



# Chemistry in Semiconductor

Anthony Liu

# Outline

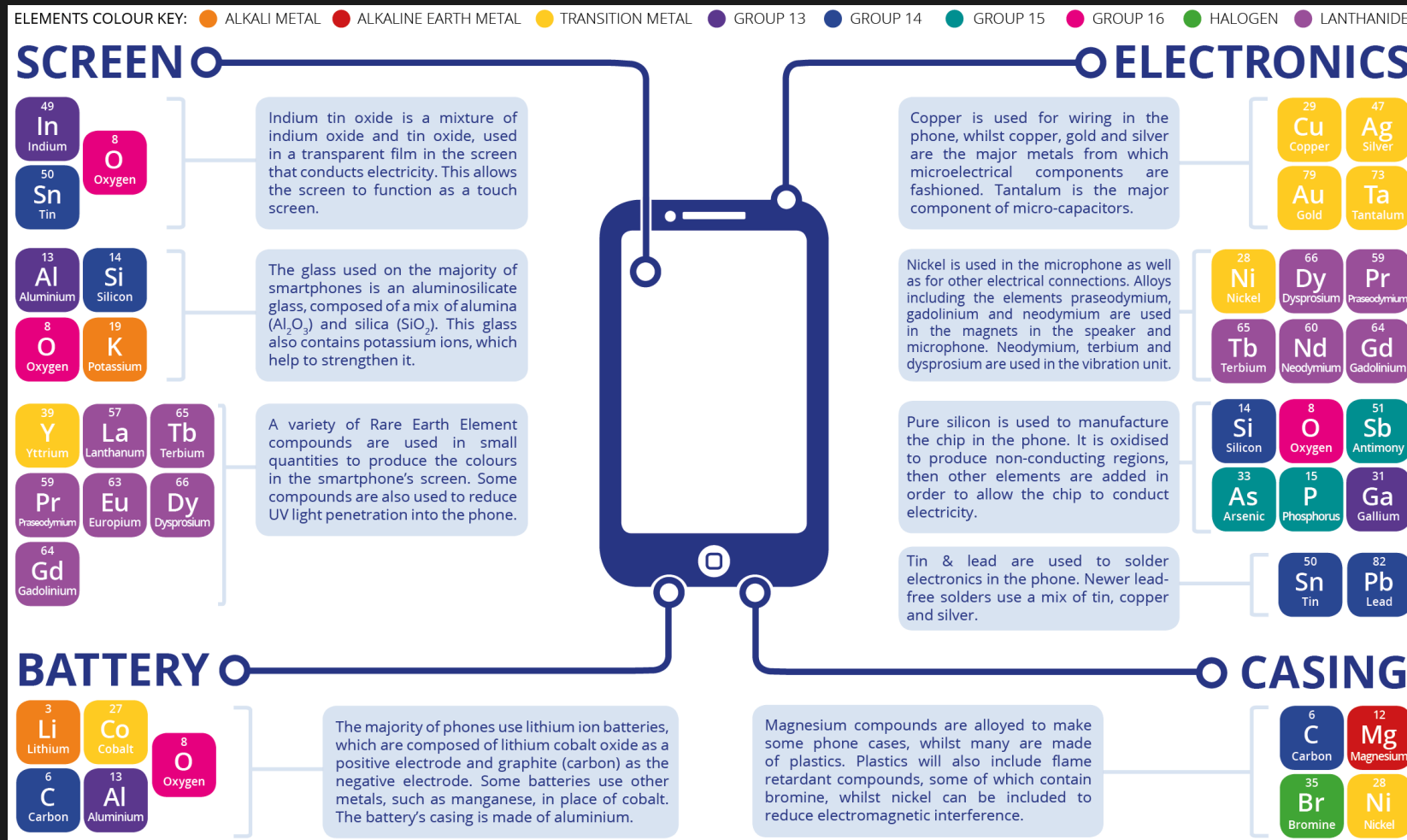
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- Elements used in semiconductor industry
- Evolution and Revolution of Transistors
- More Moore vs. More than Moore
- Carbon chemistry era
- Academia-Industry Collaboration
- How ACS journal help us to resolve issue ?
- Summary

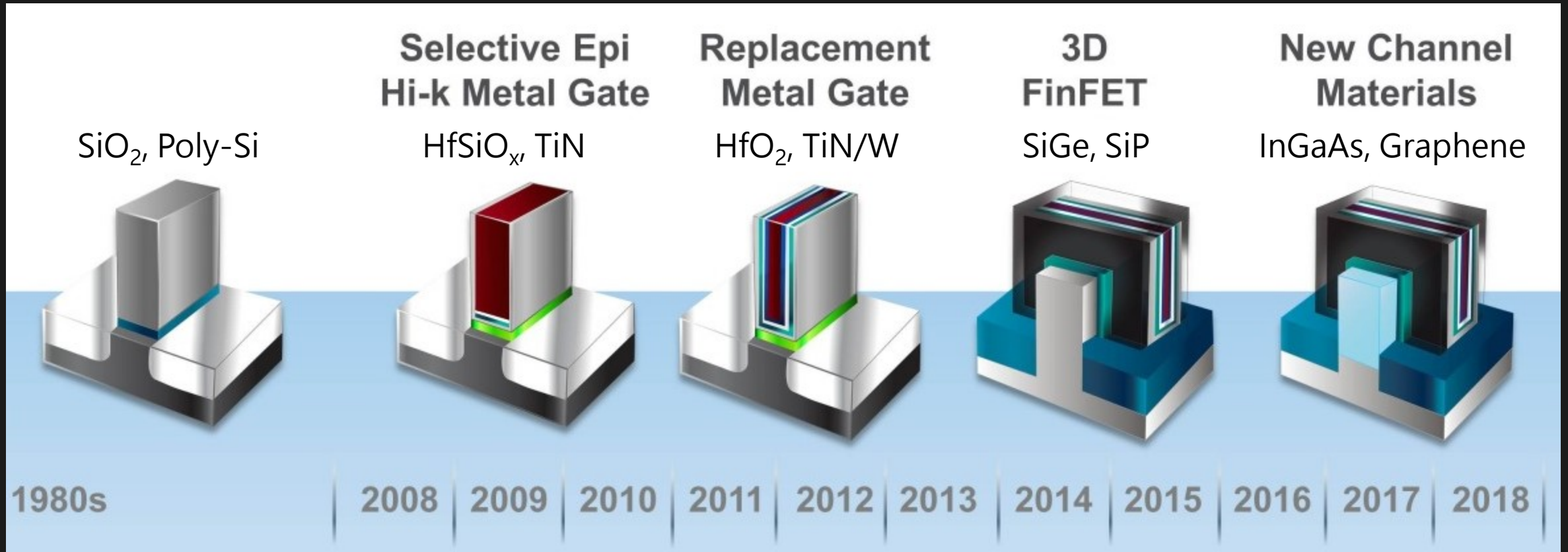
# Elements Used in Semiconductor Industry

Typical Si CMOS Fab										Additional III-V Fab							
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt									
		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
		Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		

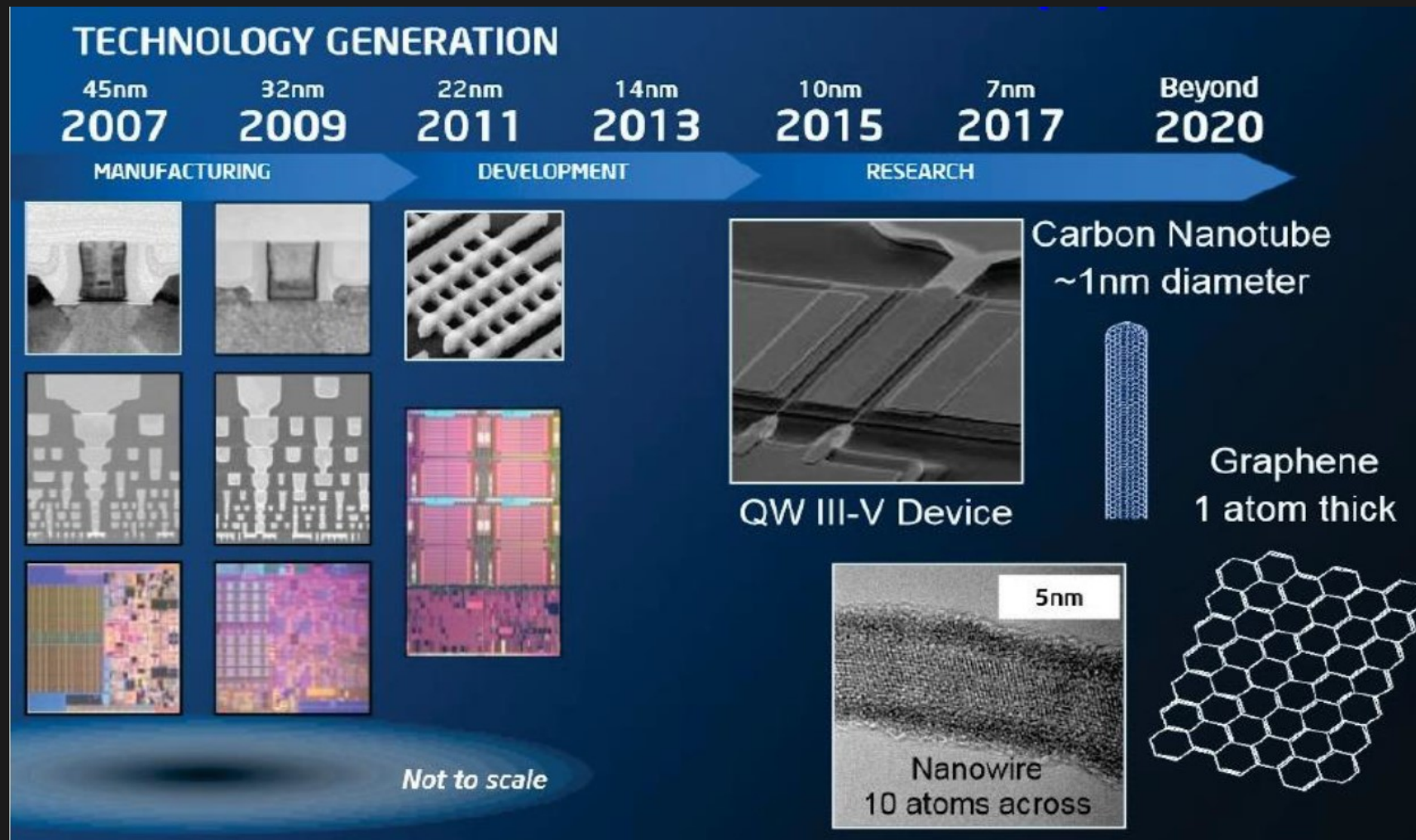
# Elements of A Smartphone



# Evolution of Transistors



# Revolution of Transistors



# The iPhone Evolution

412 MHz



2007

1.3 GHz



2012

1.85 GHz



2015

2.36 GHz



2017

# More Moore vs. More than Moore

Heterogeneous integration technology

**More Application**

Analog/RF   Passives   HV Power   Sensors Actuators   Biochips

**New Integration  
New Application**

Nano fabrication technology

**More Scaling**

130nm

90nm

65nm

45nm

32nm

22nm

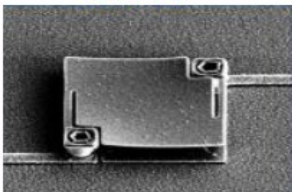
14nm

...

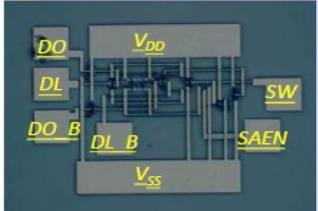
小於5nm

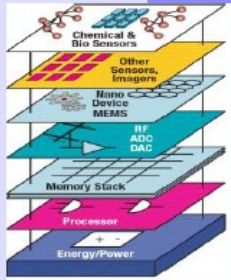
CMOS : CPU, Memory, Logic

**Sensor**

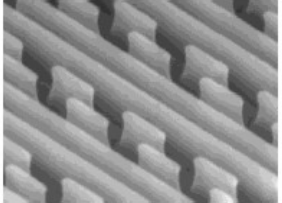


**Small scale circuit**

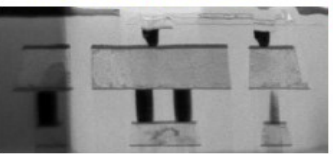




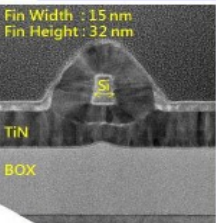
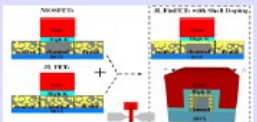
**Logic Device**



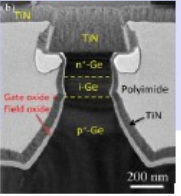
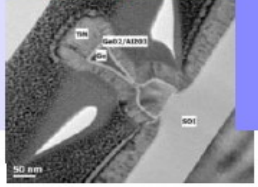
**Memory Device**



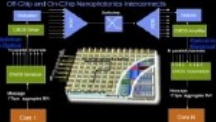
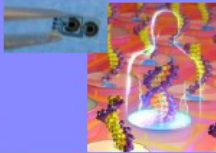

**FinFET(3D)  
Nanowire/GAA**

**Ge(Sn), III-V, 2D, Graphene**

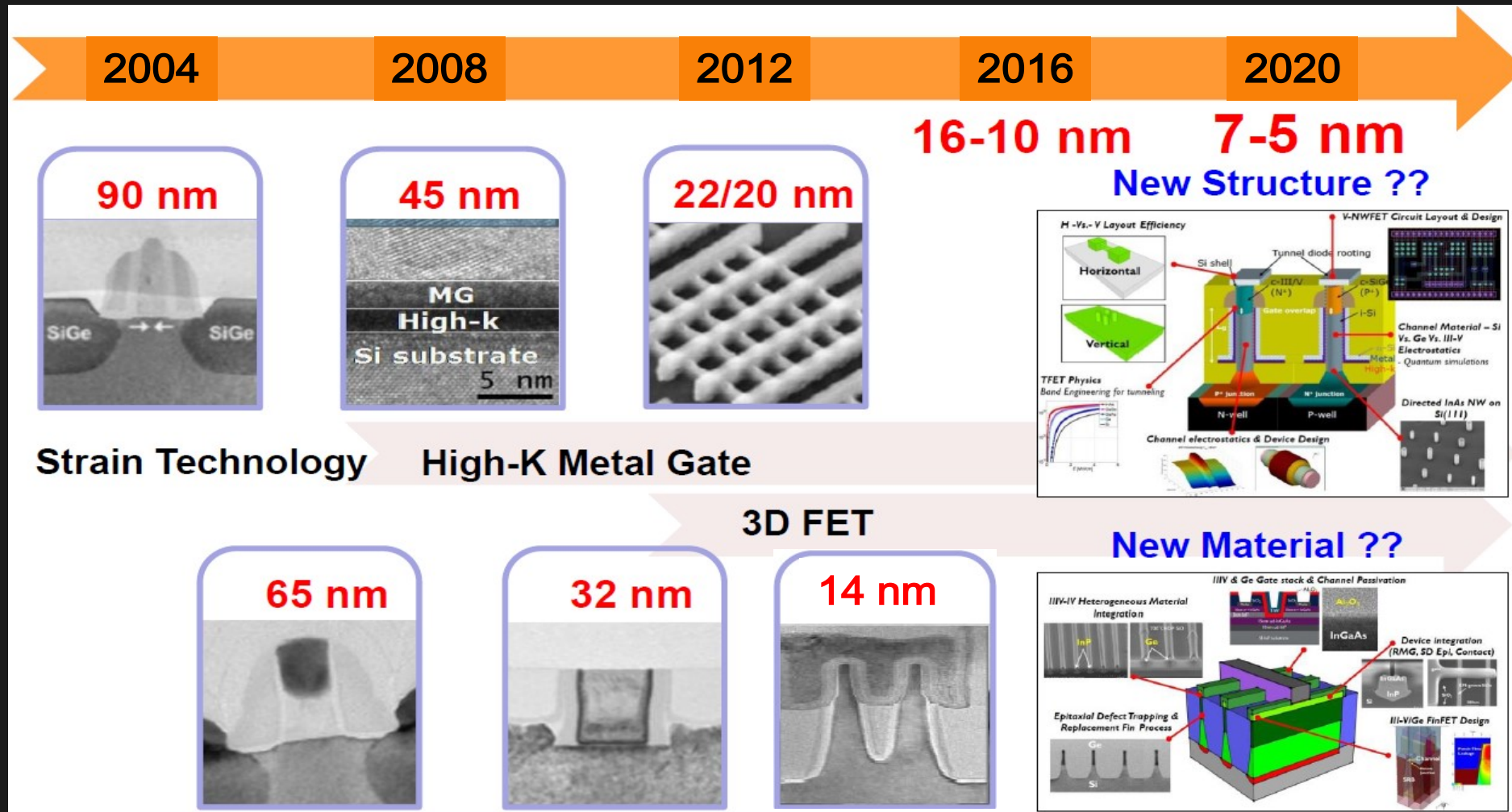
- Post-Si chip technologies that cover cutting-edge CMOS/MEMS (bio/photonic) sensor
- Heterogeneous integration for IoTs
- Wearable electronics
- Biochips

**New Structure, New Material**

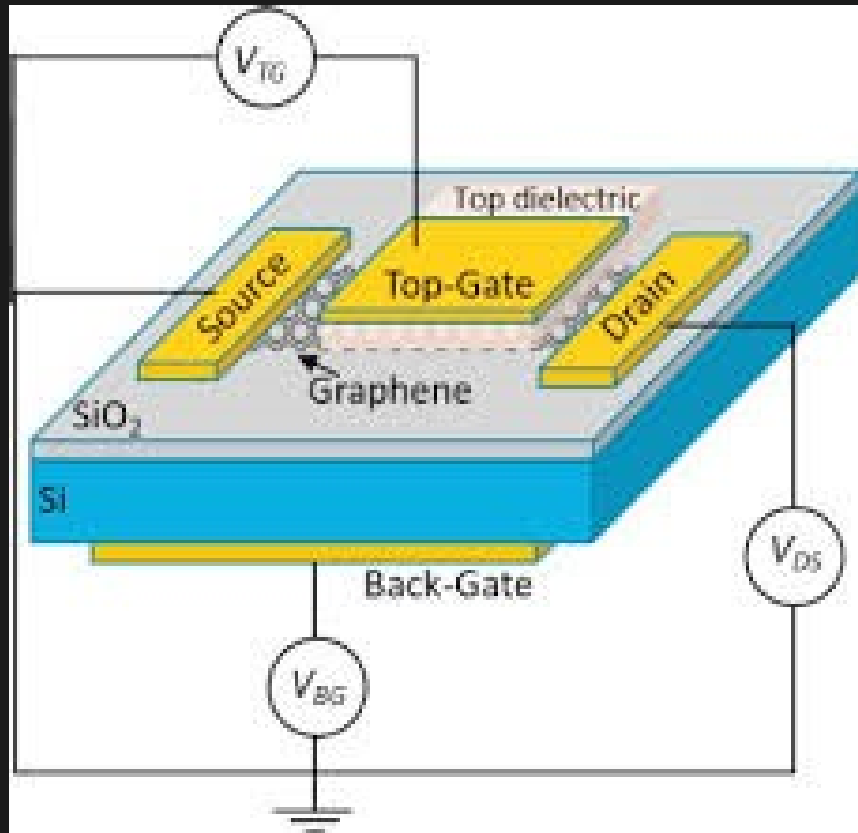


# Logic Device Trend

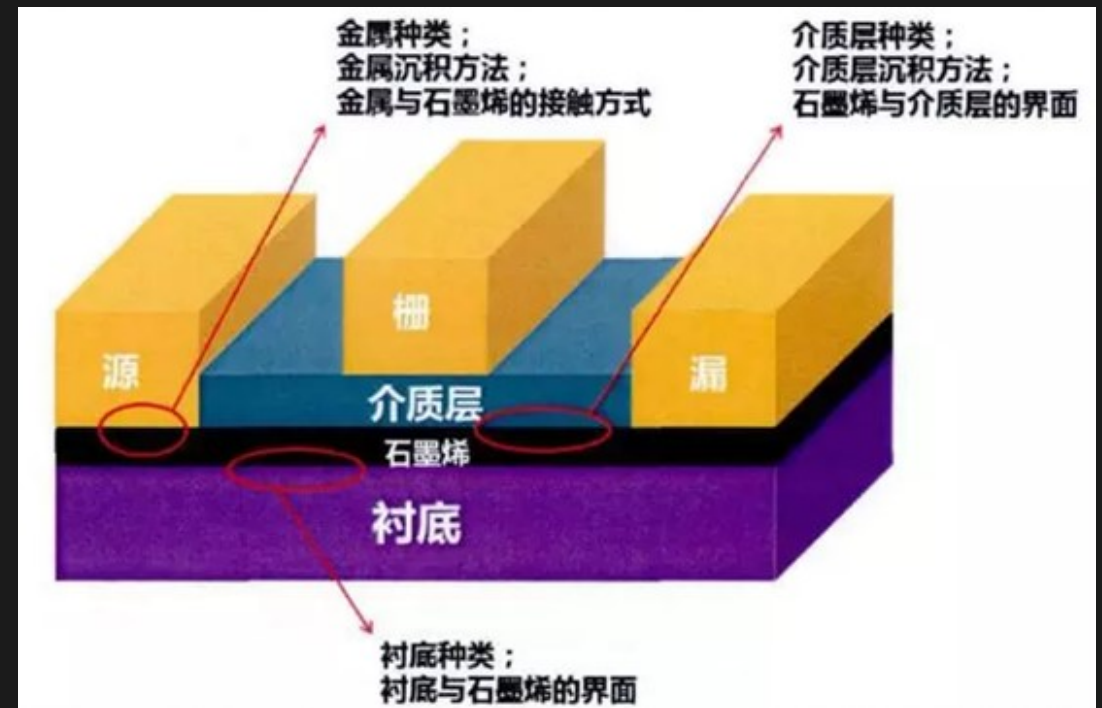


# Carbon Chemistry Era

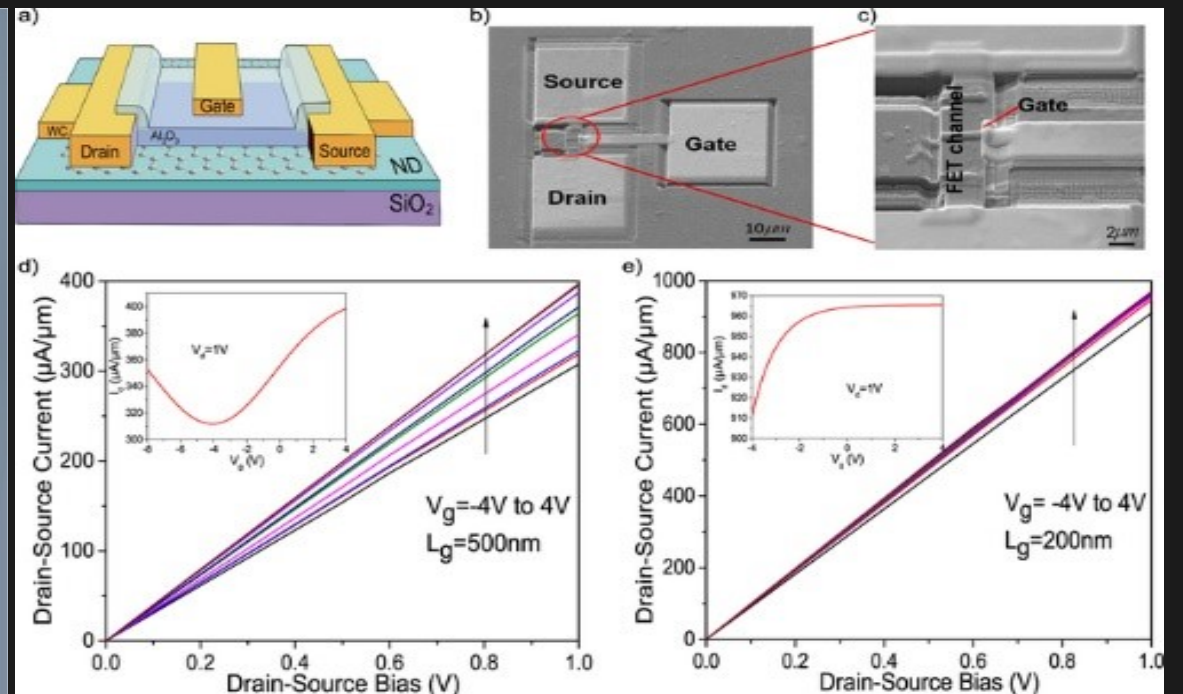
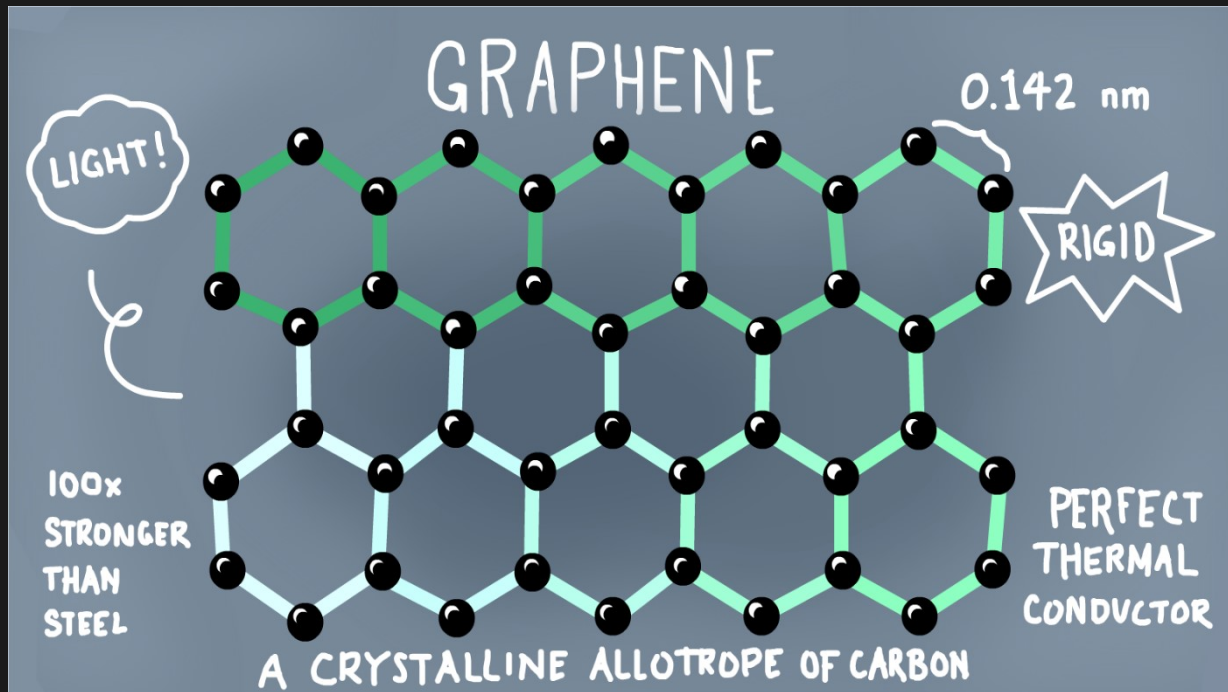
Si → Ge → III-V → 2D / Graphene



Channel	Electron Mobility (cm <sup>2</sup> /Vs)	Energy Bandgap (eV)
Si	1,400	1.12
Ge	3,900	0.67
GaAs	9,200	1.43
CNT	100,000	0.5
Graphene	200,000	0



# Why Graphene Enables Transistor?



# Academia-Industry Collaboration

**[媒體報導] 晶電、儀科中心攜央大 共創綠能新科技**

資料來源：聯合財經網 刊登日期：2014-09-24

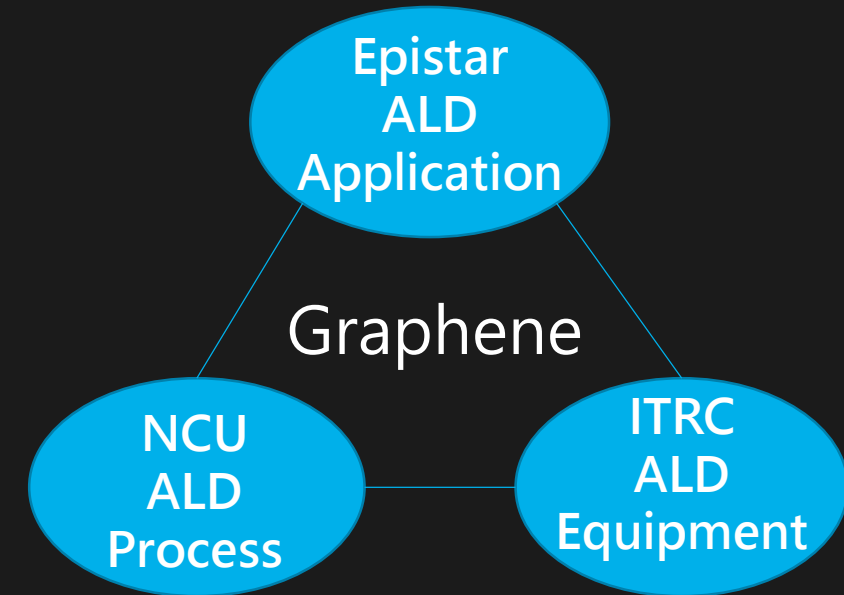
## 晶電、儀科中心攜央大 共創綠能新科技

2014-09-23 經濟日報 記者李珣瑛/即時報導

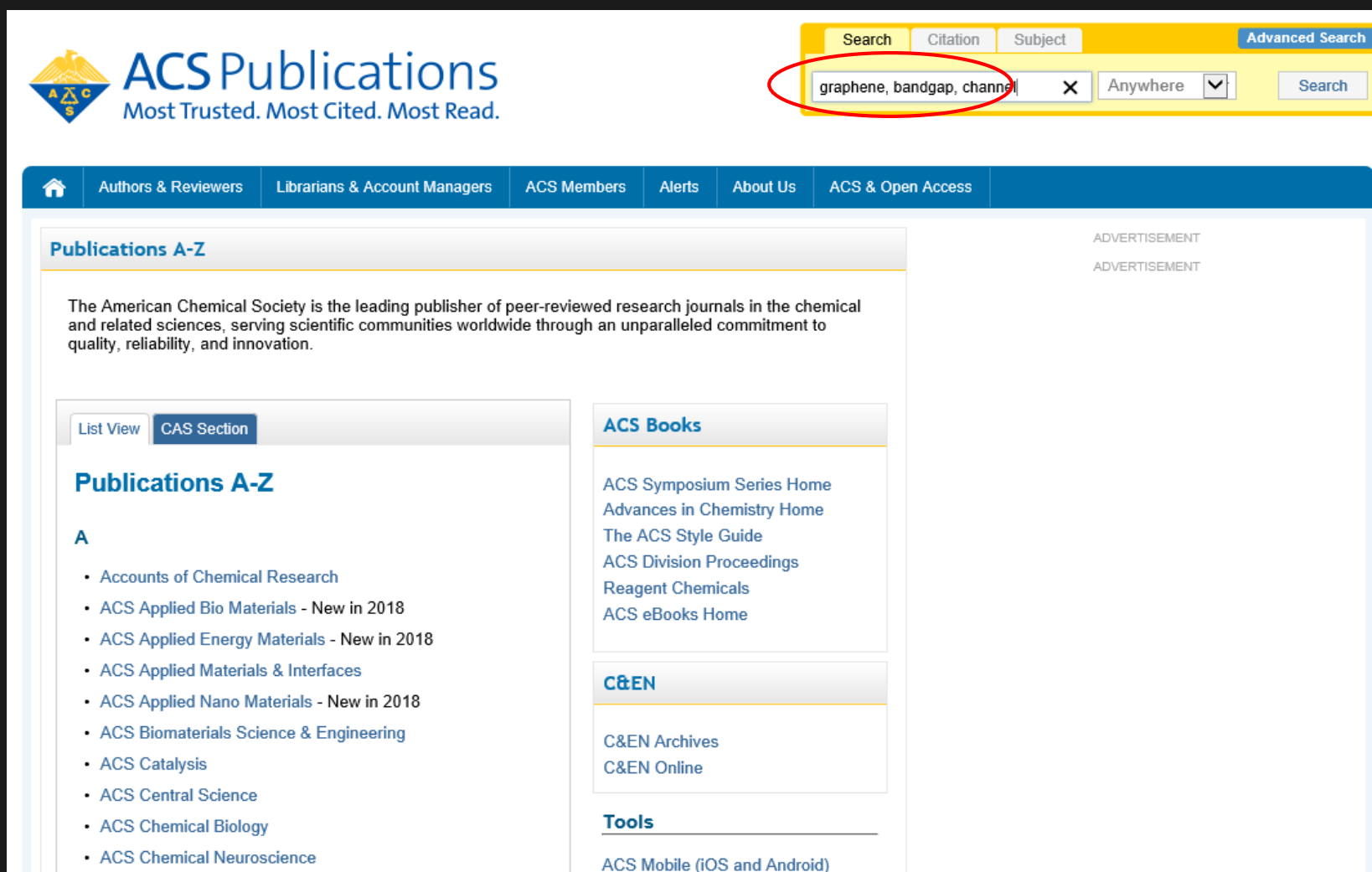
為推動我國綠能科技發展，國研院儀科中心「光學系統整合研發聯盟」主導結合全球最大LED晶片廠晶元光電、中央大學薄膜技術中心以及儀科中心等產學研三方能量，將先進材料石墨烯應用於紫外光發光二極體 (UV-LED)的製造技術，預期可提升台灣UV-LED製造技術水準，達到與美、日大廠並駕齊驅的境界，推估可有超過3.6億元以上的年產值。



## Relationship



# How ACS Journal Help Us to Resolve Issue ?



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# Searching Result

## □ Sub-100 nm Channel Length Graphene Transistors

Lei Liao, Jingwei Bai, Rui Cheng, Yung-Chen Lin, Shan Jiang, Yongquan Qu, Yu Huang, and Xiangfeng Duan

*Nano Lett.*, 2010, 10 (10), pp 3952-3956

Publication Date (Web): September 3, 2010 (Letter)

DOI: 10.1021/nl101724k

Here we report high-performance sub-100 nm channel length graphene transistors fabricated using a self-aligned approach. The graphene transistors are fabricated using a highly doped GaN nanowire as the local gate with the source and drain electrodes ...

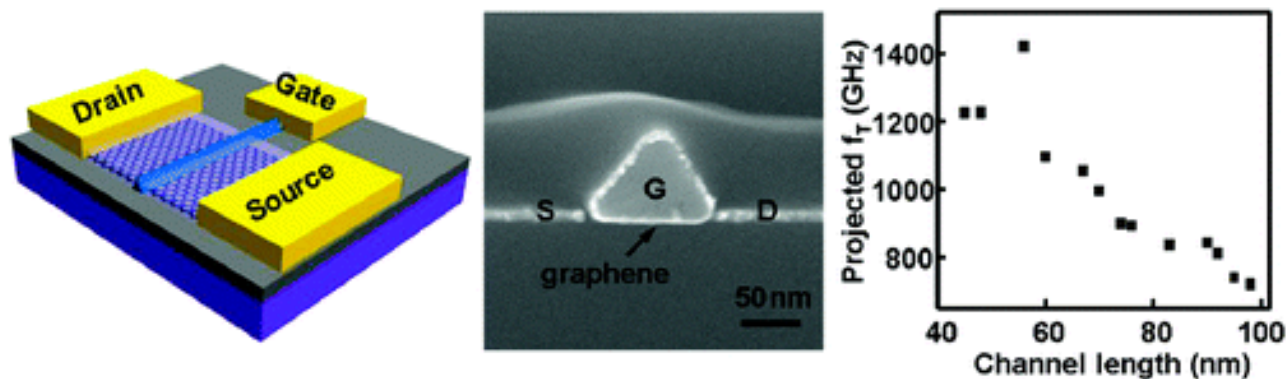


Figure 1 of 5

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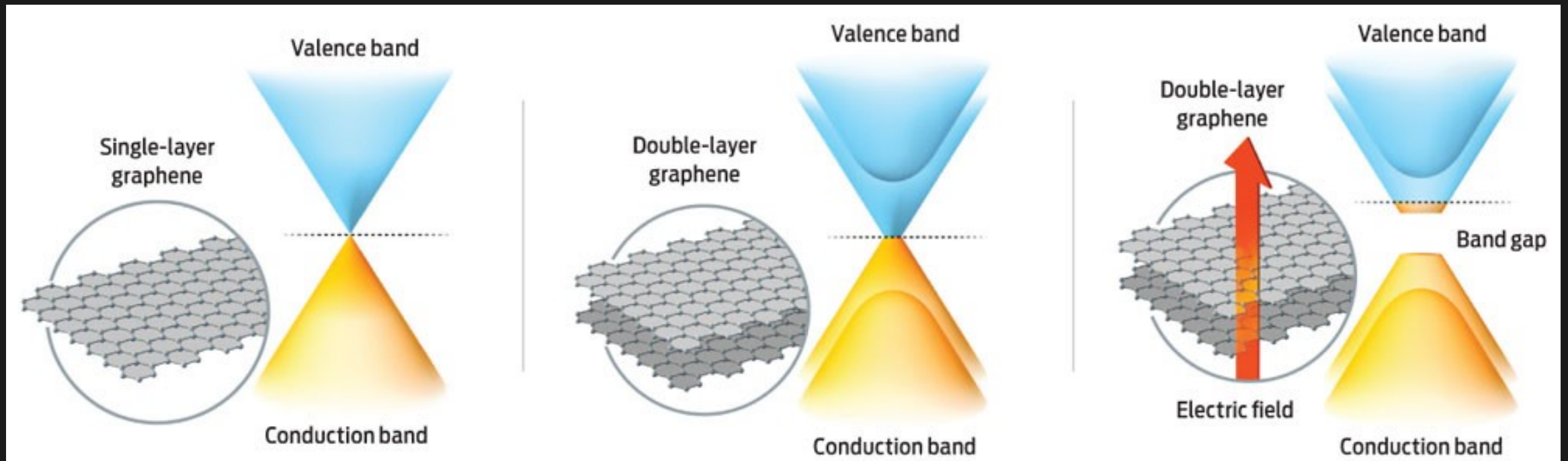
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# Alternative Way for Tunable Bandgap



# Summary

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## For More Moore

- Scaling technology is more and more tough, especially for EUV lithography process.
- New material and new structure are necessary to keep Moore's law on-going.

## For More than Moore

- New thinking for specific application can be more flexible to create new market.
- Technology needs to be compatible with Si-base IC technology and low cost.