonators as ultra-sensitive mass detectors
- Ultra-high mobility Graphene FET
- Graphene/carbon NEMS for wireless electronics
- Carbon nanotubes as Terahertz antennas



Nanotubes and graphene still making headlines.

Challenges

There are several fabrication challenges that limit the performance of current nanotube and graphene devices:

- Device location is random
- Back gates not compatible with high frequency applications
- Side gates not efficient enough
- Top gating creates new problems
  - Mechanical stress
  - Charge trapping in dielectrics
  - Impurity doping

BRIDGE Architecture

Concept

The conventional gate structure is replaced by a suspended top-gate. This allows efficient high frequency gating without gate dielectric. Furthermore, by under-etching the device the active part can be completely isolated.

Challenges

Difficult to achieve by standard techniques:

- Multi-step lithography induces alignment errors
- errors limit achievable size/geometries

Focused ion beam processing is perfect tool for creating 3d nanostructures, but Gaussian beam shape causes

- Ga+ doping
- Defects

Solution

- Combination of FIB and conventional lithography
- FIB processing before lift-off
- Sample protected by metallization layer
- 3d structure can be used as shadow mask
- Process compatible with etching

BRIDGE Gate

1. Initial Stage

E.g. Graphene on Si/SiO_2

2. Lithography

Electrodes are defined by photo or electron beam lithography

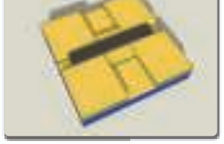
3. Metallization

Electrode metallization by sputtering or evaporation

4. Bridging

Gate support is created by ion beam induced metal deposition

5. Release



Gate electrode is released by fib milling

6. Lift-Off

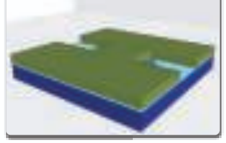
Gate electrode is suspended by conventional lift-off process

BRIDGE Nanoribbon

1. Initial Stage

E.g. Graphene on Si/SiO_2

2. Lithography



Electrodes are defined by photo or electron beam lithography

3. Metallization

Electrode metallization by sputtering or evaporation

4. Bridging

Bridge created by ion beam assisted insulator deposition

5. Lift-Off

Mask bridge is suspended by conventional lift-off

6. Thinning

Mask and ribbon are thinned by differential fib milling (low kV)

FIB Processing

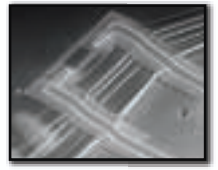
Proof-of-Concept

To test the mechanical stability parallel Pd/Al/Pd (3/60/3 nm) electrodes were defined by optical lithography. The 10 micron gap between two electrodes was bridged using ion beam deposition of Pt. Subsequently the wafer was diced and lift-off was performed in Acetone. The device was subsequently cleaned in Isopropanol and dried using pressurized N_2.

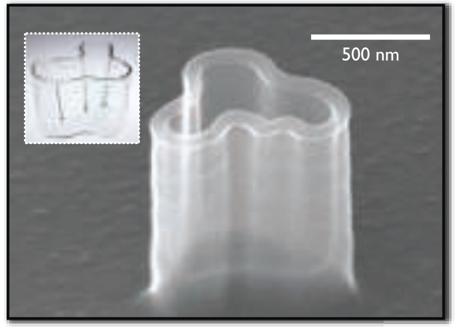
1st proof-of-concept bridge structure. Structure withstood dicing and lift-off.

Miscellaneous Images

Other recent samples/devices fabricated in our Nanolab.



FIB fabricated graphene ribbons.



Worlds smallest Alvar Aalto vase (material: Silicon, volume 0.1 fL) ★

Micronova Center for Micro and Nanofabrication

Overview

- Center for the design, development and fabrication of micro- and nanosystems.
- Run jointly by the VTT Technical Research Centre of Finland and Helsinki University of Technology (TKK).
- Expertise: sensors based on MEMS, optical and wireless sensors, wireless communications and photonics systems, biosensors and fluidistics, nano and quantum devices, and millimeter wave and optical instruments for space applications.
- 2600 m2 of cleanrooms ISO 4 (10) and processing lines for silicon BiCMOS, MEMS, III-V optoelectronics and thin film devices.

Focused Ion Beam

Model: Helios Nanolab (since Jan. 2008)
No. of Users: 20
Main Usage:

- Nanofabrication (photonics, mems, NIL, nano-electronics)
- TEM Preparation
- Analytics

Accessory:

- Pt-deposition
- Idep
- Delination etch
- STEM (12 segment, HADF)
- Nanomanipulator (Kleindiek)

Additional Accessory (scheduled for 2009): EDX, W-deposition, AutoTEM

★ Image and fabrication by Nikolai Checurov