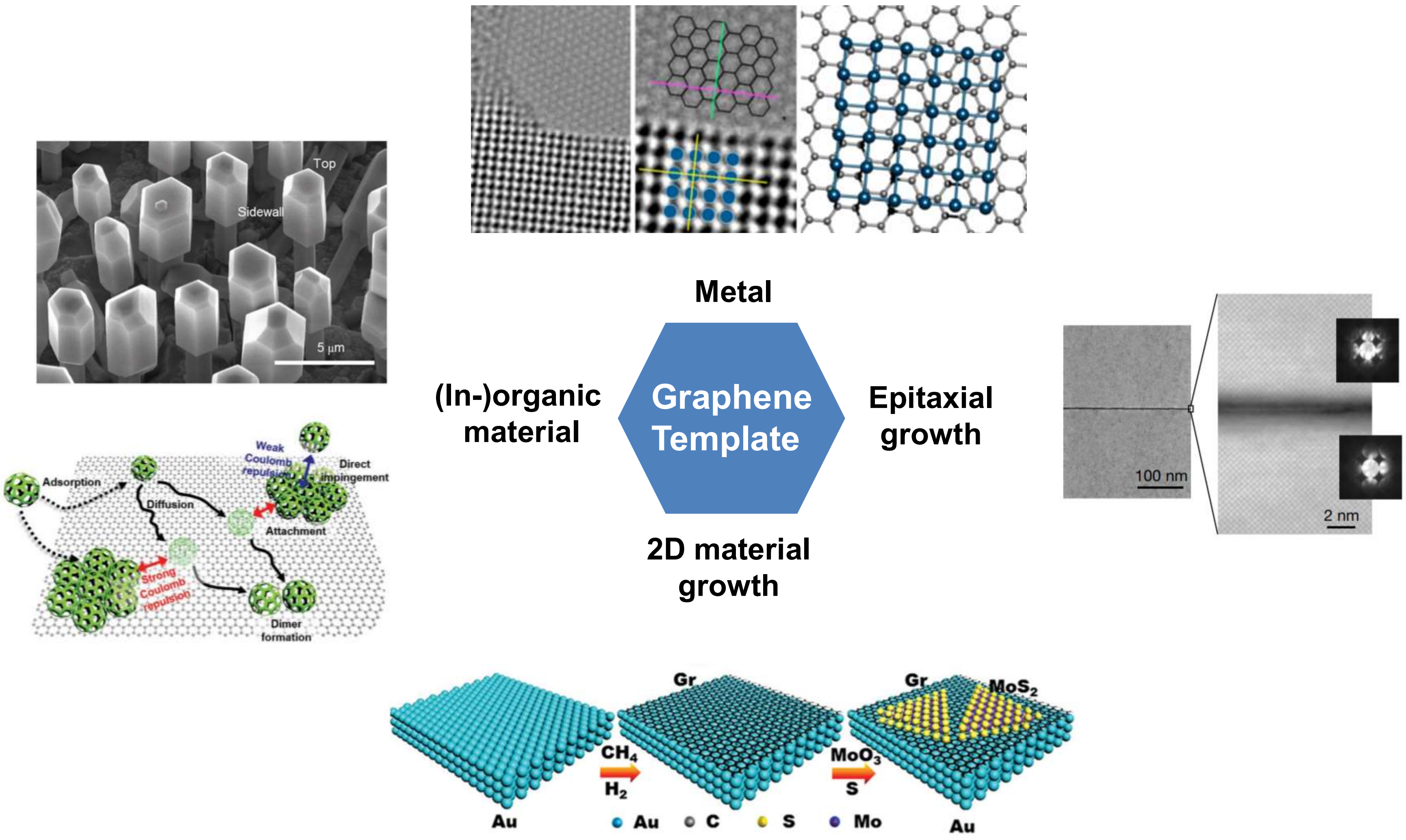
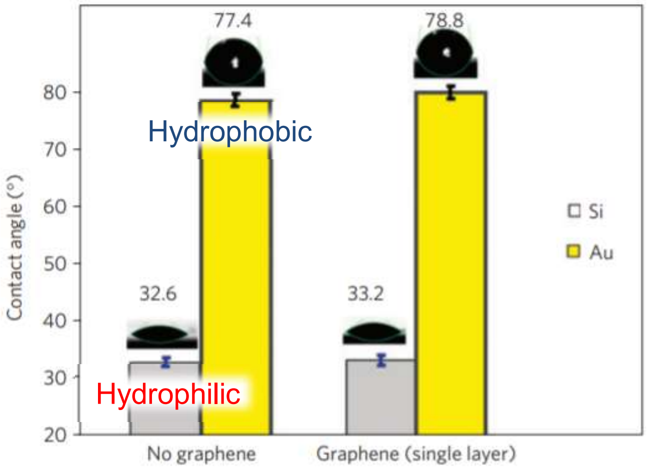
# 5. Production of 2D Materials
# Part 3

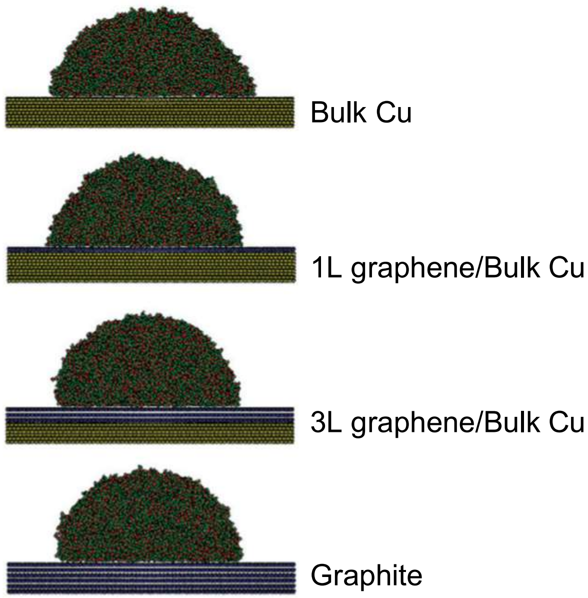
# Productions of 2D Materials



# Surface Properties of Graphene

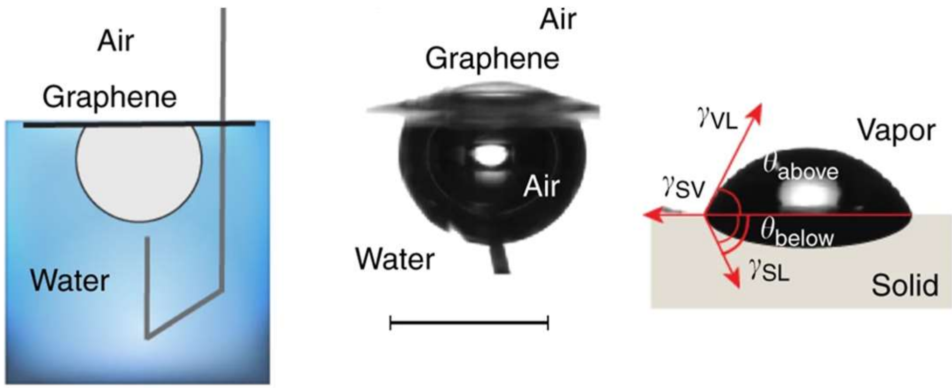
## Wetting transparency of graphene

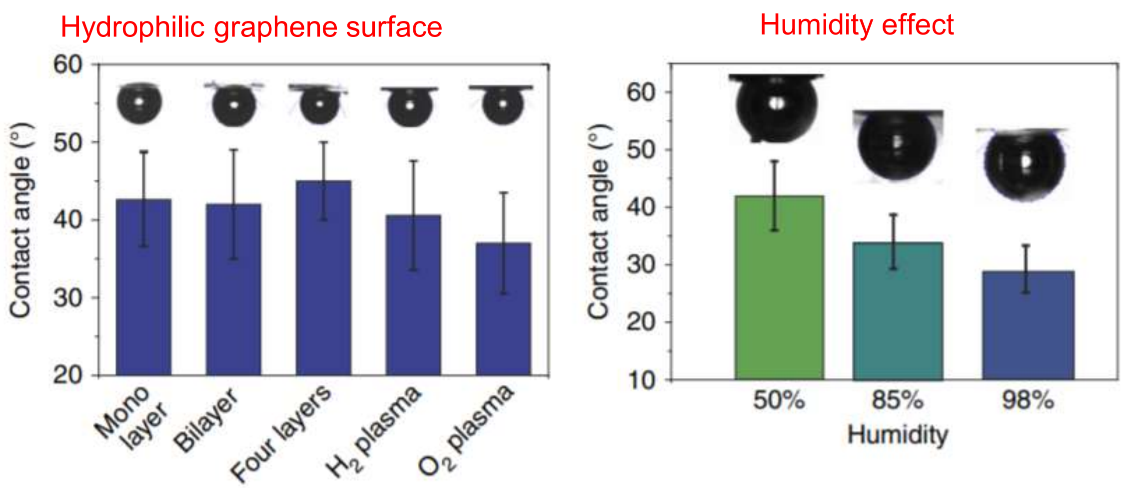



*Nature Materials 11(3), 217–222 (2012)*

## Contact angle of graphene

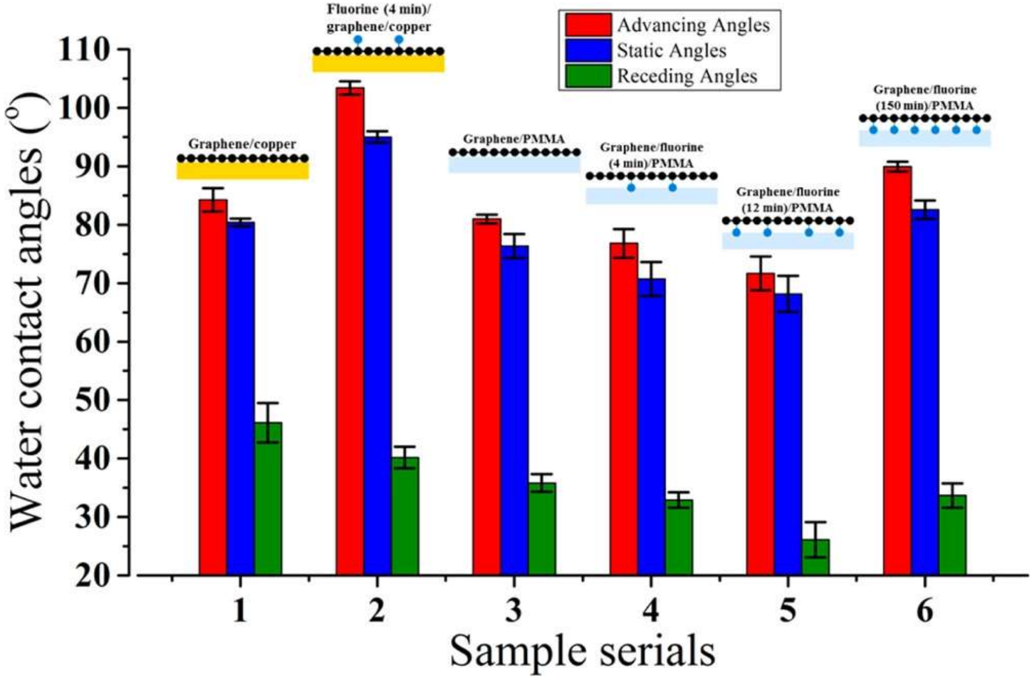


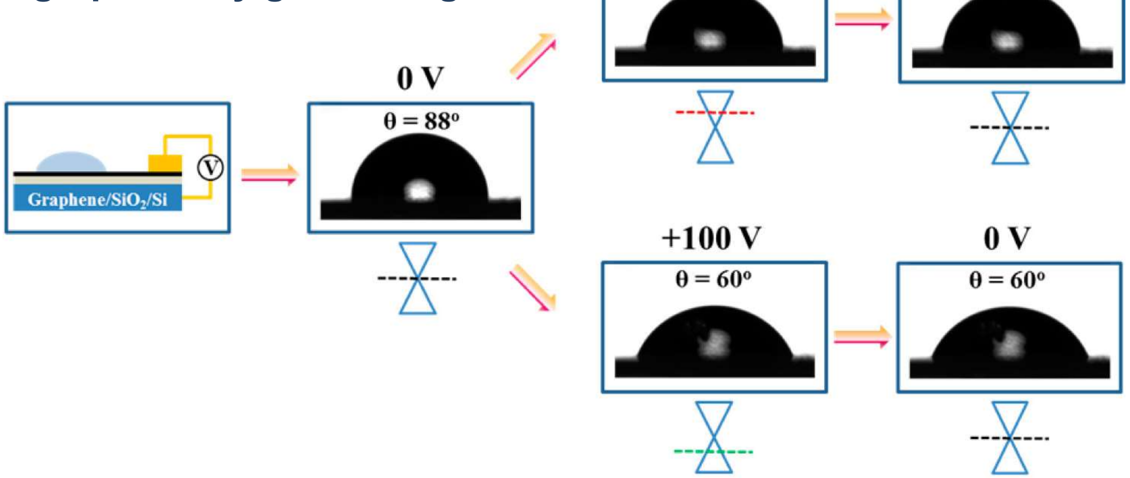

- Hydrophilicity of graphene can be influence and modulated by environment.

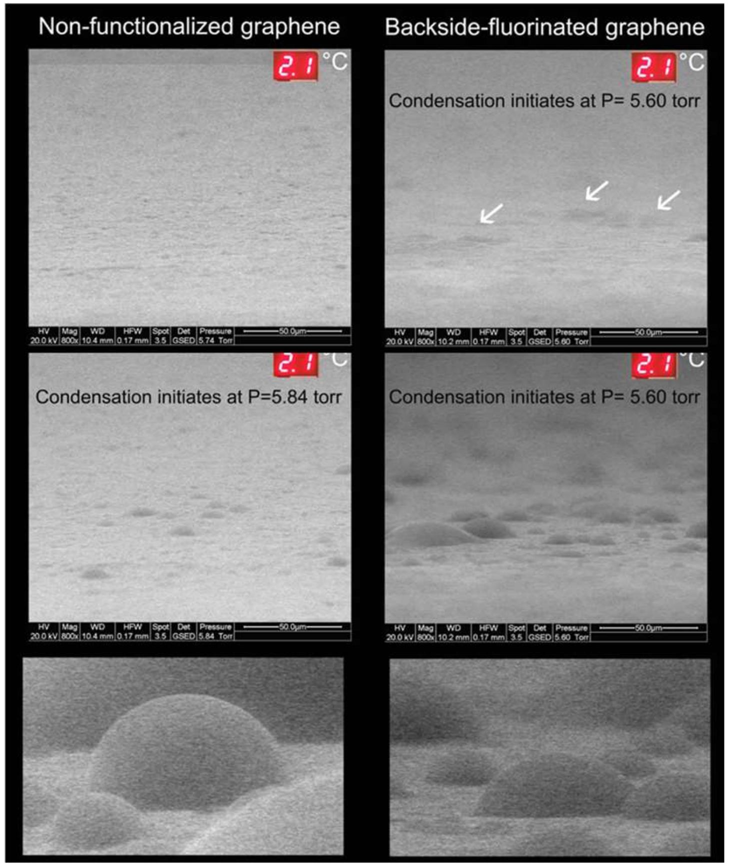
*Nature Communications, 9, 1 (2018)*

# Surface Properties of Graphene




**Contact angle control of graphene by gate voltage**

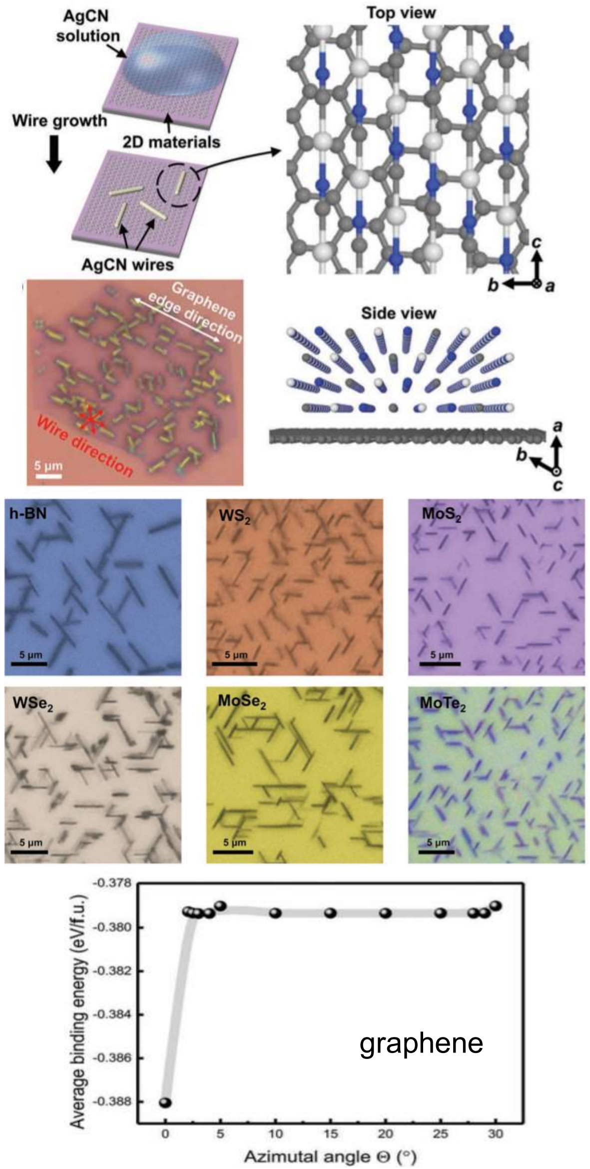



*Nano Letters, 16(7), 4447–4453 (2016)*

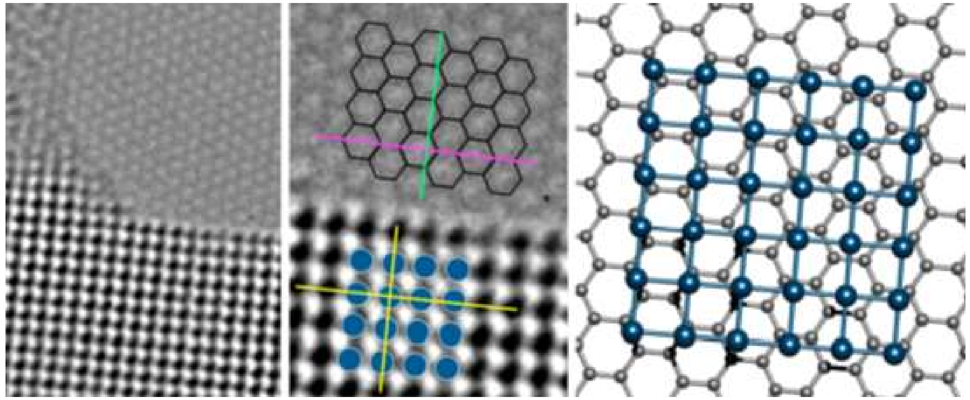
# Metals on Graphene

## Cyanide on 2D hexagonal crystals



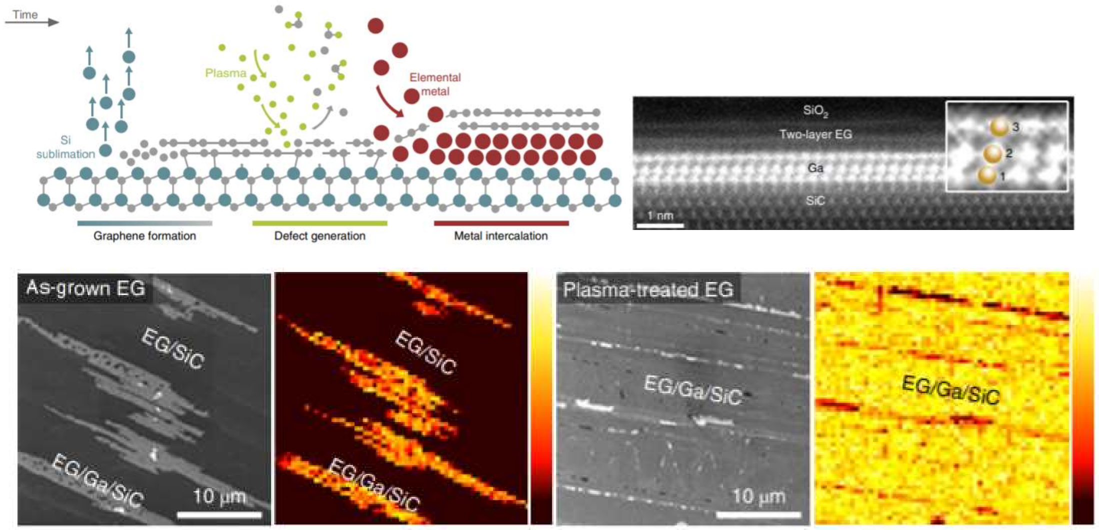

*Adv. Sci. 1900757 (2019)*

## InGaN/GaN core–shell microrods on graphene



*ACS Nano 13, 10, 12162-12170 (2019)*

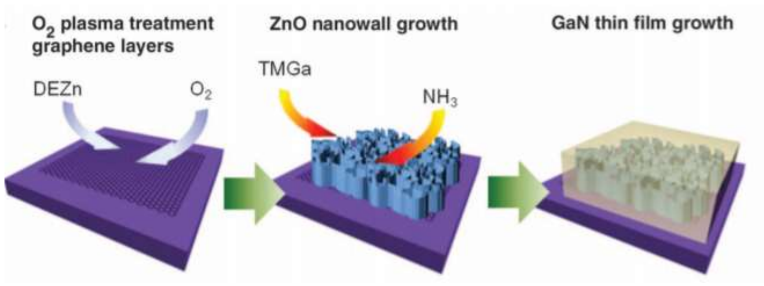
## Single-crystal 2D metals at the interface of graphene and SiC



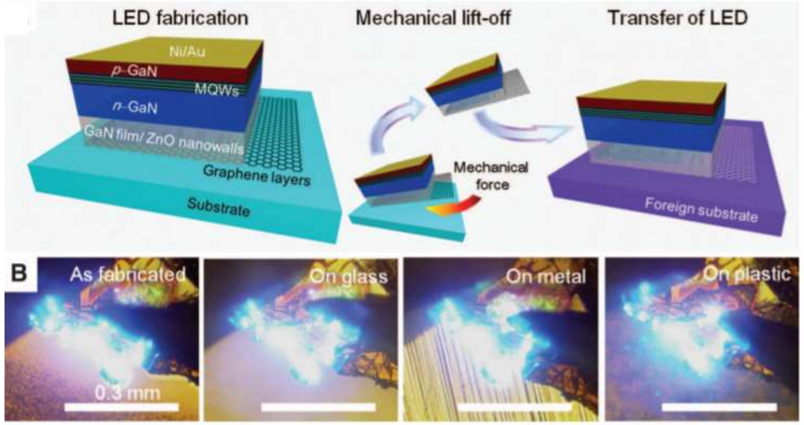

*N. Briggs et al. Nature Materials (2020)*

# Inorganic material growth on Graphene

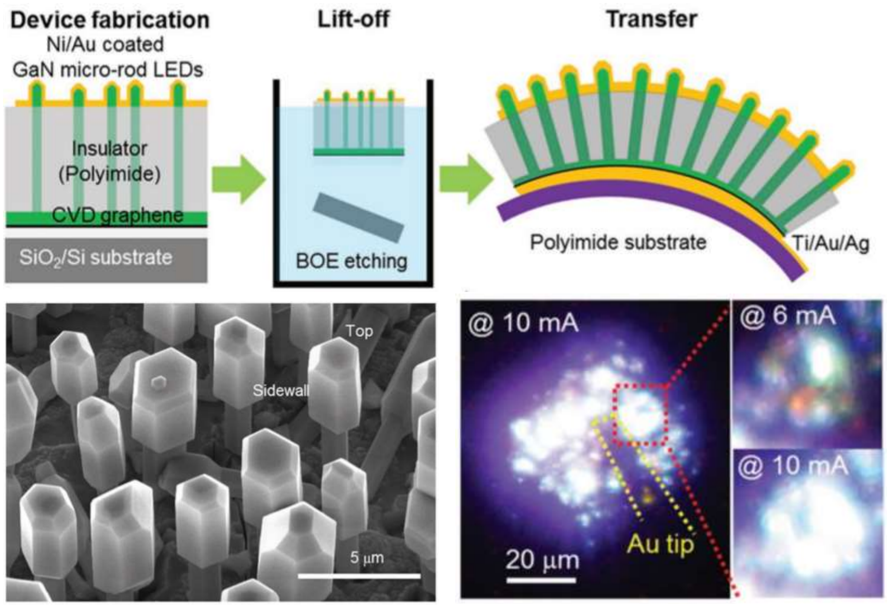
## GaN on ZnO-coated Graphene




*Science, 330, 6004, 655–657 (2010)*

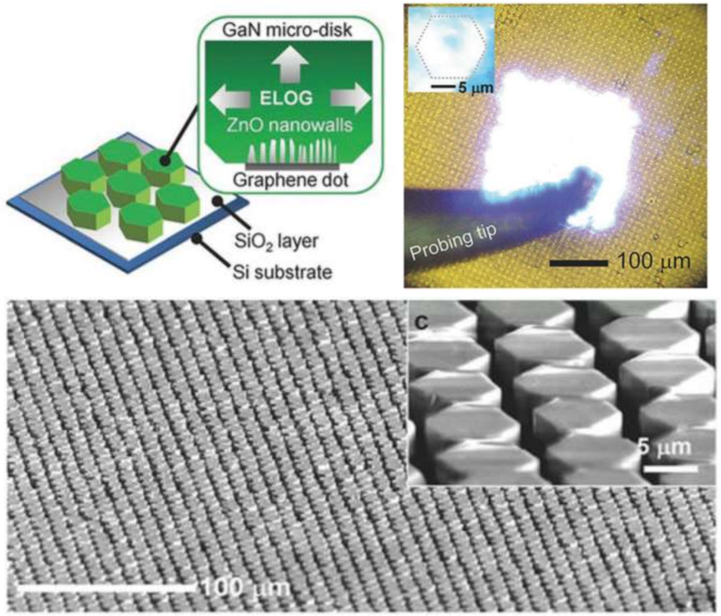



## InGaN/GaN core–shell microrods on graphene




*APL Mater. 2, 092512 (2014)*

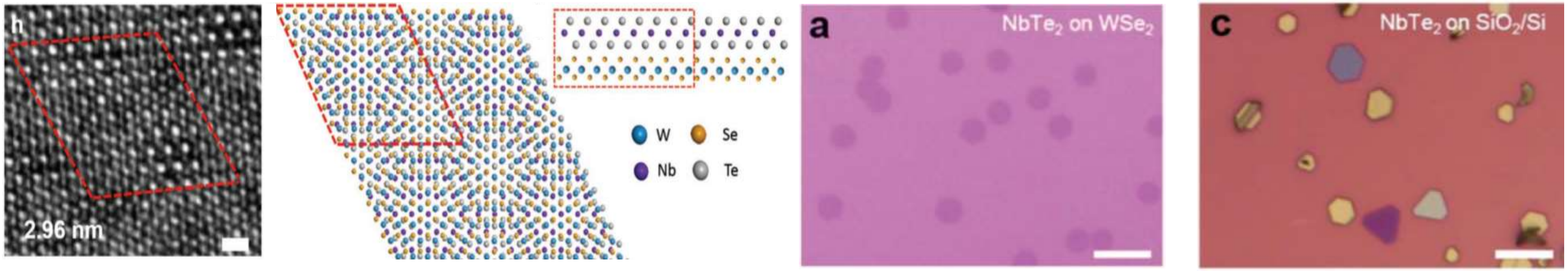
## GaN microdisk arrays on ZnO/graphene dots




*Adv. Mater. 28, 7688 (2016)*

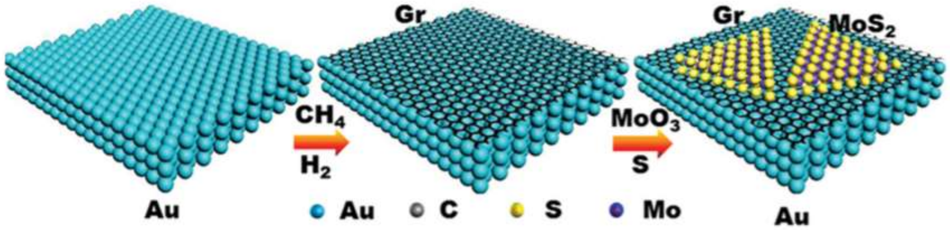
# Growth of 2D material on 2D material

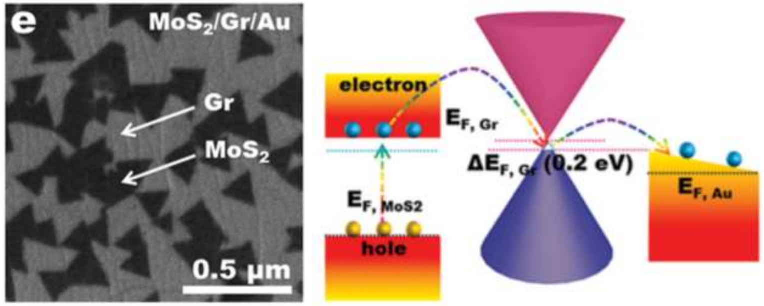
## 2D metal on $WSe_2$ ($WS_2$)




*Adv. Funct. Mater. 1806611 (2019)*

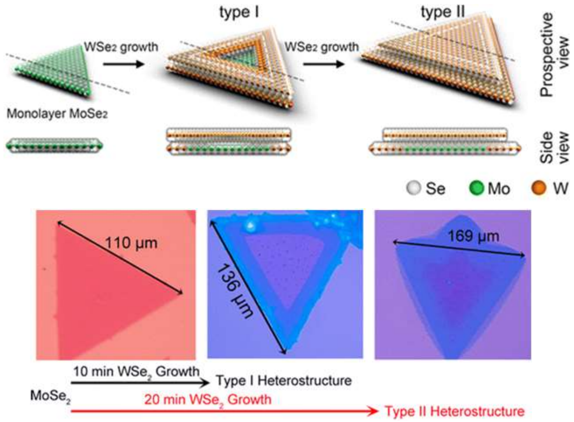
## $MoS_2$ on graphene

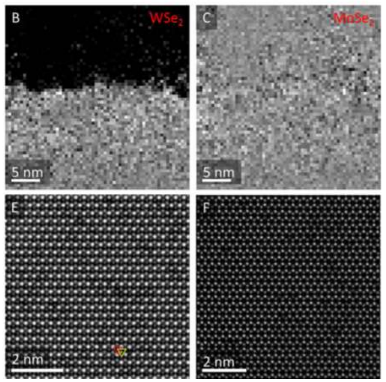


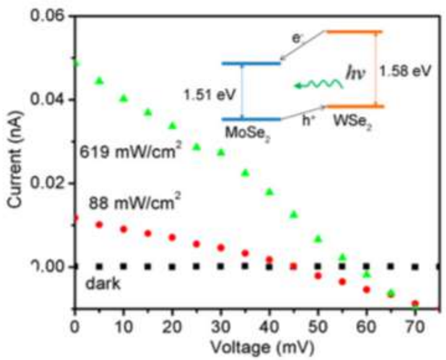




*Adv. Mater. 27, 7086–7092 (2015)*

## $WSe_2$ ($WS_2$) on $MoSe_2$

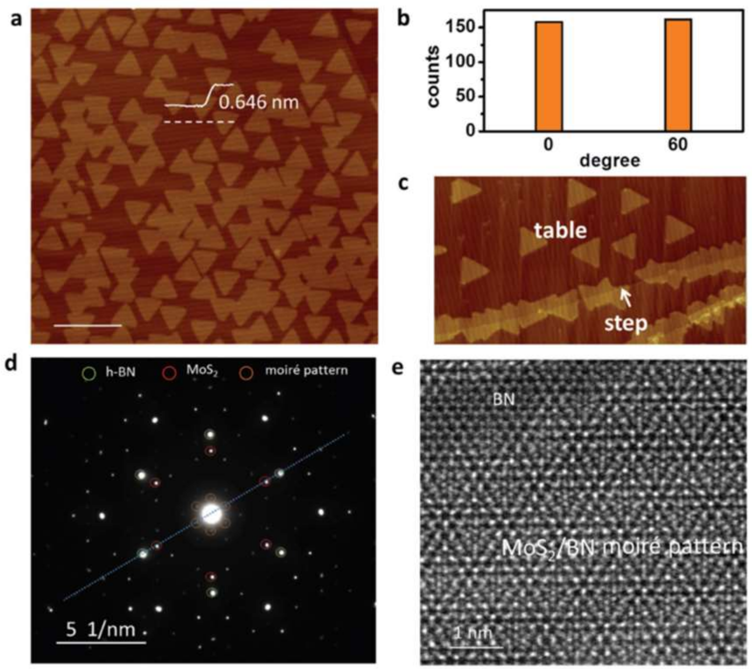


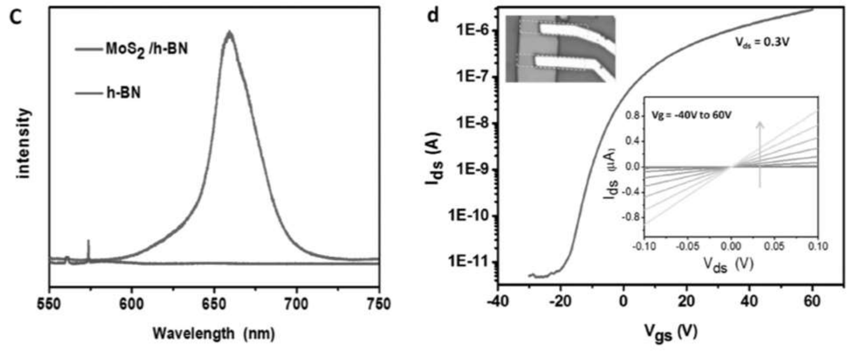



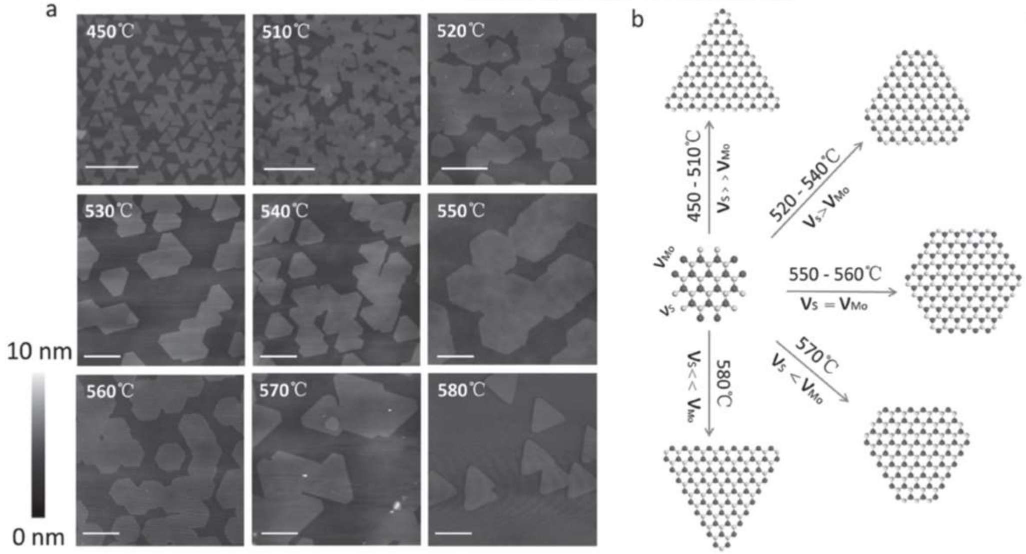



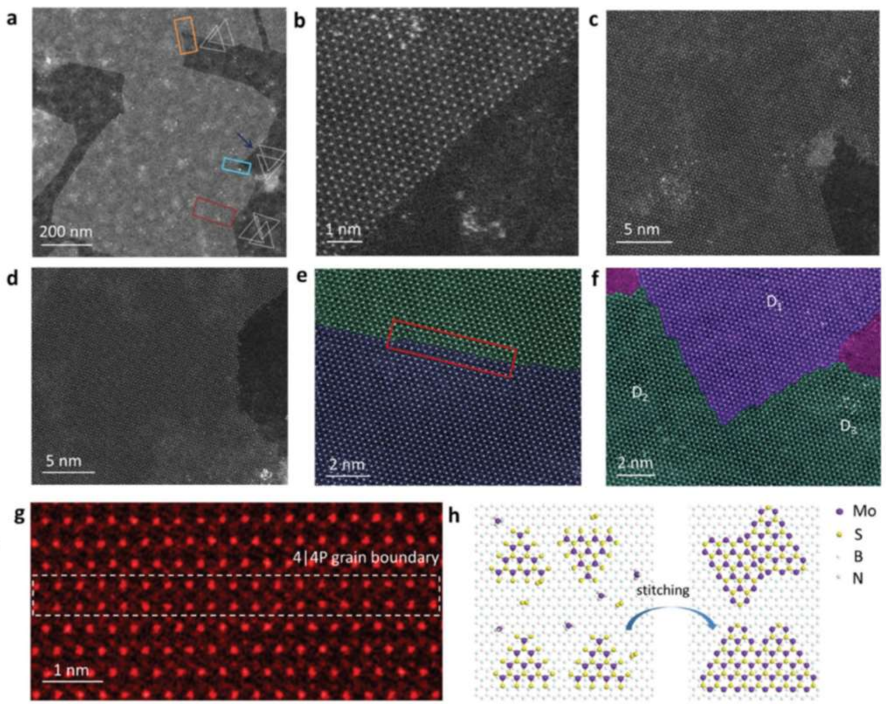
# Growth of 2D material on 2D material

## $MoS_2$ on hBN



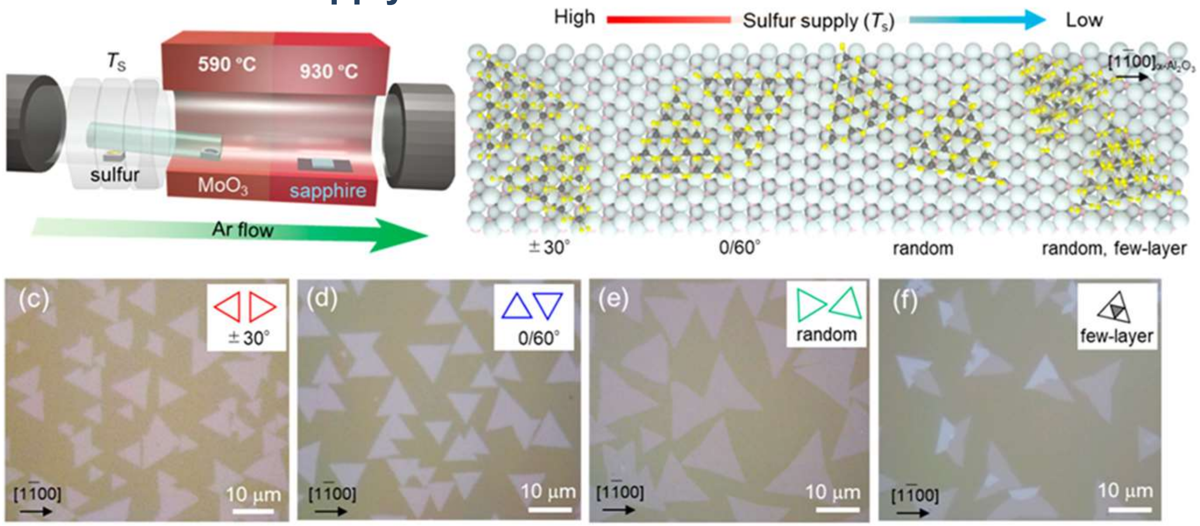



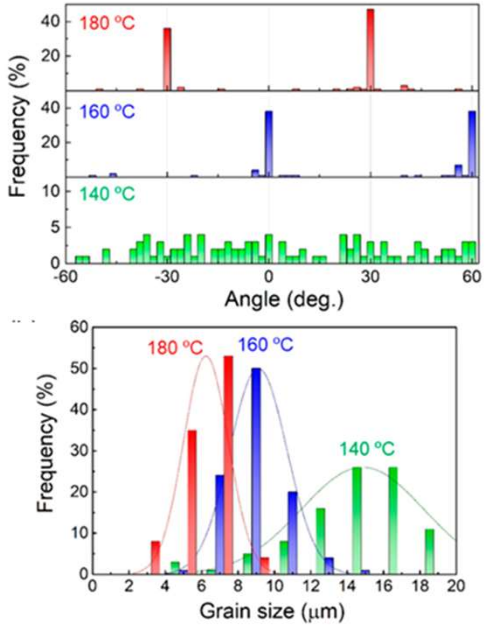




*H. Yu et al. Small 13, 160300527 (2017)*

# Growth of 2D material on 2D material

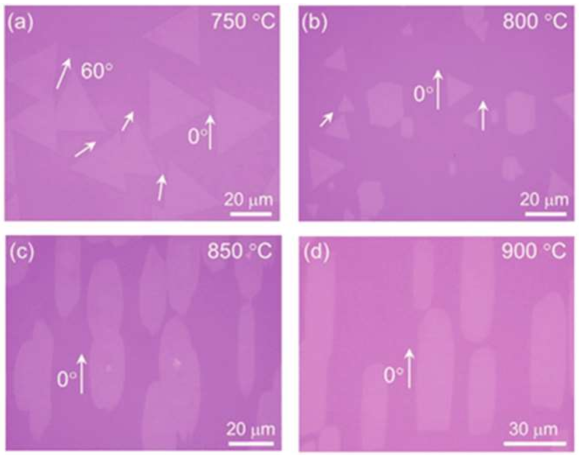
## Effect of sulfur supply

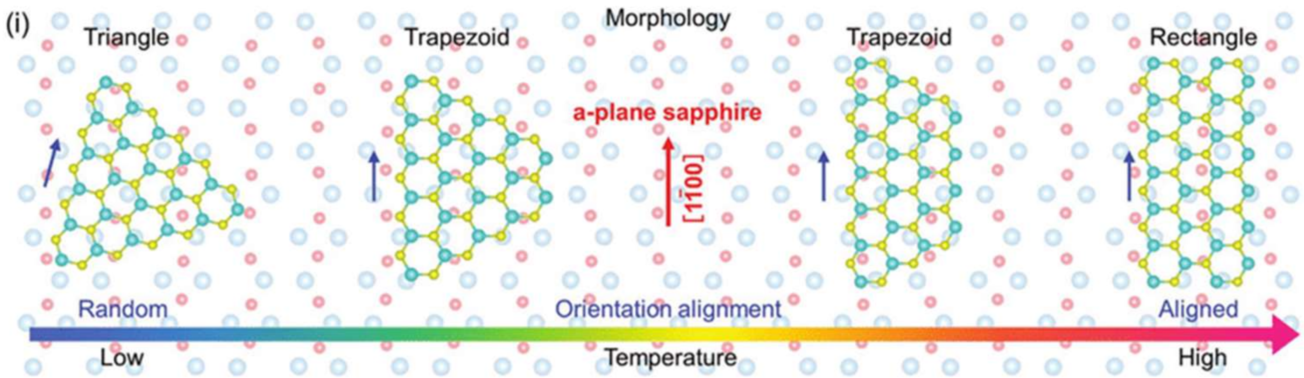



ACS Nano 12, 10, 10032-10044 (2018)

## Effect of substrate crystalline direction and growth temperature

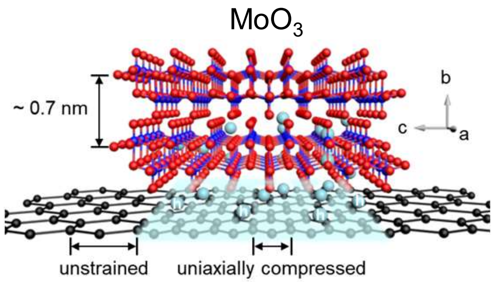


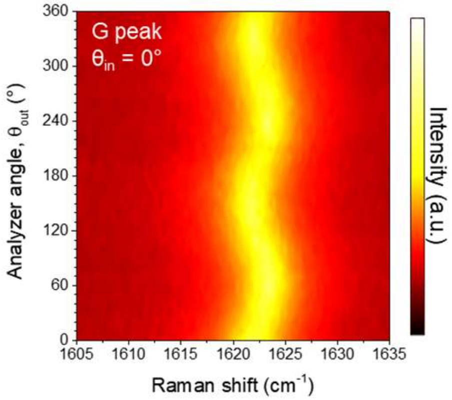



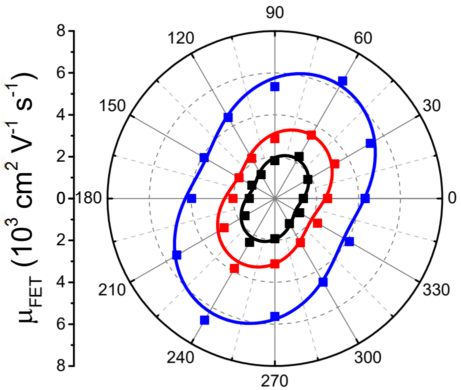

Small 16, 16, 2000596 (2020)

# Growth of 2D material on 2D material

### van der Waals epitaxy and conductivity anisotropy of graphene



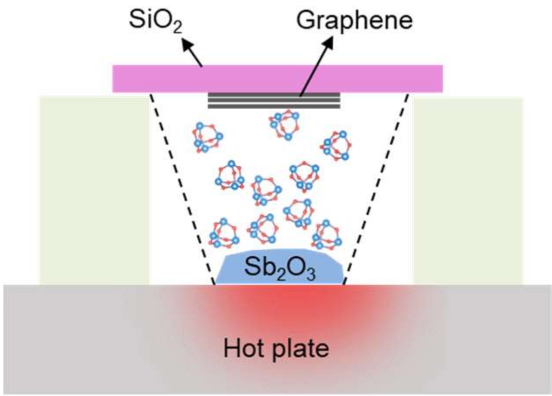



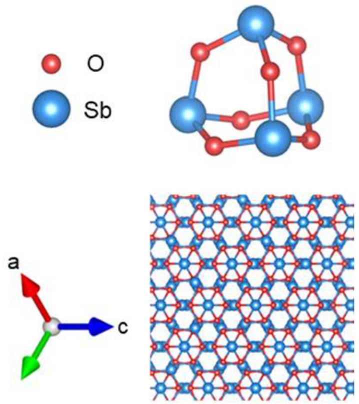




*In preparation*

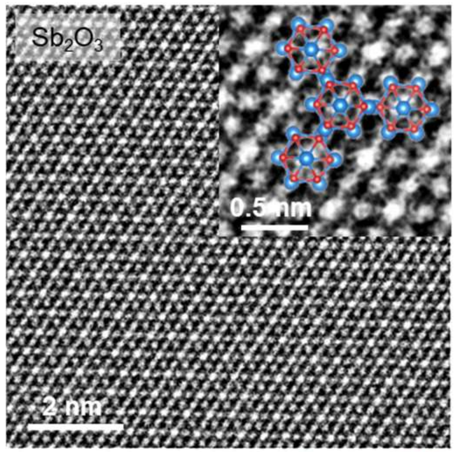
*H.G. Kim et al. Science Advances (2023)*

### Epitaxial growth of high-k dielectric on graphene




*In progress*

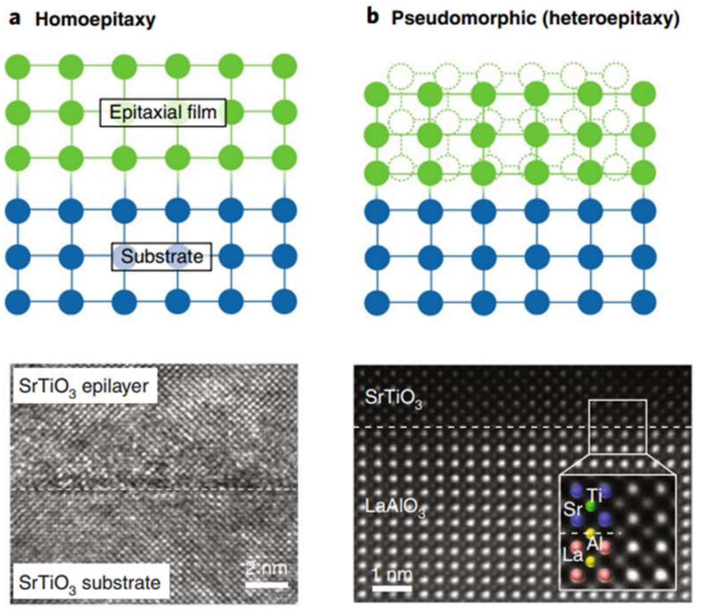


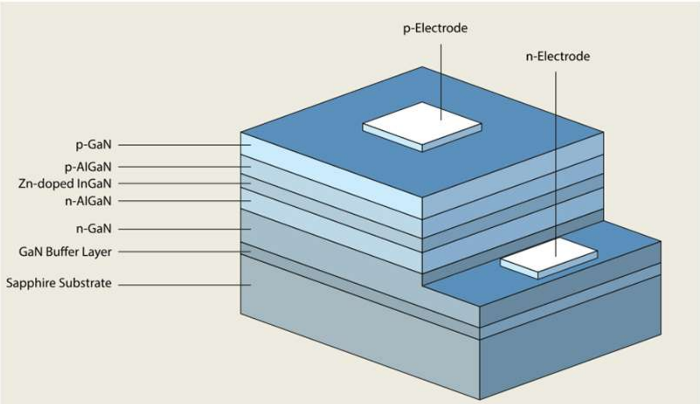

$k_{Sb2O3}$ ~ **12.5**

*H.J. Ryu et al. in preparation*

# Advantages of van der Waals Epitaxy

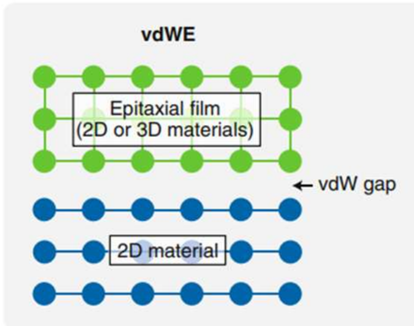
## Conventional epitaxy

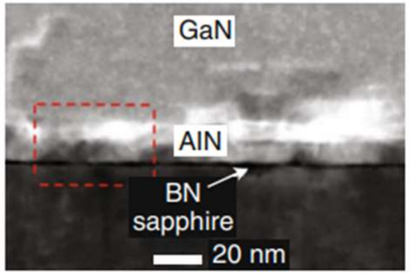


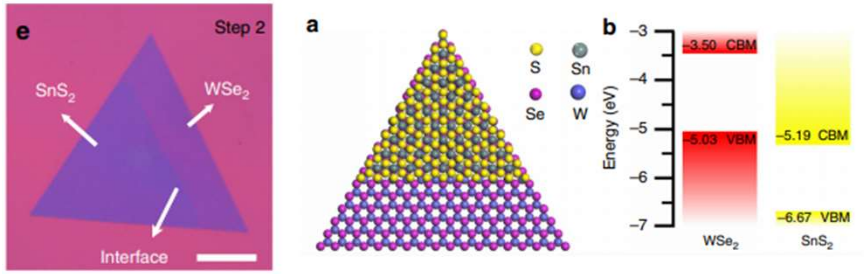

*Nobel Prizes, 2014*

## Van der Waals epitaxy

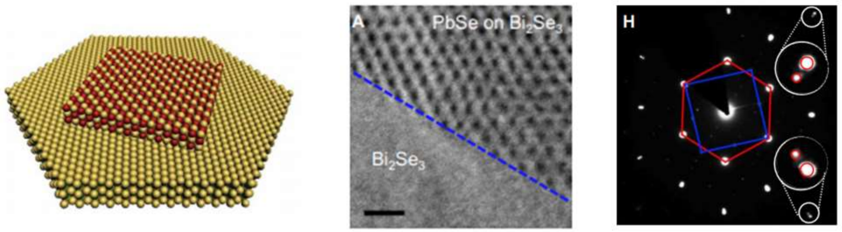



*Nature Electronics, 2, 2019*




*Nature Comm. 2017*

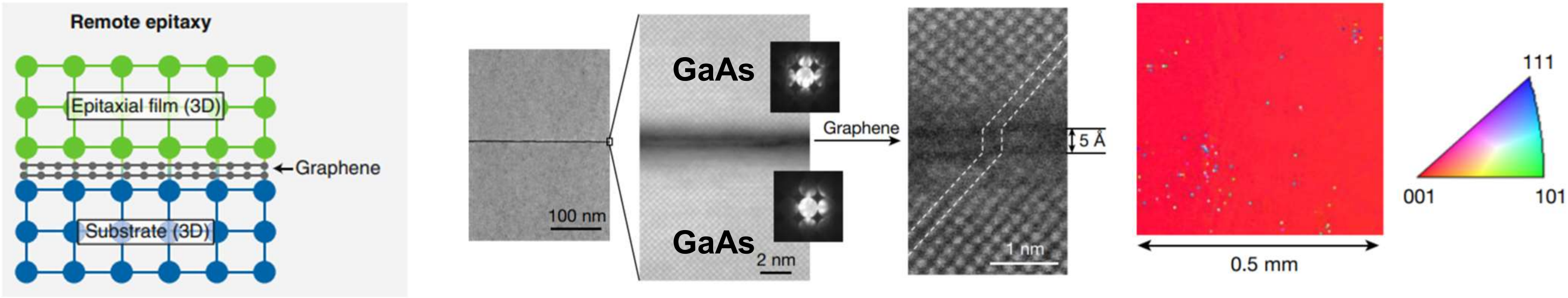



*Sci. Adv. (2016)*

- ❑ Interface with weak van der Waals interaction
- ❑ Higher tolerance in lattice mismatch (~40%)
- ❑ Symmetry-mismatch growth

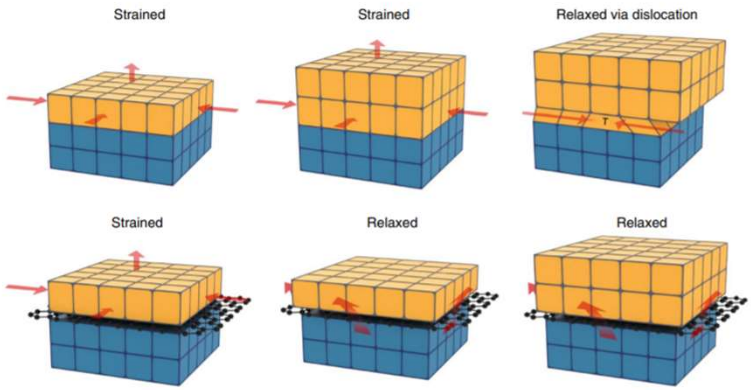
# Remote Epitaxial Growth

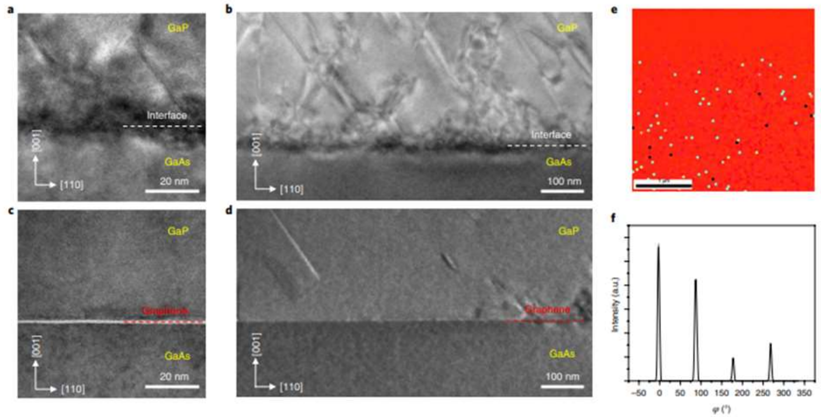
## GaAs(001) on graphene/GaAs(001)




*Nature (2017)*

## InGaP on graphene/GaAs




*Nature Nanotechnology (2020)*

- ❑ Epitaxial growth through transparent graphene
- ❑ Strain relaxation by slippery interface without dislocation