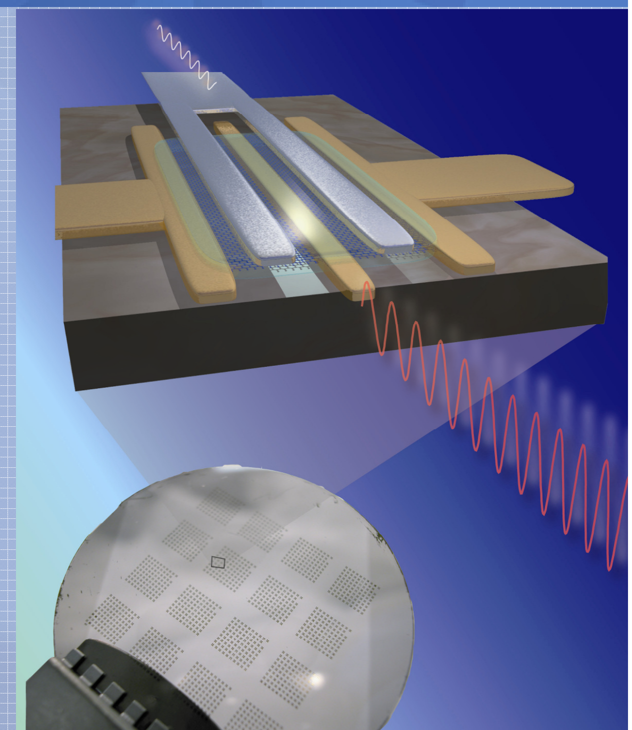
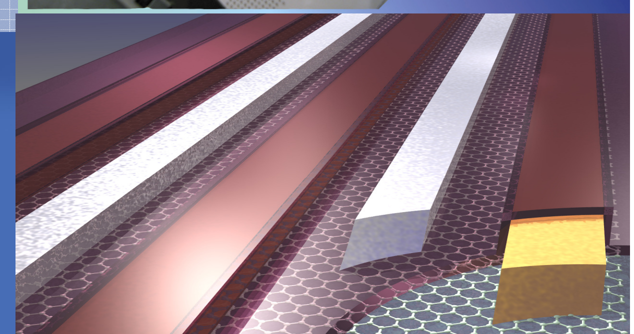
IBM Research | Science & Technology





IBM Graphene Nanoelectronics Technologies

C.Y Sung
Program Manager
IBM T.J. Watson Research Center
Science & Technology Strategy Department

Outline

- Motivation
- Synthesis (CVD and Epi)
- Device Fabrication and Performance
- Future Applications
- Conclusions

IBM Research Worldwide

Technical Transition Plan

Fundamental Research

Screen new materials & processes

IBM Almaden & Yorktown

Advanced Semiconductor R&D

Innovation in integrated device & process technology

Albany Nanotech Center

Technology Development

Multi-company co-located joint development

IBM East Fishkill

Manufacturing

Process synchronized fabricators (GDSII compatible)

USA

Frontiers of IT Nanosystem Vision

New systems enable us to reach the greatest potential for our creativity, innovation and ingenuity.

Learning Systems Will Impact Every Sector

Financial

Fraud Prevention

Retail

Revenue Maximization

Medical

Enhanced Wellness

General Business

Product Design, Launch and
Time to Revenue & Profit Optimization

Defense and Security

Better Security in a Complex World

NRI Scope and Objectives

NRI Scope :

Discover New Switch Device for Beyond CMOS by 2020

NRI Objectives :

By 2020, discover and reduce to practice via technology transfer to industry non-CMOS devices, technologies and new manufacturing paradigms, which will **provide a new scaling path and extend the historical cost / function reduction with increased performance and density** for another several orders of magnitude beyond the limits of CMOS.

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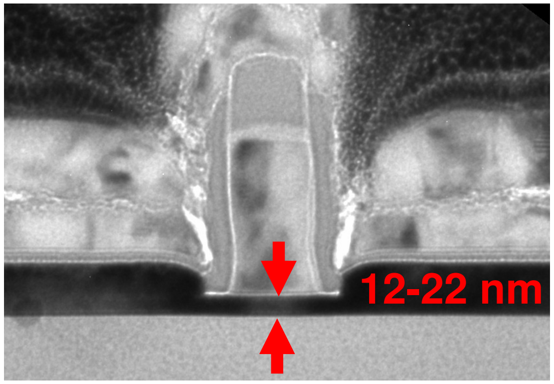
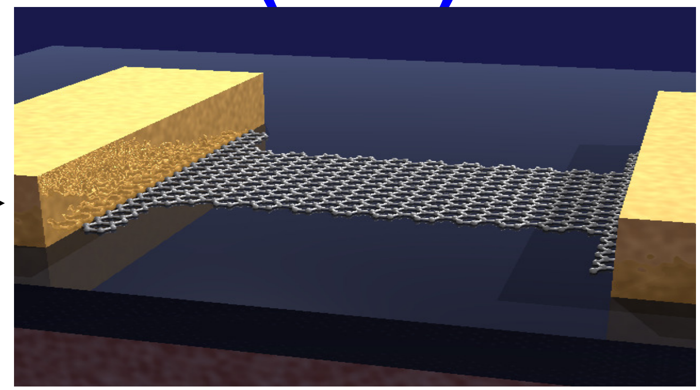
Carbon on Insulator (COI)





Graphene Attractive Properties:

- Extraordinary high e- and h+ mobility (20,000 cm2/Vs, >100X of Si)
  Long carrier mean free paths (~a few µm @ Room Temp.)
  ->Enable High Performance Devices
- Ultra-thin body (one-atom thick) Ideal electrostatics:
  ->Enable Scaling Paths
- High thermal conductance and high current carrying capability
  ->Allow Low Power Operations
- Linear energy dispersion and massless ballistics transport
  ->New Physics for New Devices
- Planar structure
  -> CMOS Process Compatible

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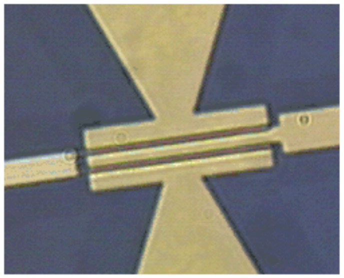
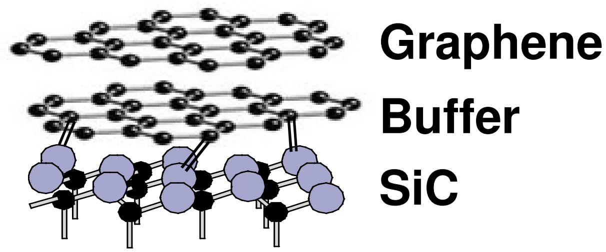
Epi Graphene on SiC

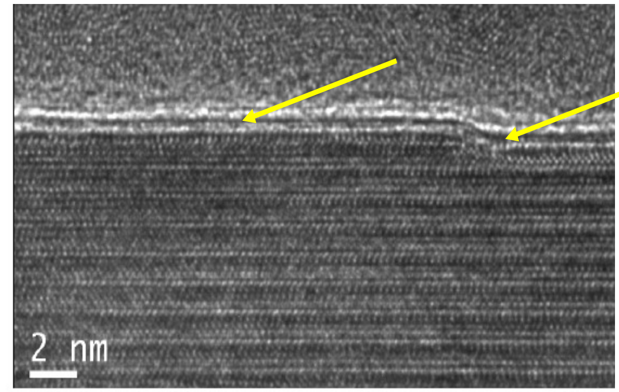
Graphene Mono Atomic Layer on 2" SiC Wafer

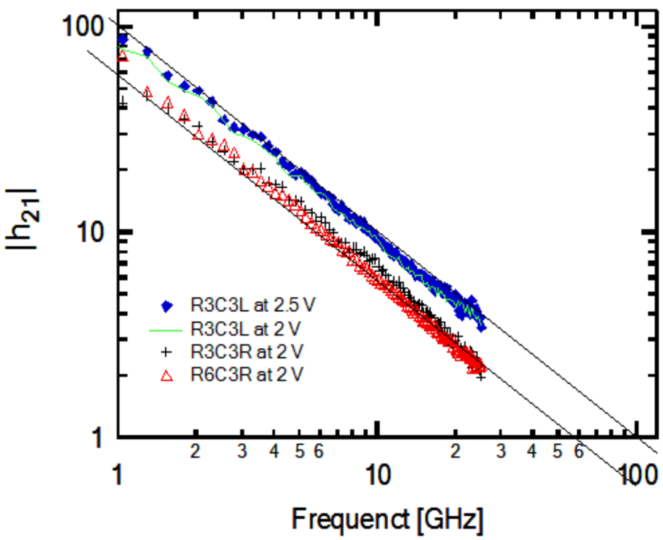


200nm gate length (3 devices)

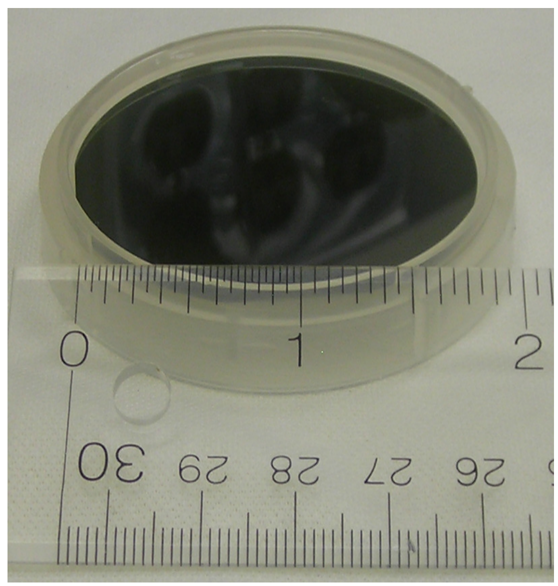
Graphene on Si-face of SiC

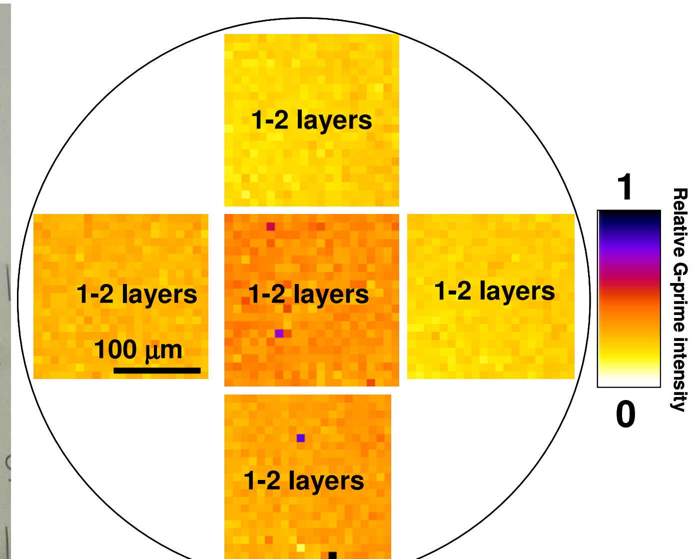




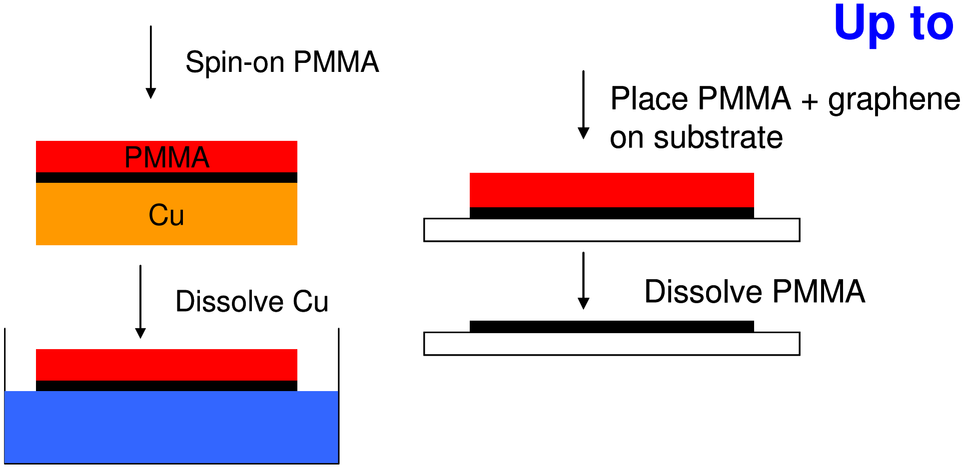


f_T ~ 60-100 GHz

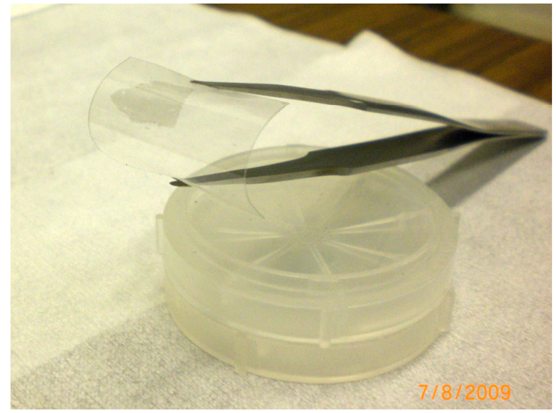




Graphene Growth on Cu Foils by CVD

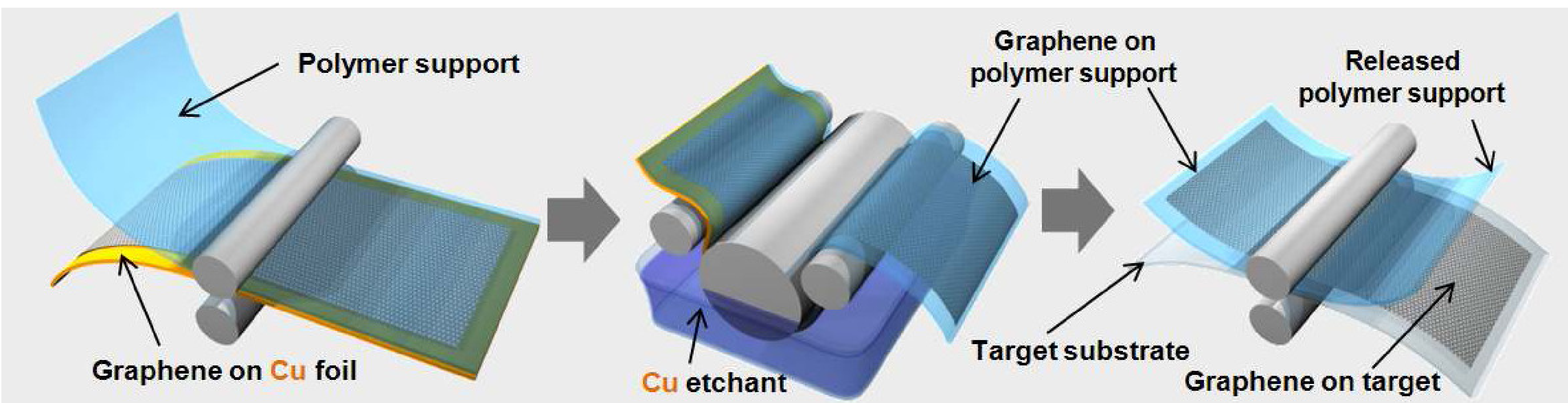


Up to 12" Successfully Demonstrated



Roll-Based Producing Graphene Films

Sukang Bae,[1*] Hyeong Keun Kim,[3*] Xianfang Xu,[5] Jayakumar Balakrishnan,[5] Tian Lei,[1] Young Il Song,[6] Young Jin Kim,[1,3] Barbaros Özyilmaz,[5] Jong-Hyun Ahn[1,4†], Byung Hee Hong[1,2†], Sumio Iijima[1,7]



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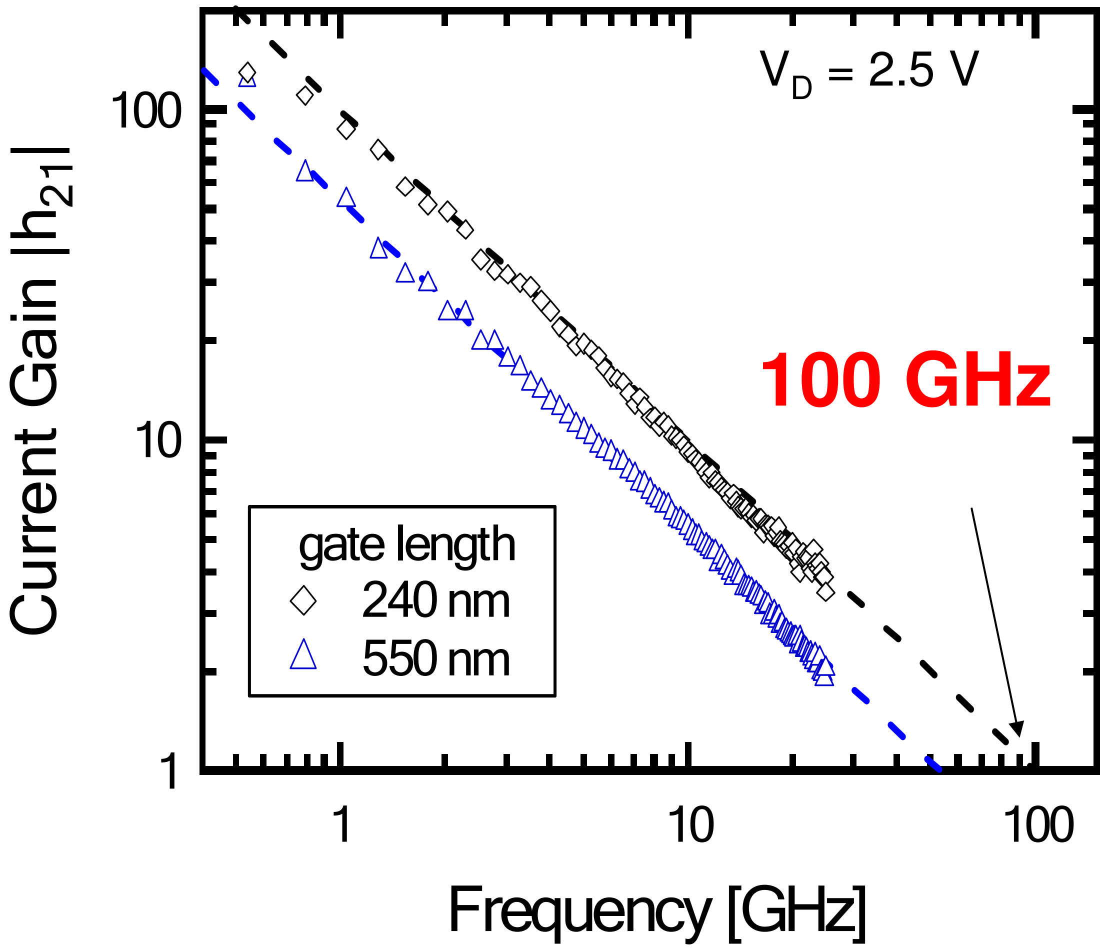
220nm Single Atomic Layer Graphene Transistor on 2” SiC Wafer



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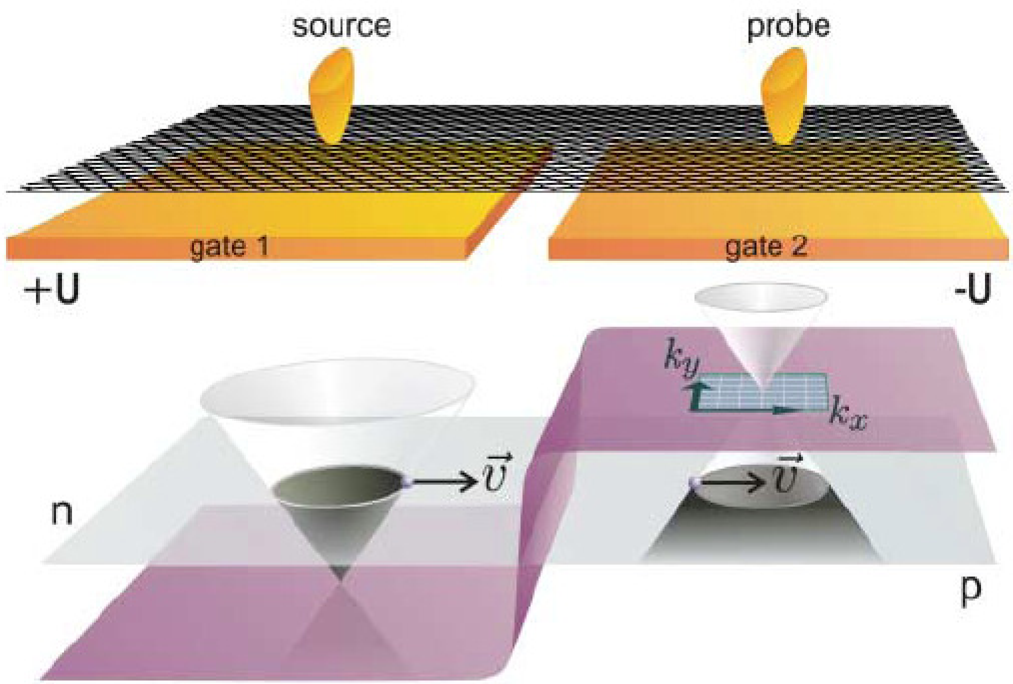
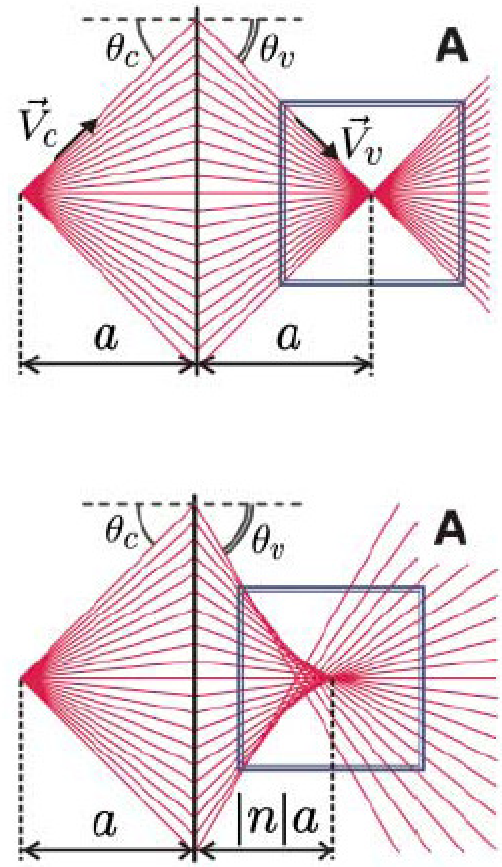
Graphene Logic Devices
(Innovative Concepts)

Veselago Lens Switches



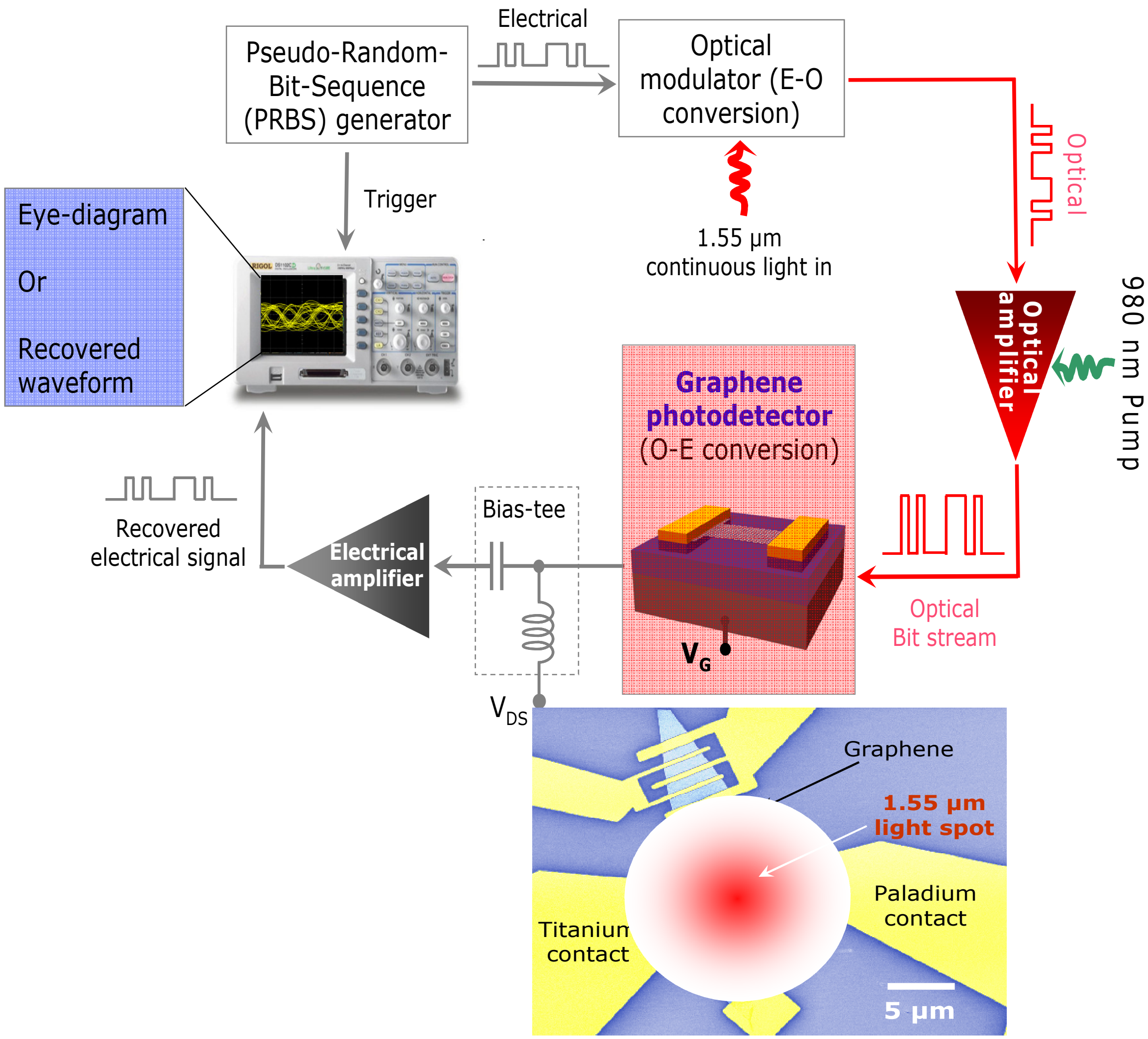


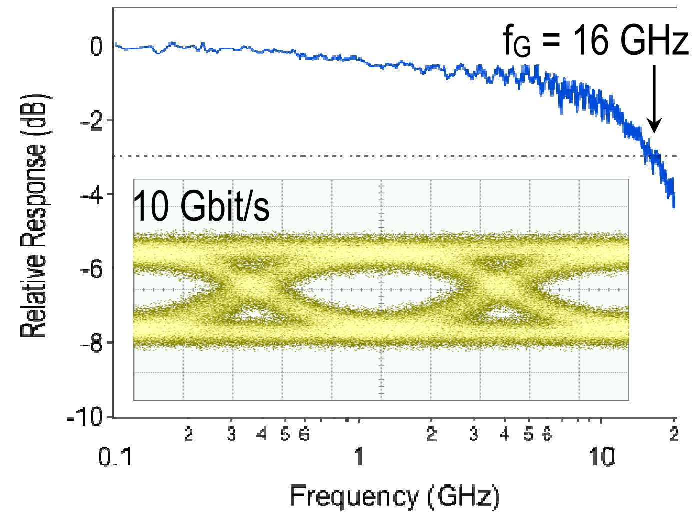
- On/Off via electron focusing
- Speed

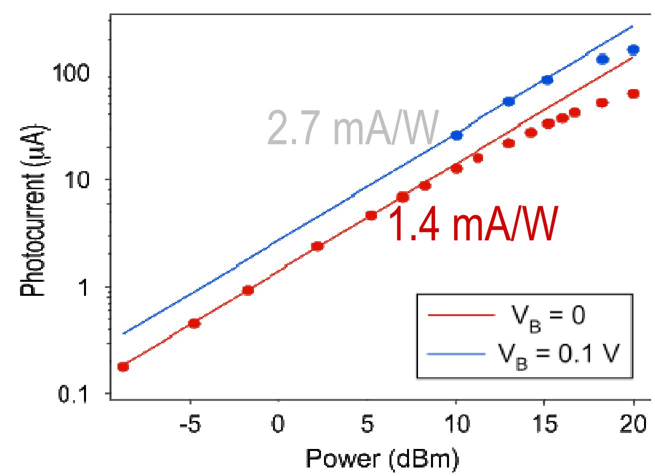
Cheianov, Fal'ko & Altshuler, *Science* (2007)

Graphene Optoelectronics

Graphene Photodetector in 10 Gbit/s 1.55 µm Optical Communication Link

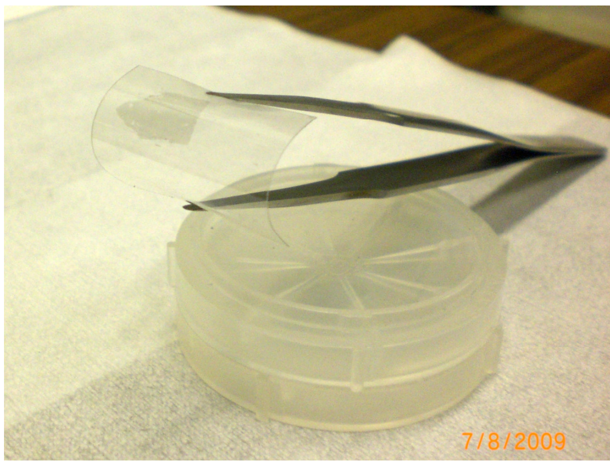




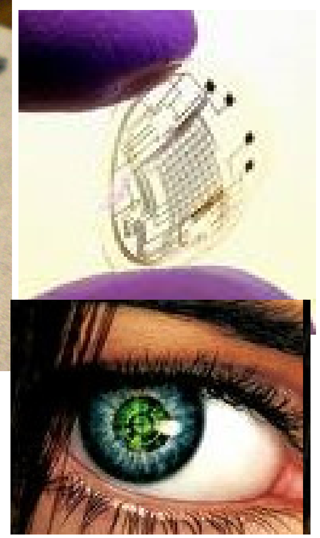


Graphene Sensor and Energy Devices

Graphene RF Thin Film Sensors

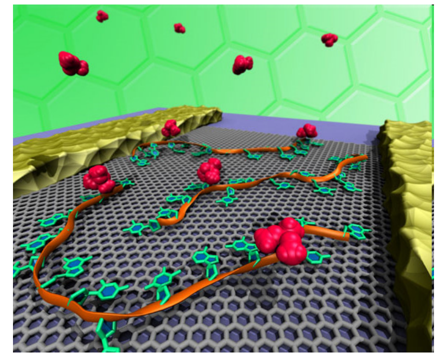


Graphene Thin Film

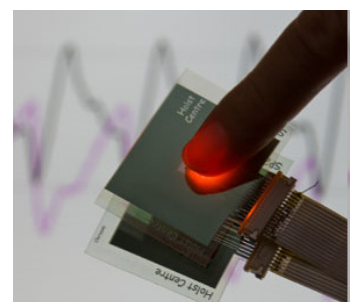


Digital Contact Lens

Smart Graphene Bandage

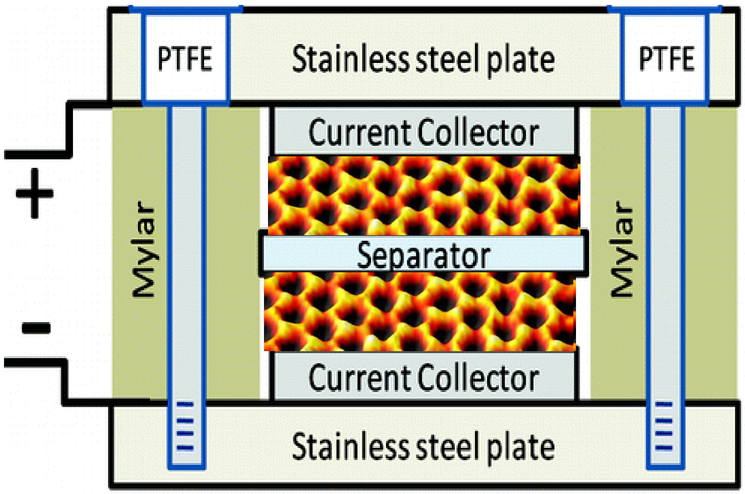


Sensitive Sensor for toxic gases and proteins

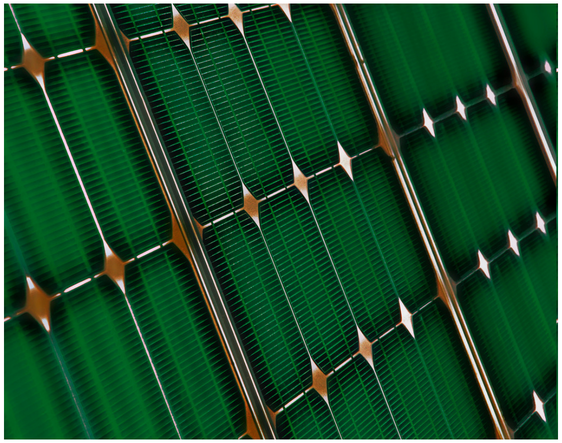


Green applications: Photovoltaics/ Supercapacitors

• Graphene Energy Devices for Low Weight
•High Performance Battery Cells
•Supercapacitors.



•Graphene based photovoltaics device create more efficient cell.



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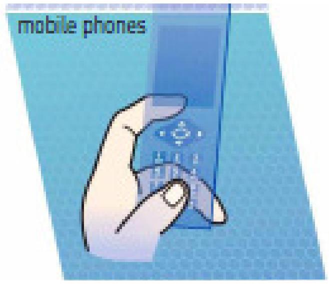
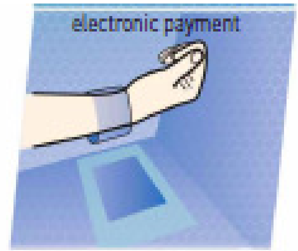
Mobile Phones

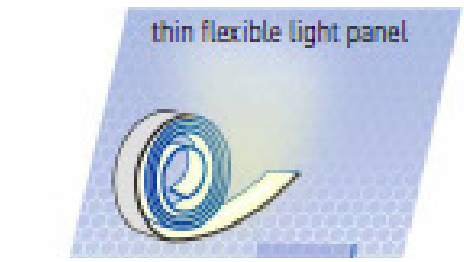


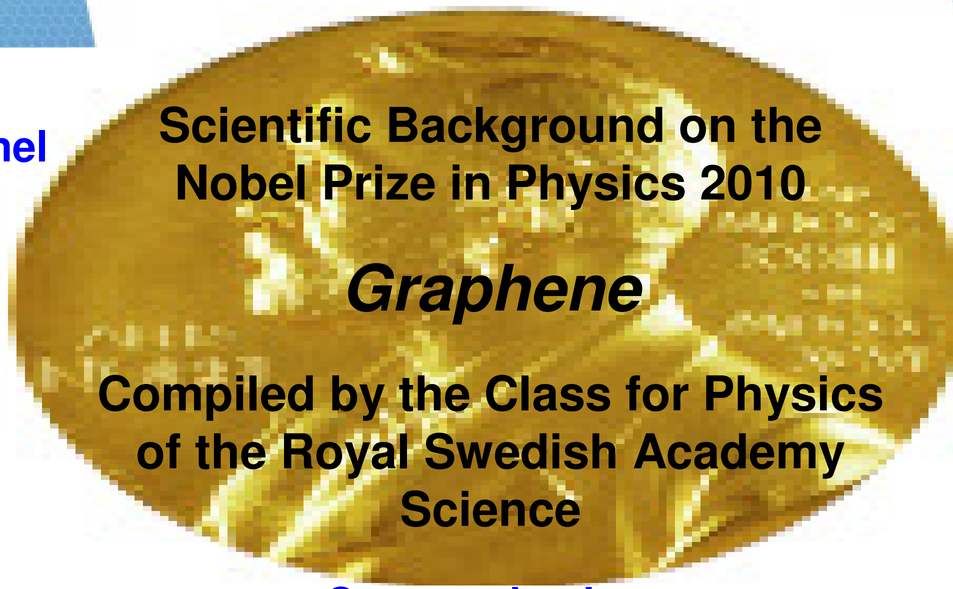
Electronics Payments



Watches/Calendars

Thin Flexible Light Panel





Scientific Background on the Nobel Prize in Physics 2010

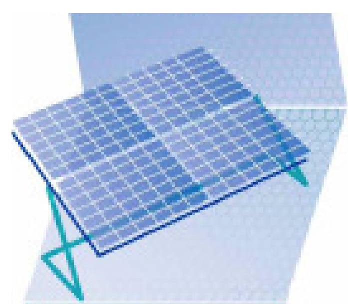
Graphene

Compiled by the Class for Physics of the Royal Swedish Academy Science

Composite Materials

Tablet Computer

Communications



Touch Screens/ Microelectronics