Epitaxial Graphene on cubic silicon carbide: a platform on silicon for integrated technologies

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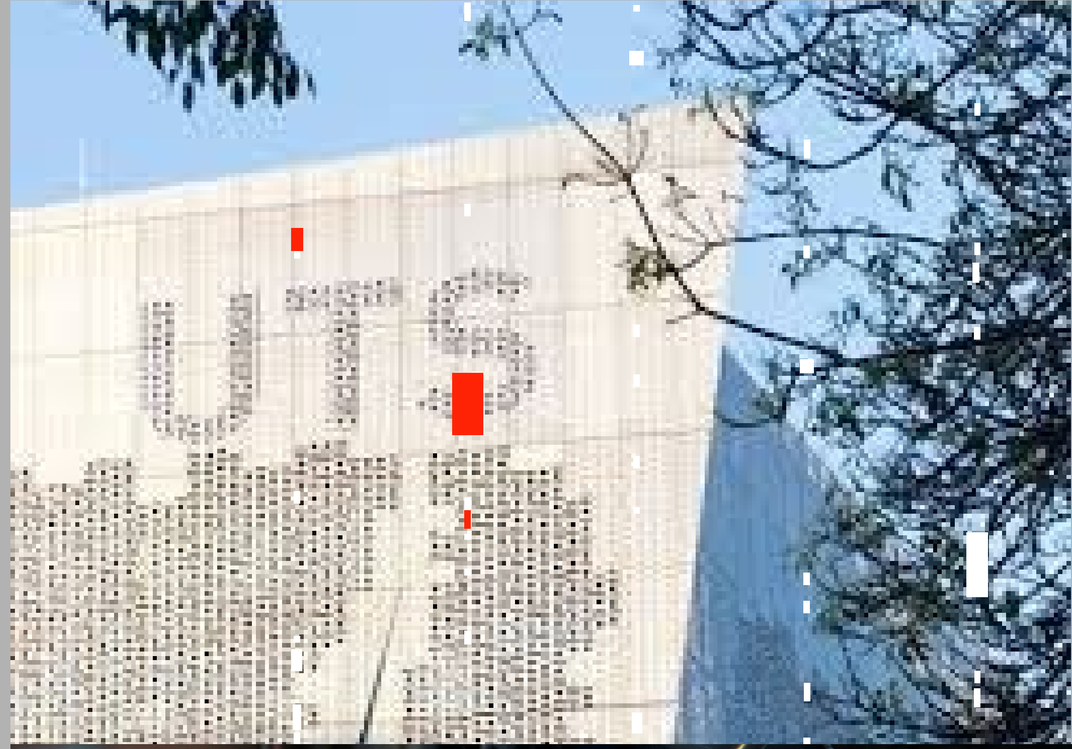
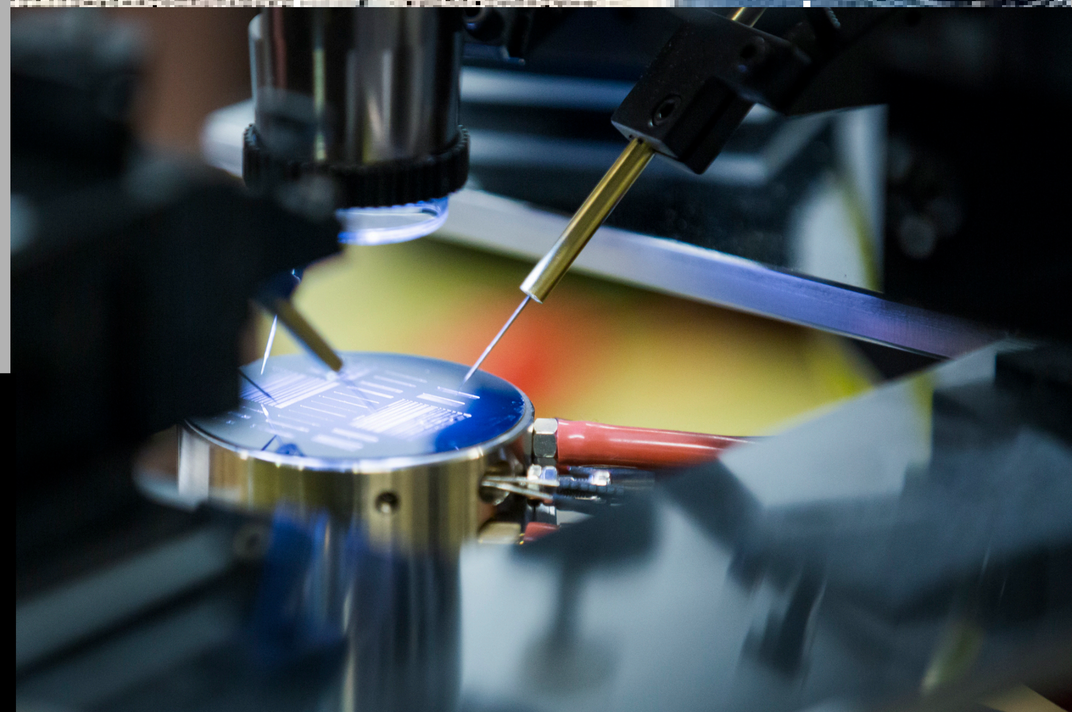
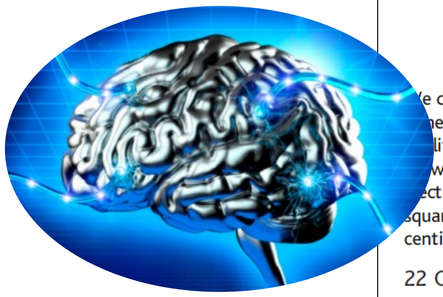


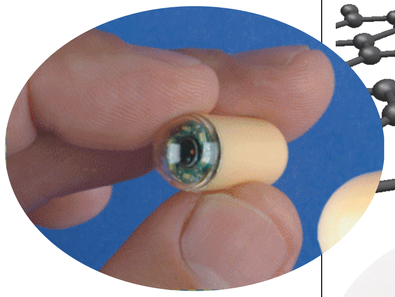


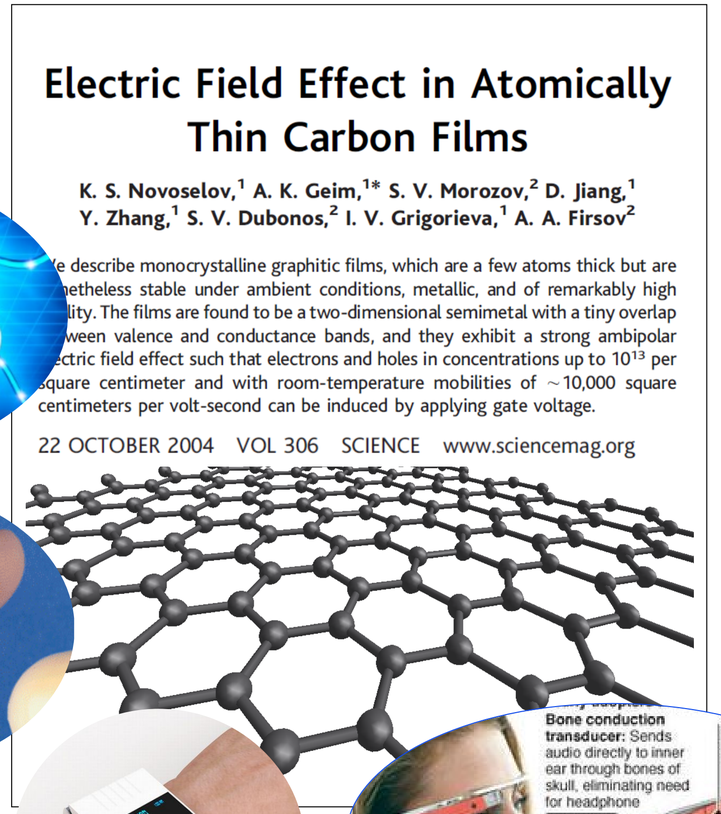
Ultimate miniaturization with epi graphene on silicon

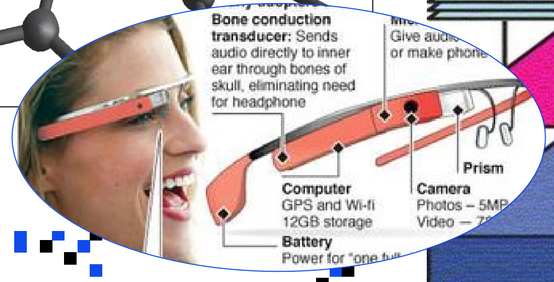
Graphene on silicon to augment:

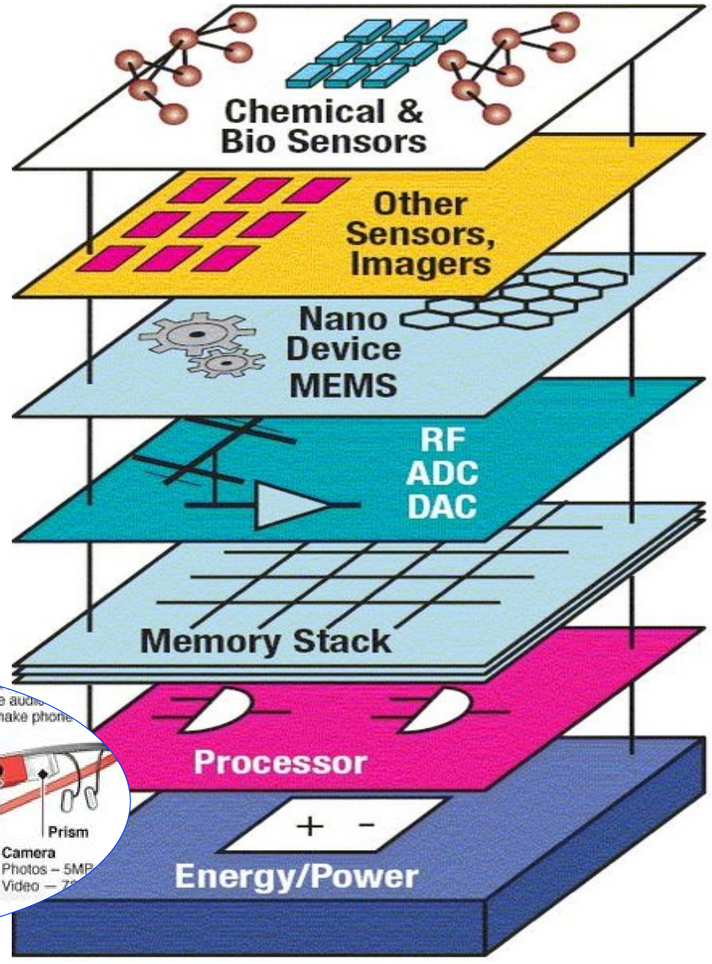
- Interconnects
- Energy storage
- Photonics
- (bio)Sensing
- Thermal management



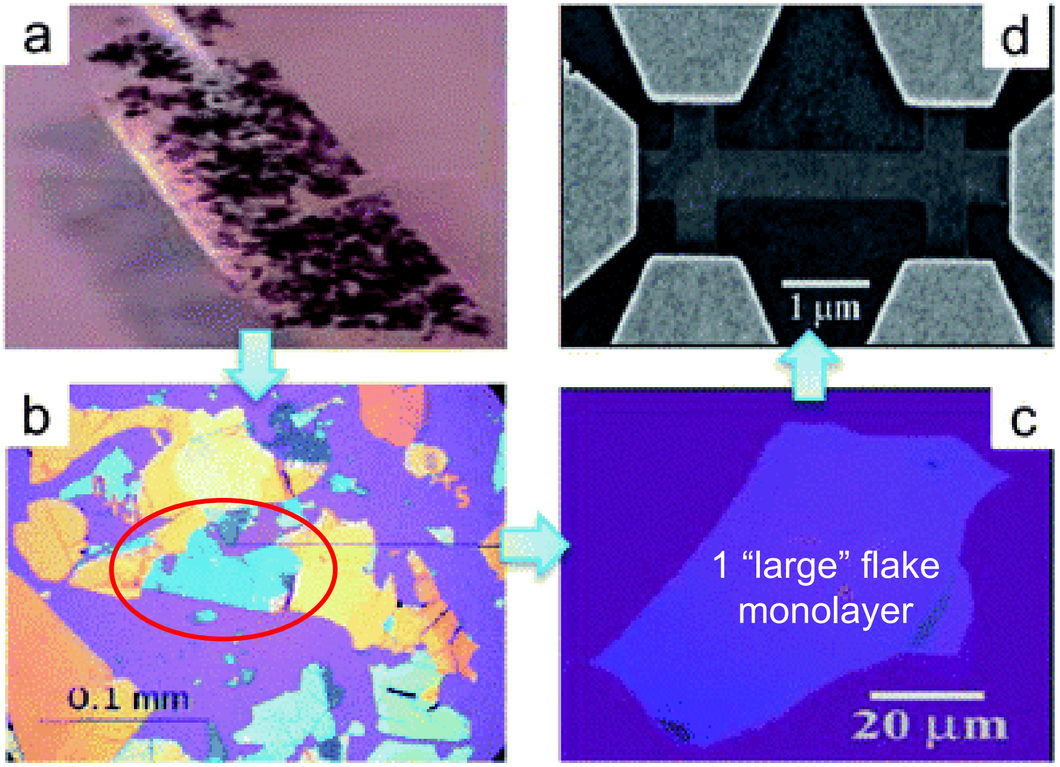


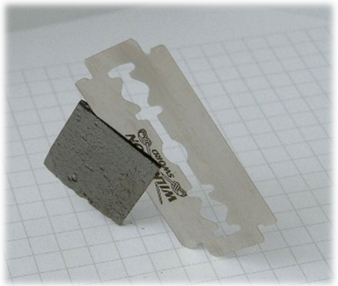


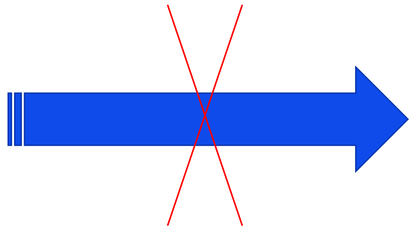


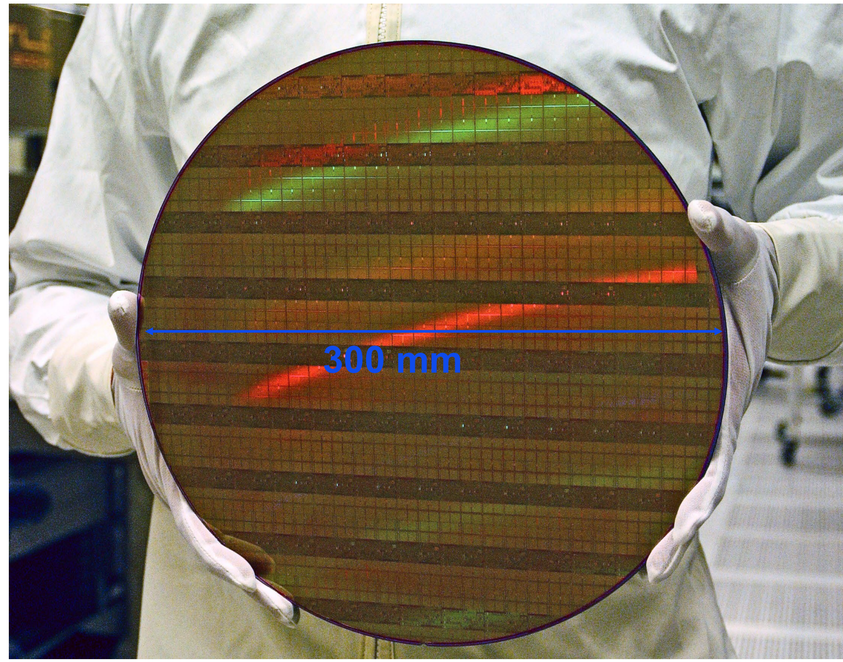


Scaling to wafer –level?







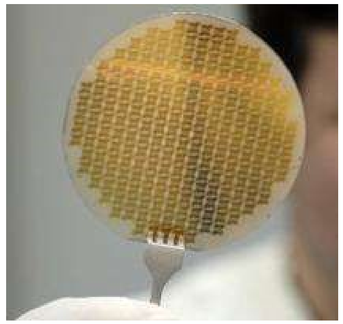


Challenges for wafer –scale transfer :

Manufacturability, reproducibility, yield, standards, predictability, reliability more important than absolute quality

Epitaxial Graphene (EG) on SiC wafers

PennState



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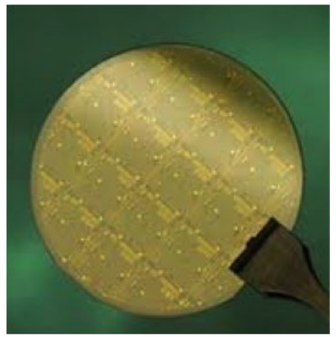

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Letter | Published: 05 February 2014

Exceptional ballistic transport in epitaxial graphene nanoribbons

Jens Baringhaus, Ming Ruan, Frederik Edler, Antonio Tejeda, Muriel Sicot, Amina Taleb-Ibrahimi, An-Ping Li, Zhigang Jiang, Edward H. Conrad, Claire Berger, Christoph Tegenkamp & Walt A. de Heer

Nature **506**, 349–354(2014) | Cite this article

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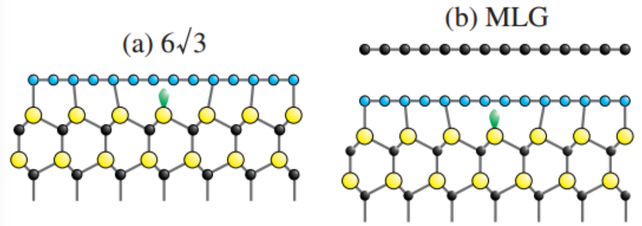
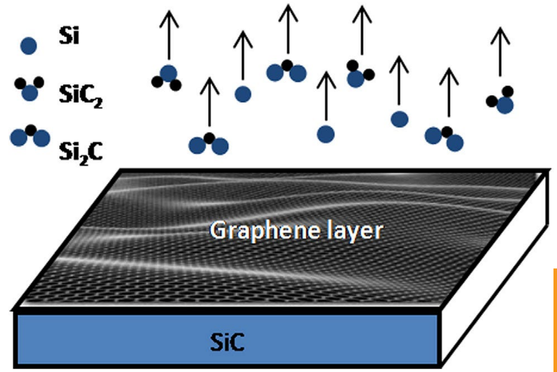
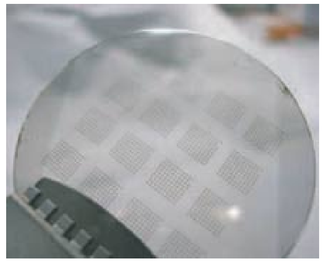
Abstract

Graphene nanoribbons will be essential components in future graphene nanoelectronics[1]. However, in typical nanoribbons produced from lithographically patterned exfoliated graphene, the charge carriers travel

Fromm et al, NJ of Physics, 2013







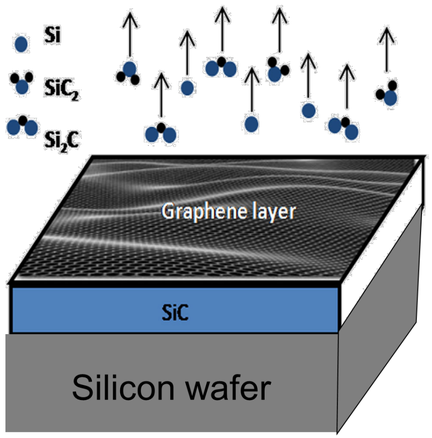
IBM TJ Watson

Solid –source growth

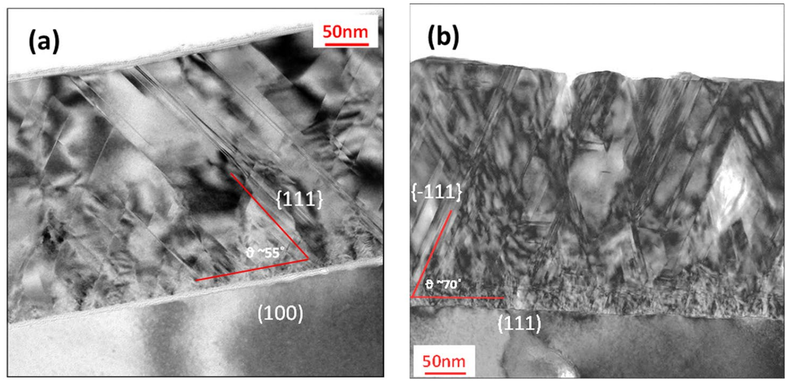
EG on 3C-SiC/silicon?

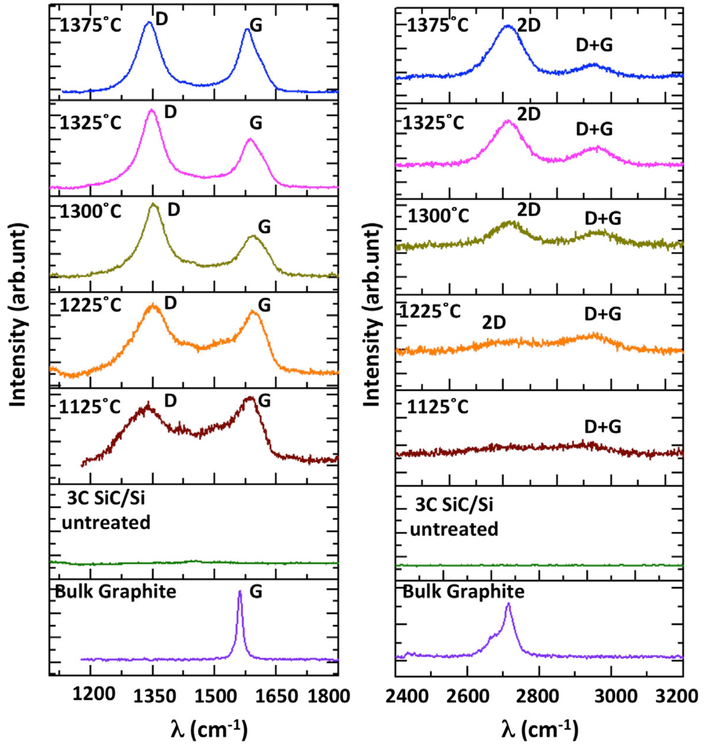
Advantages vs EG on SiC wafers:
- Directly integrated with silicon
- Wafers cost, size, quality, etc
- Site –selective growth

Beneficial features:
- Site –selective growth
- High substrate adhesion
- Combination of SiC/graphene:
  - Electronics: EG on WBG material
  - Photonics: metamaterial
  - MEMS:
  - Both high stiffness (high Q)
  - Both highly biocompatible
  - Both harsh-environment compatible



SiC(100) **SiC(111)**

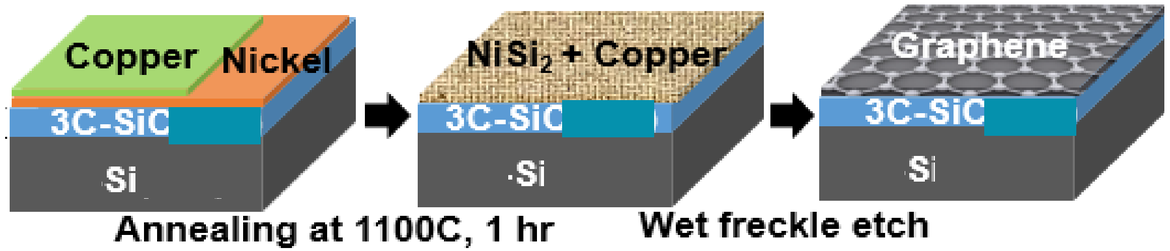




Challenges: Temperature limit, stresses, defects ➔ I_D/I_G >1

Novel approach: Ni/Cu –assisted epi graphene

- Solid state source, LPE approach
- Ni controls release of C
- Cu controls graphitization



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Catalytic alloy used to grow high quality graphene on SiC on Si wafers

By Meg Marquardt

Materials Research Society/MRS Bulletin | Published: 13 February 2015

When it comes to creating wafer graphene technology on widely

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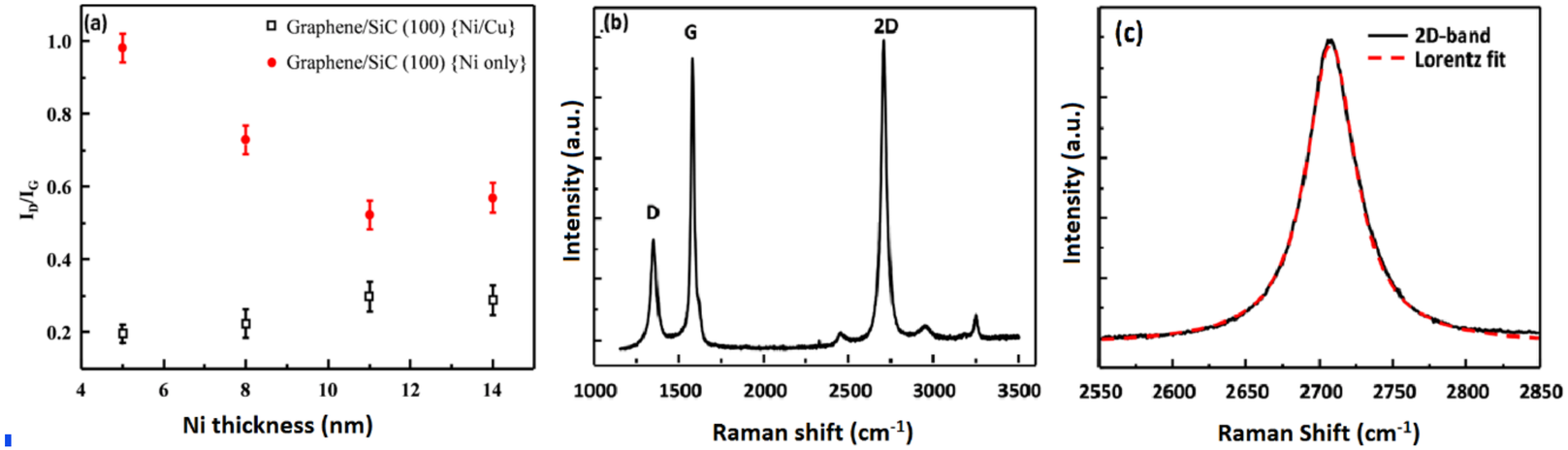
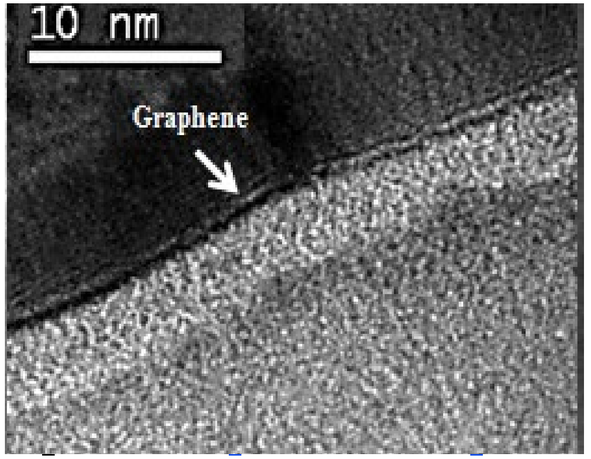




Wafer-level, site -selective graphene on silicon

Epitaxial SiC on Silicon

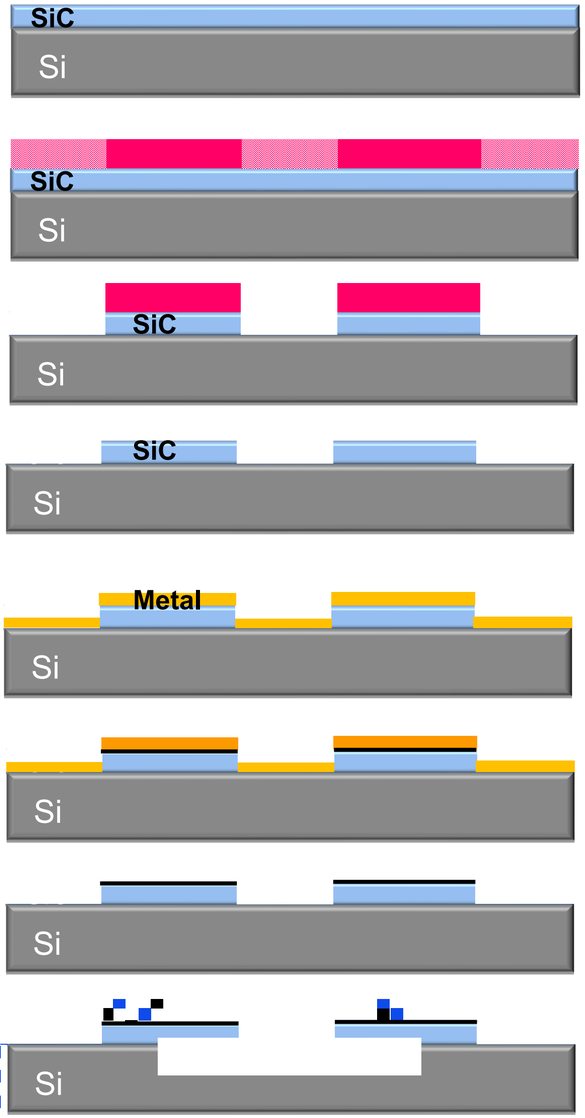
Patterning of the SiC

Deposition of metal alloy (Ni-Cu)

Catalytic self-aligned graphitization at 1000-1100 C

Wet removal of the metal layer

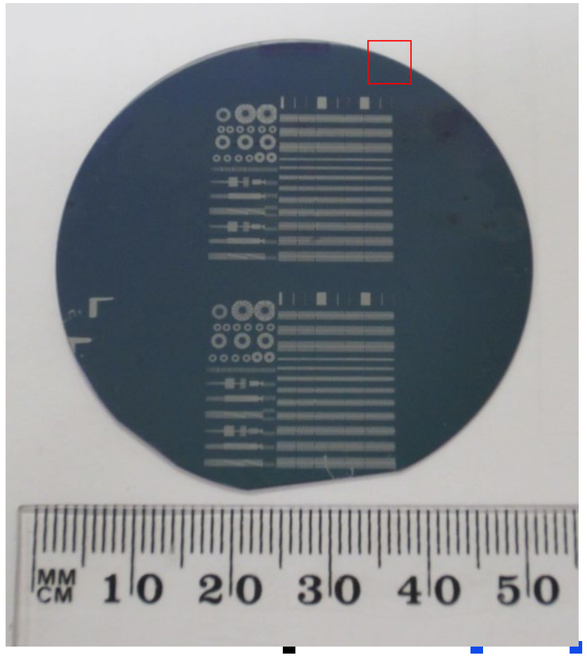
Release of the micro-structures

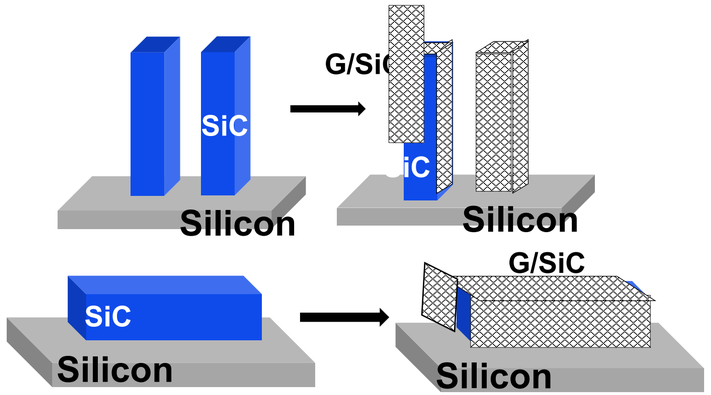


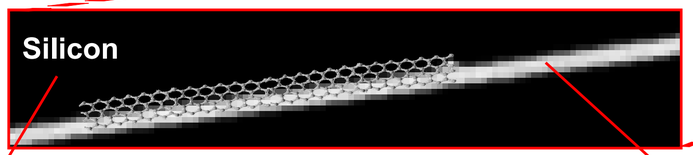
Wafer-level, site -selective graphene on silicon

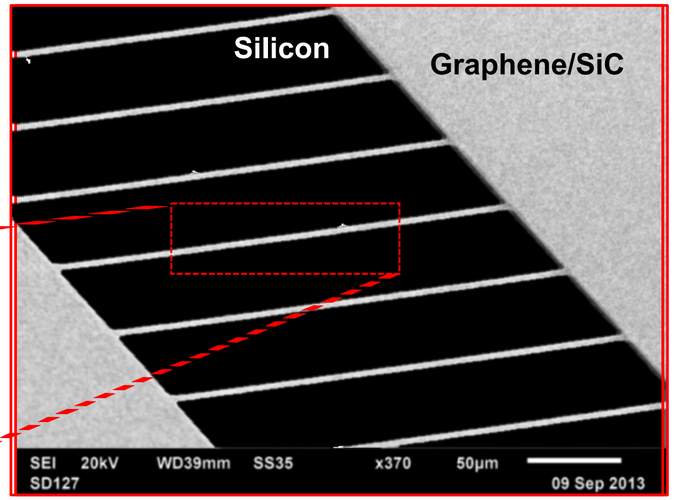
Global Innovation Award, Washington DC, May 2014

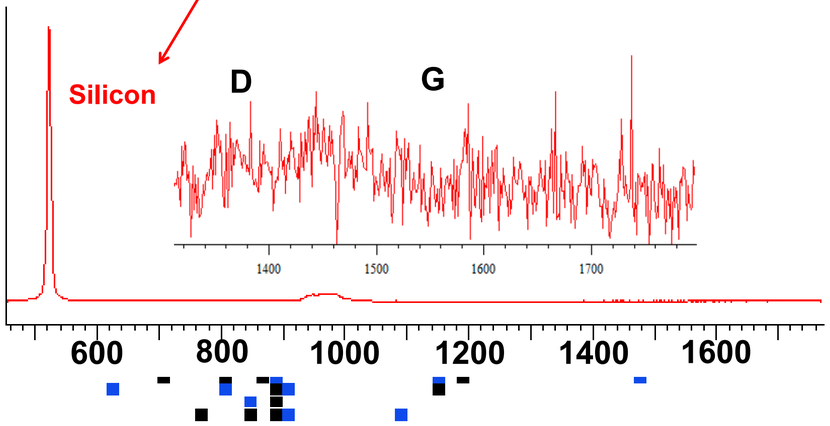
TechConnect Innovation Awards

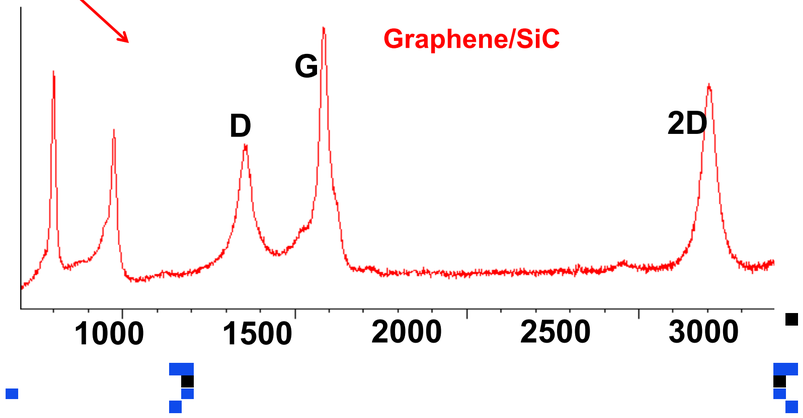






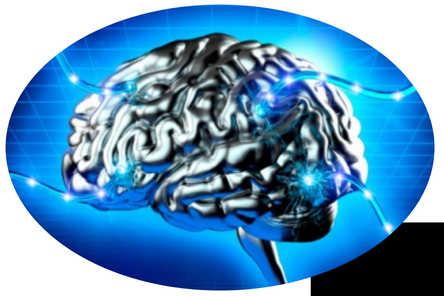






Integrated Energy Storage

NIR-MIR Nanophotonics and metasurfaces

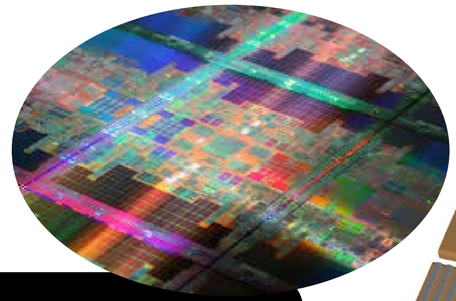


Biocompatible nanodevices

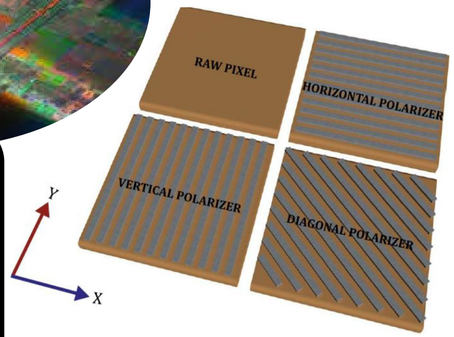
Epi graphene on SiC/silicon

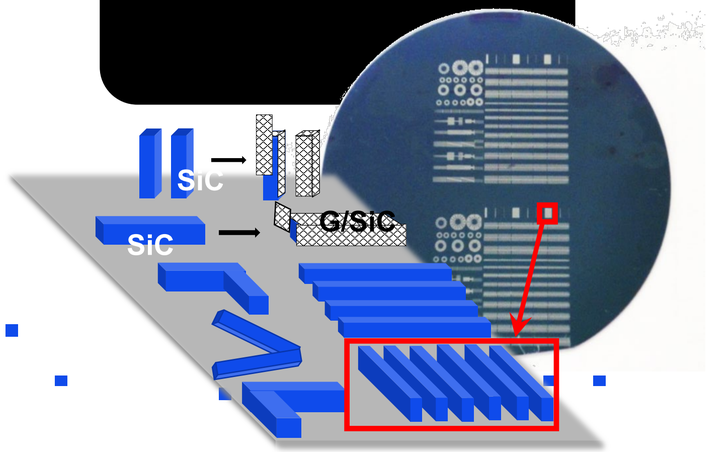
Self- aligned, synthesis and patterning @ wafer -level

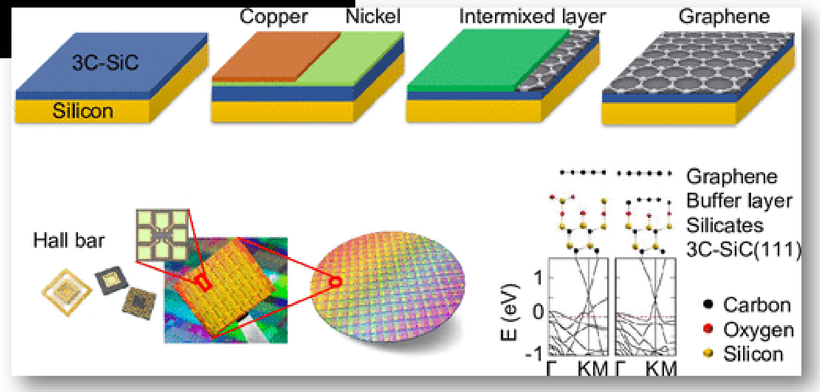
Strong adhesion to the substrate



Low-power and THz electronics



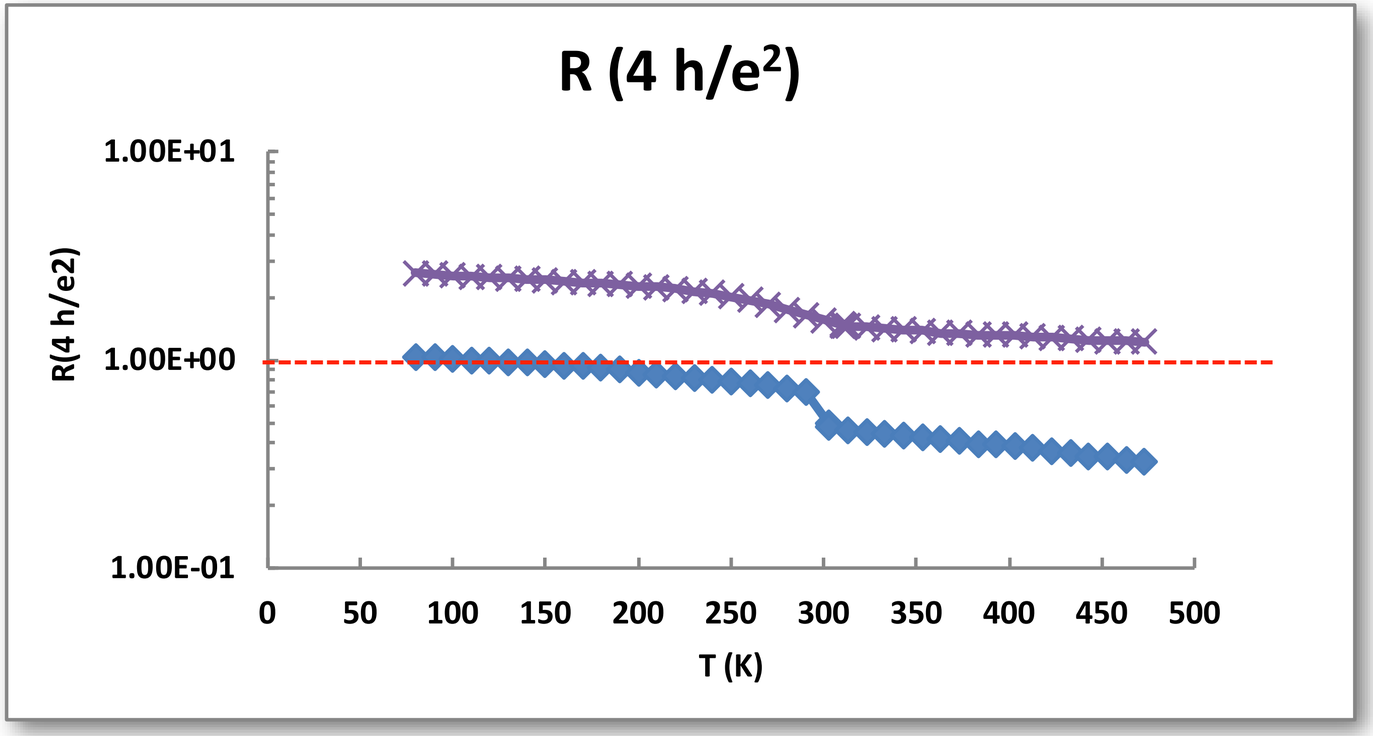




Wafer –scale, epi graphene on SiC/silicon: sheet resistance

Sheet resistance in the same ballpark as EG/SiC bulk despite far smaller grain sizes

A.Pradeepkumar et al., ACS Applied Nanomaterials, 2020



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