

Deterministic and Scalable Growth of Electrically Self-Contacted 2D Materials-Based Devices

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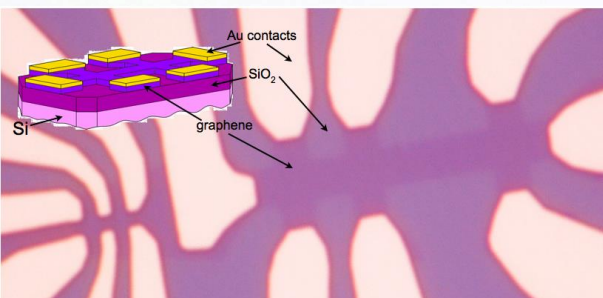
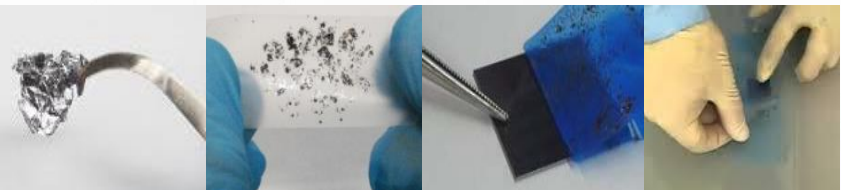


7th edition of the largest European Conference & Exhibition in Graphene and 2D Materials

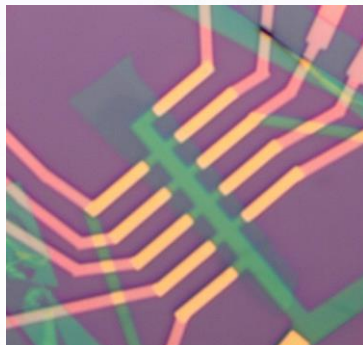
The logo for the Graphene 2017 conference. It features a large, stylized 'G' in a blue circle, followed by the word 'Graphene' in a bold, sans-serif font. Below this, the year '2017' is written in a large, blue font, and the dates 'March 28-31' and 'Barcelona (Spain)' are written in a smaller, blue font.

Graphene
2017
March 28-31
Barcelona (Spain)

Mechanical Exfoliation



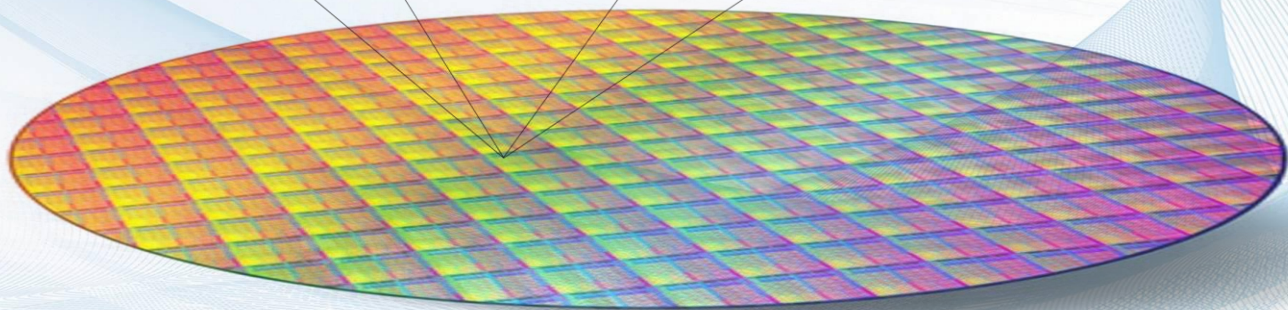
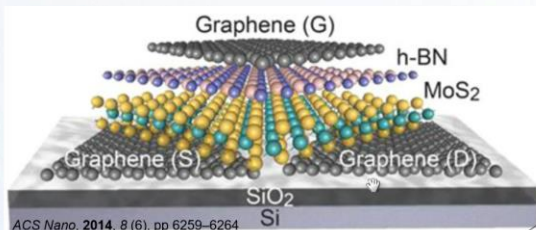
<http://graphene.nus.edu.sg/content/graphene>



http://www.planarmaterials.com/store/p144/High_mobility_graphene_heterostructures.html



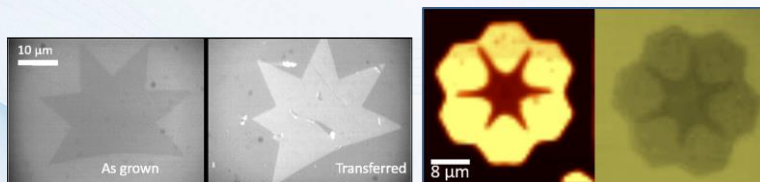
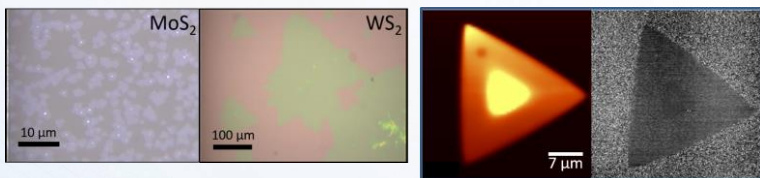
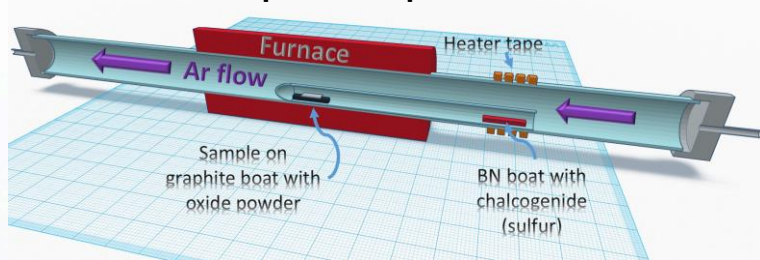
Nanocarbon group, DTU Nanotech, Technical University of Denmark



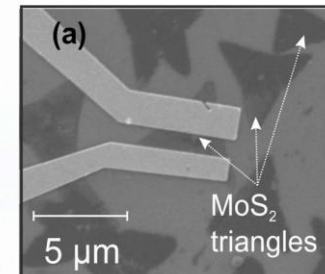
Challenges

- Variability
- Reproducibility
- Contacting
- **Scalability**

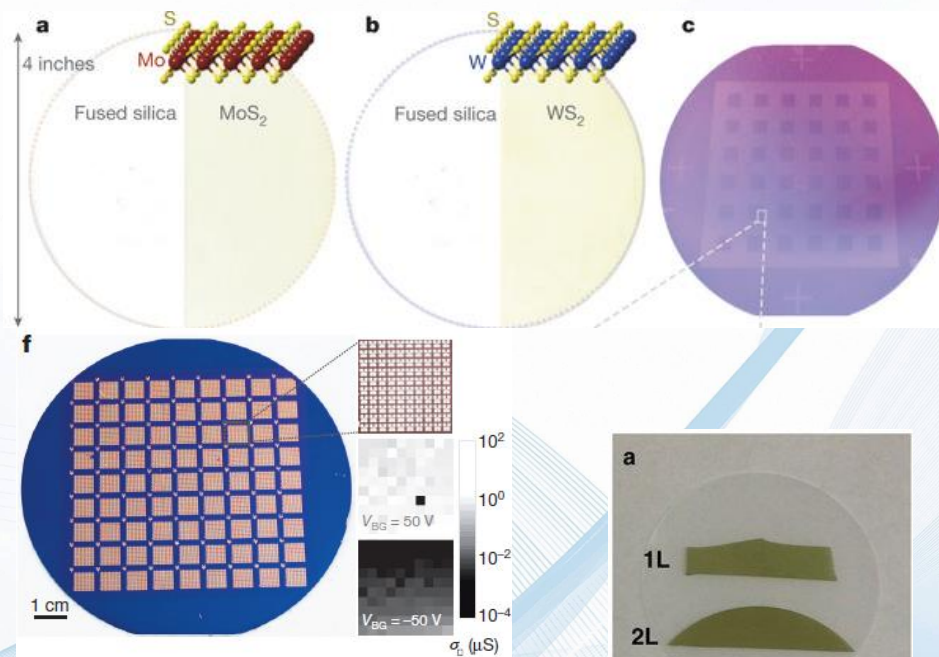
Chemical Vapor Deposition



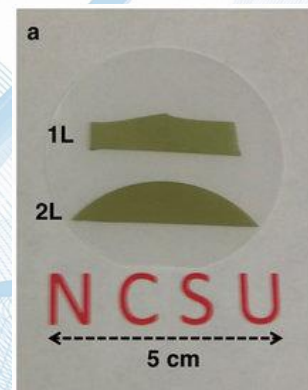
CVD method



2D Mater., 2014, 1, 011004



Kibum Kang, et al, *Nature*, 520, 656 (2015)



Scientific reports 3 (2013): 1866.

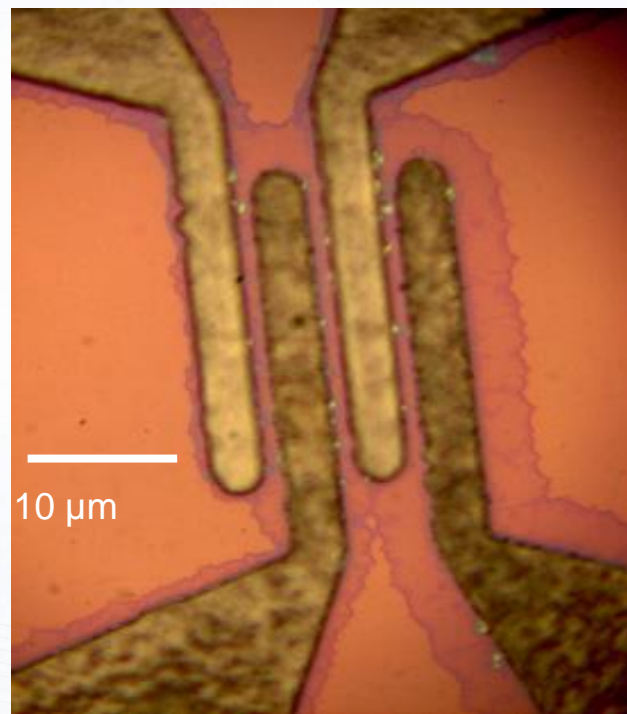
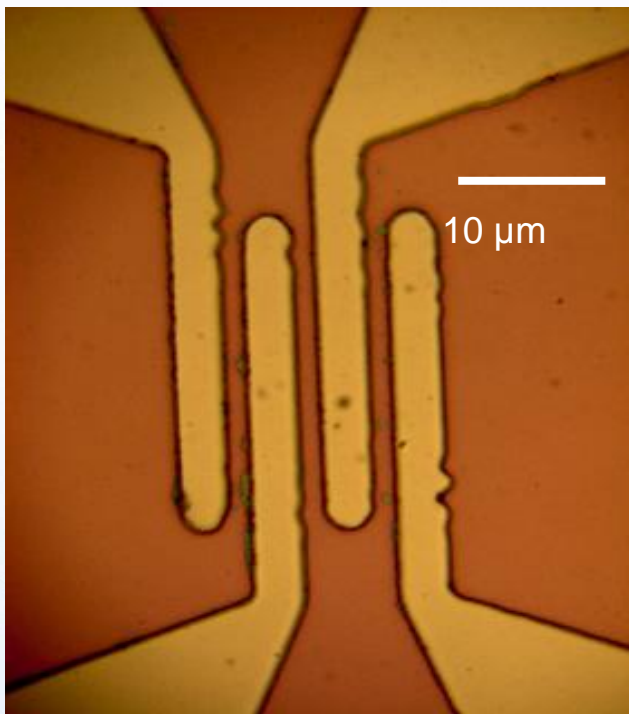
Challenges

- Processing variability
- Material modification
- Transfer

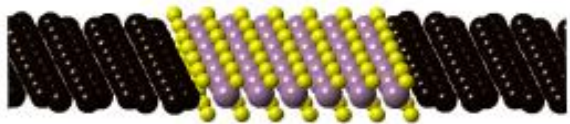
Start with device structure



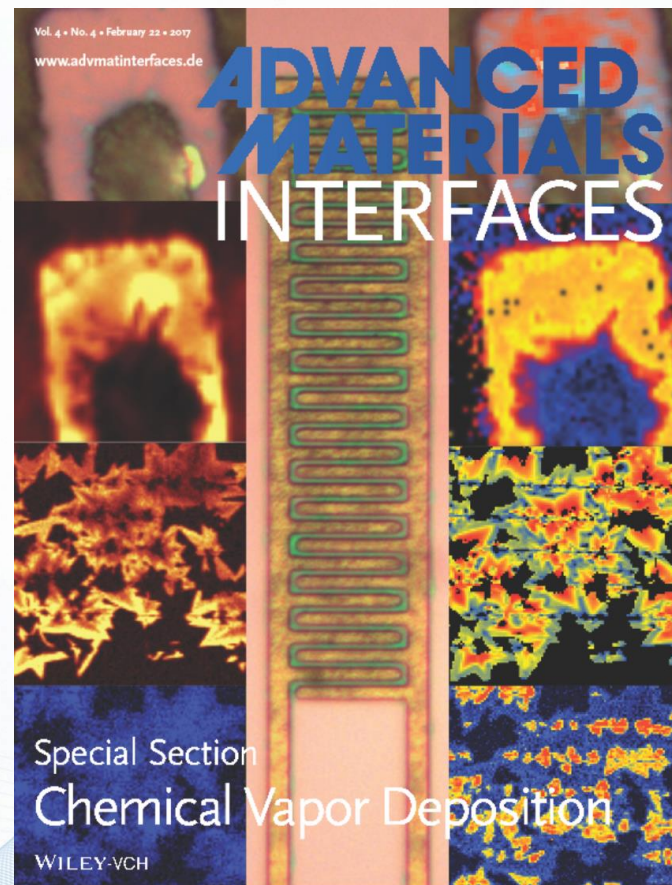
Grow material

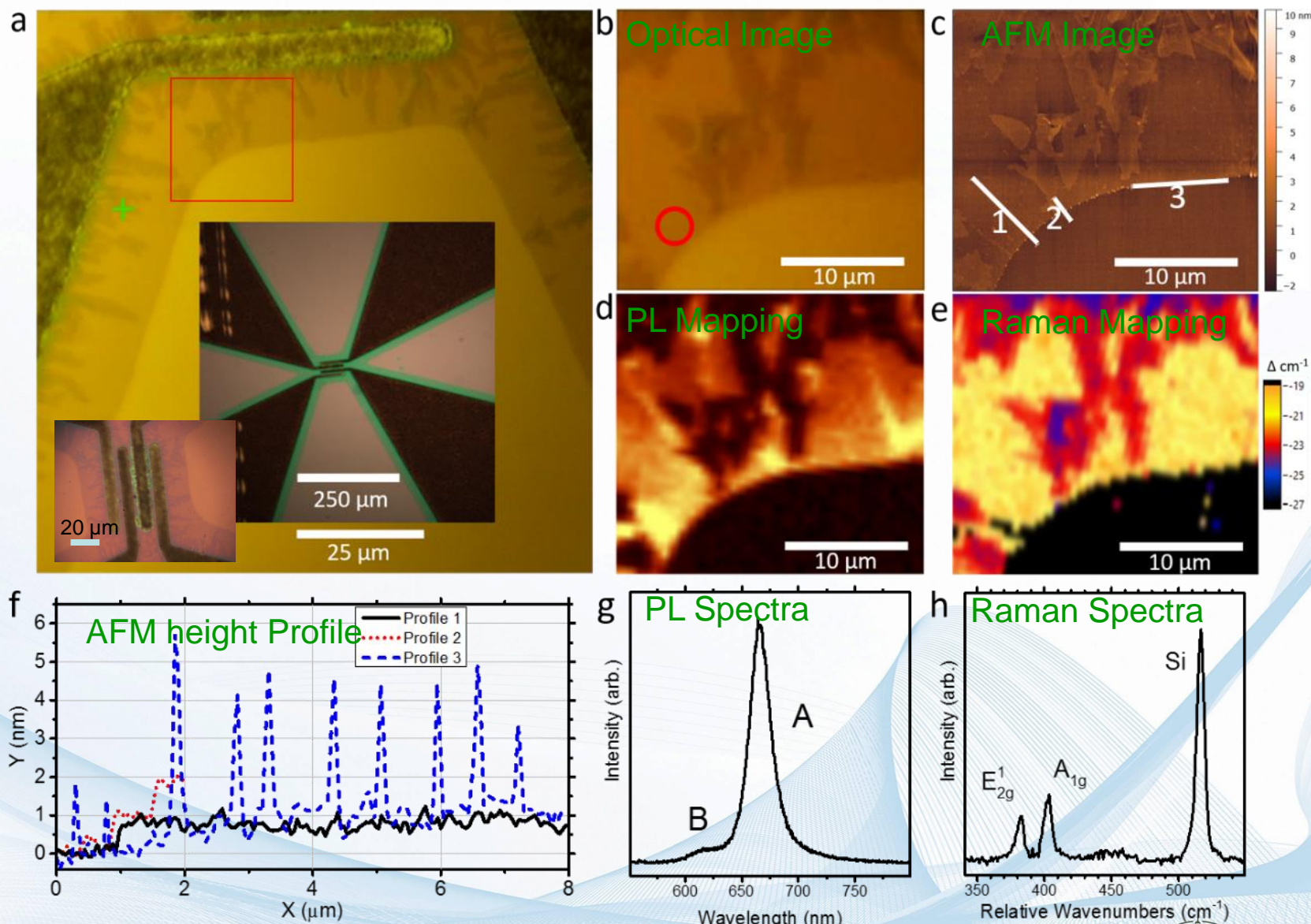


1DG

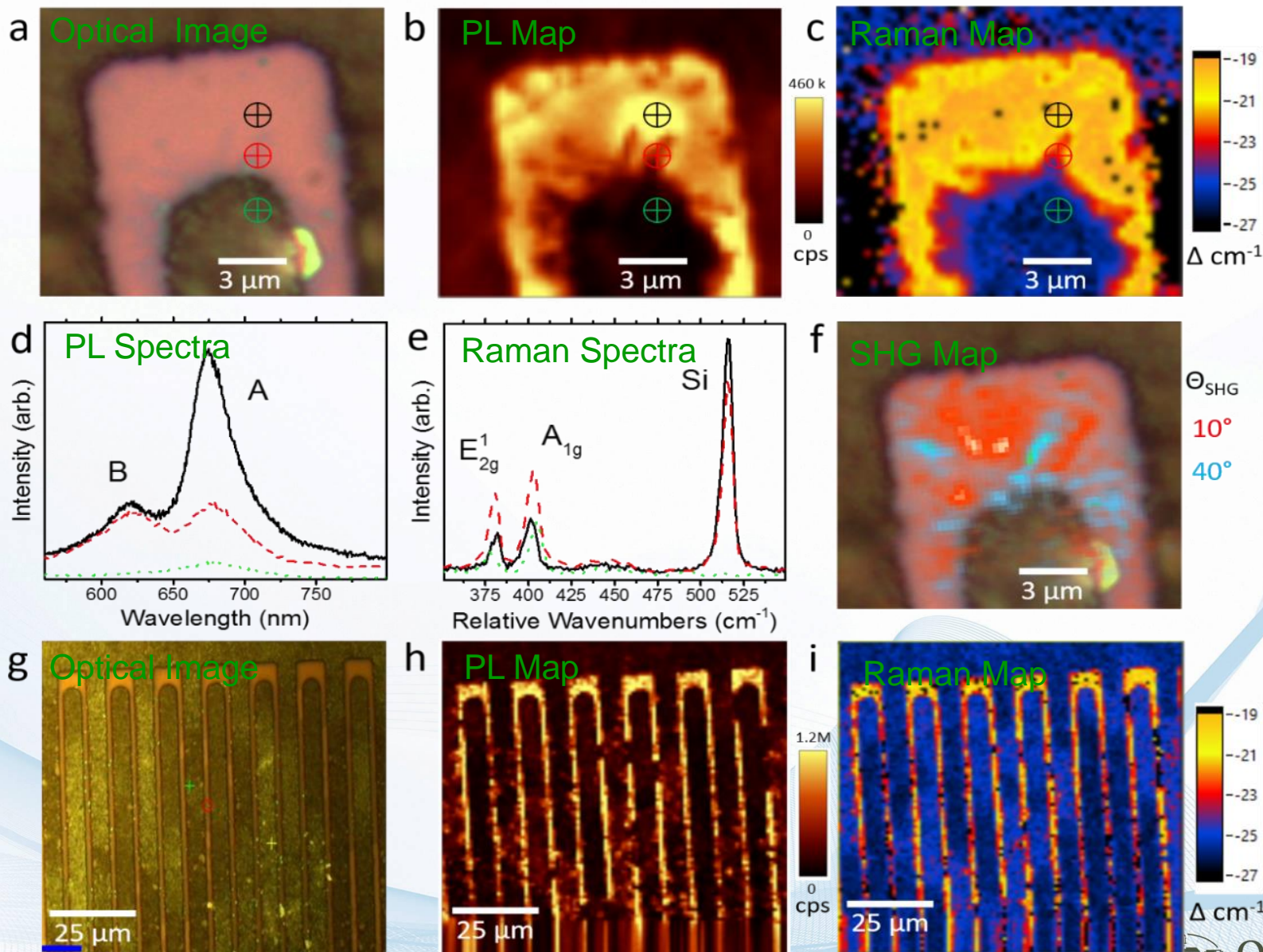


- Deterministic
- Scalable
- Compatible with existing silicon processing
- Provides concurrent, as-grown, electrical contacts
- Heterostructures
- Direct on-chip optics?
- Doping?
- Complex geometries?



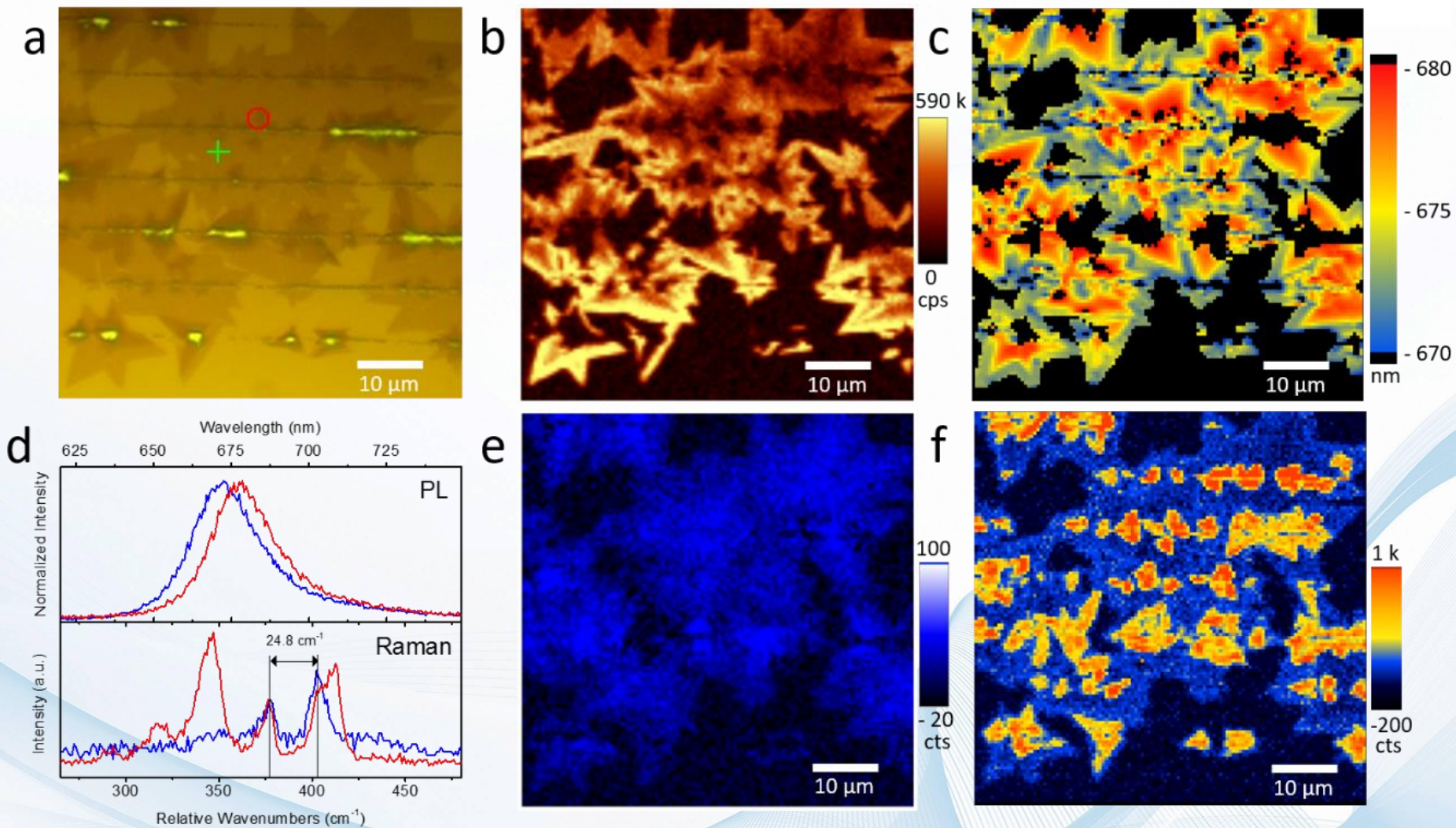


ONQPI Continuous mono MoS₂ between the patterns



Khadka S., et al. *Advanced Materials Interfaces* (2016)

DOI: 10.1002/admi.201600599 or arXiv:1611.03887



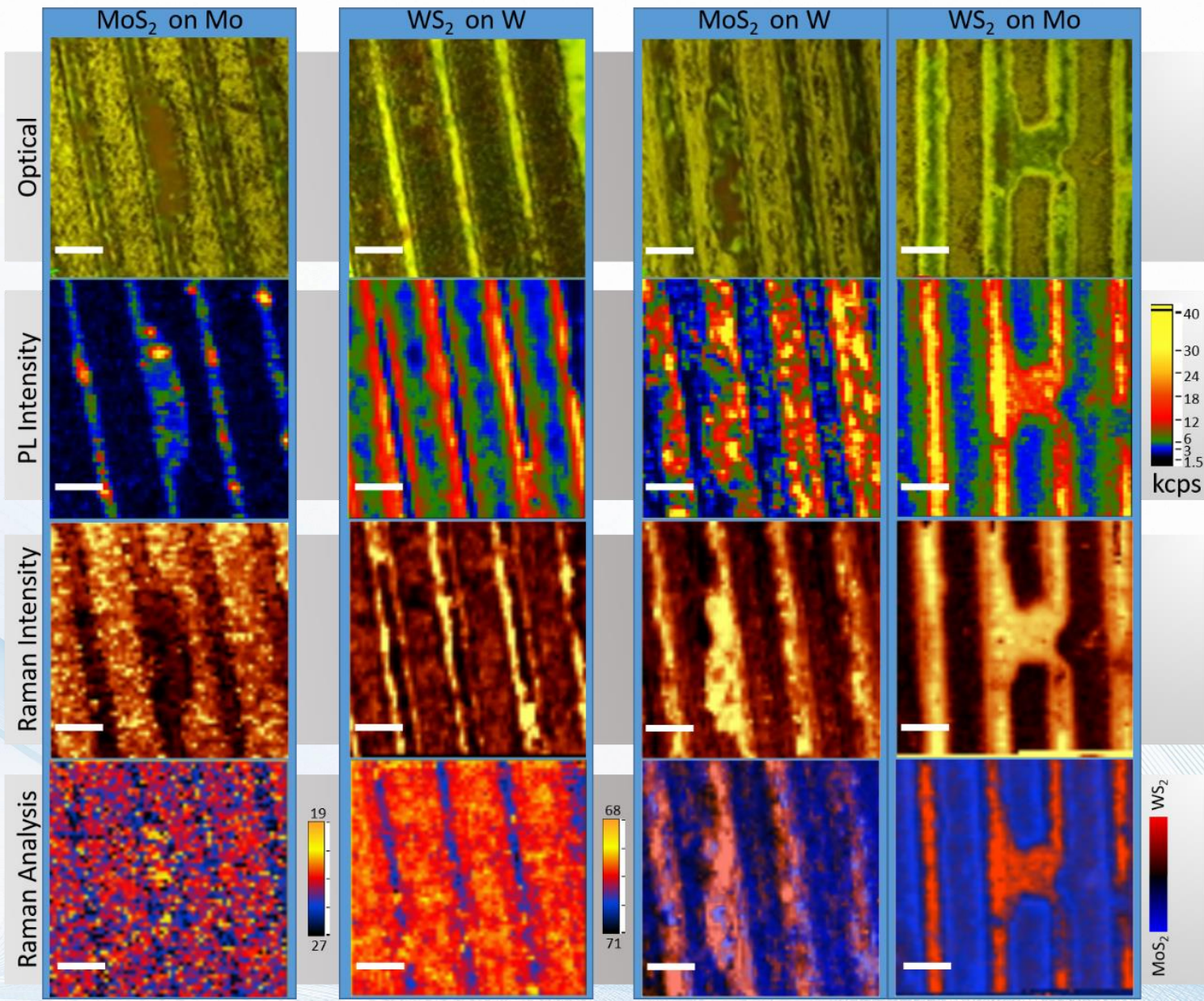
- MoS_2/WS_2 vertical heterostructures grown on tungsten wires

Khadka S., et al. *Advanced Materials Interfaces* (2016)

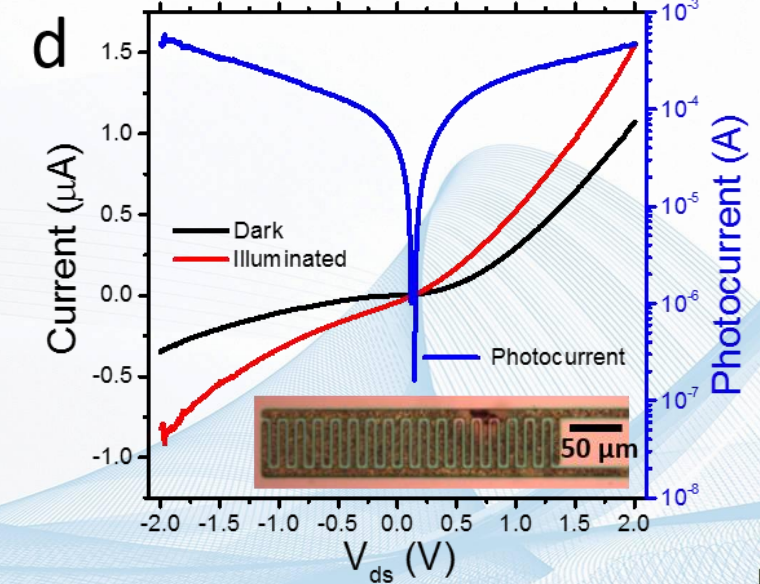
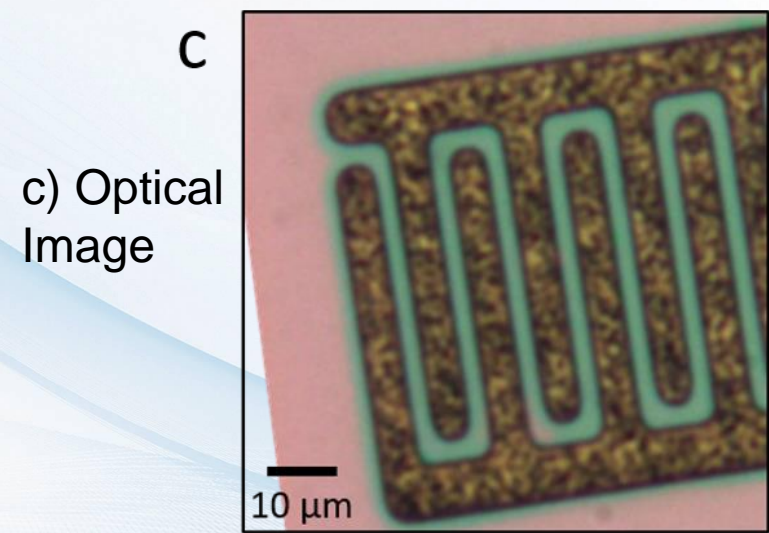
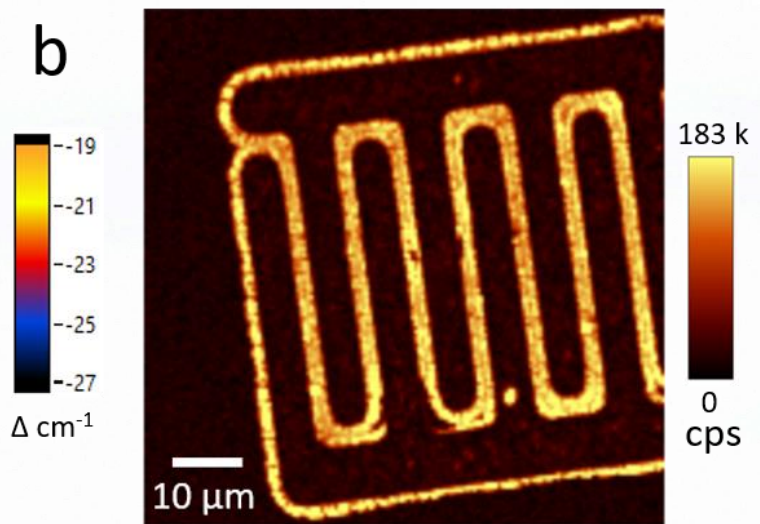
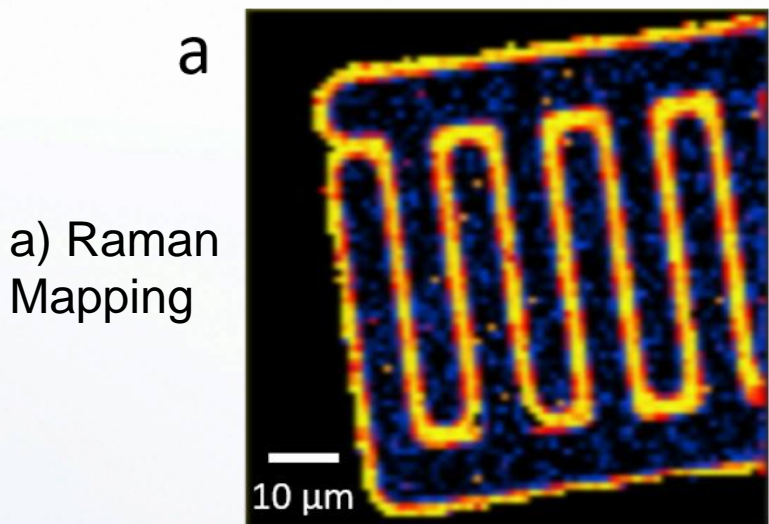
DOI: 10.1002/admi.201600599 or arXiv:1611.03887

Intra-species growth

Inter-species growth



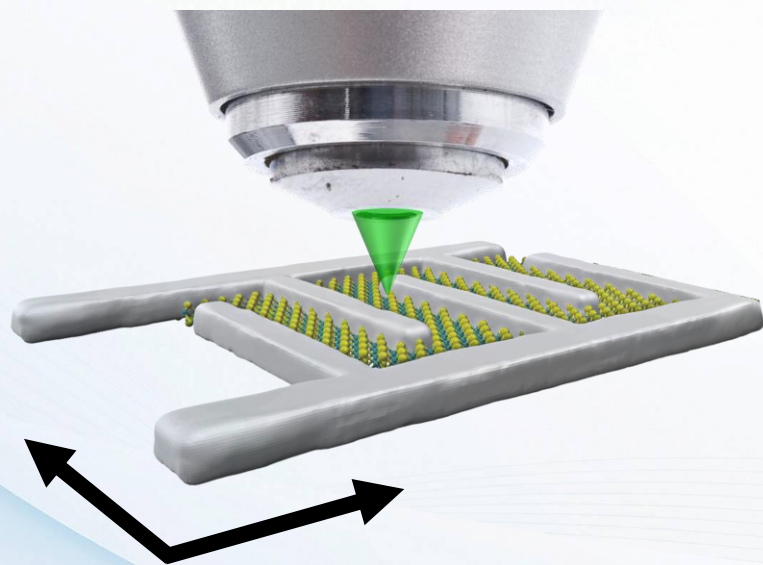
Combinations of metal pattern and oxide precursor may lead to straightforward production of complex device structures



b) PL Mapping

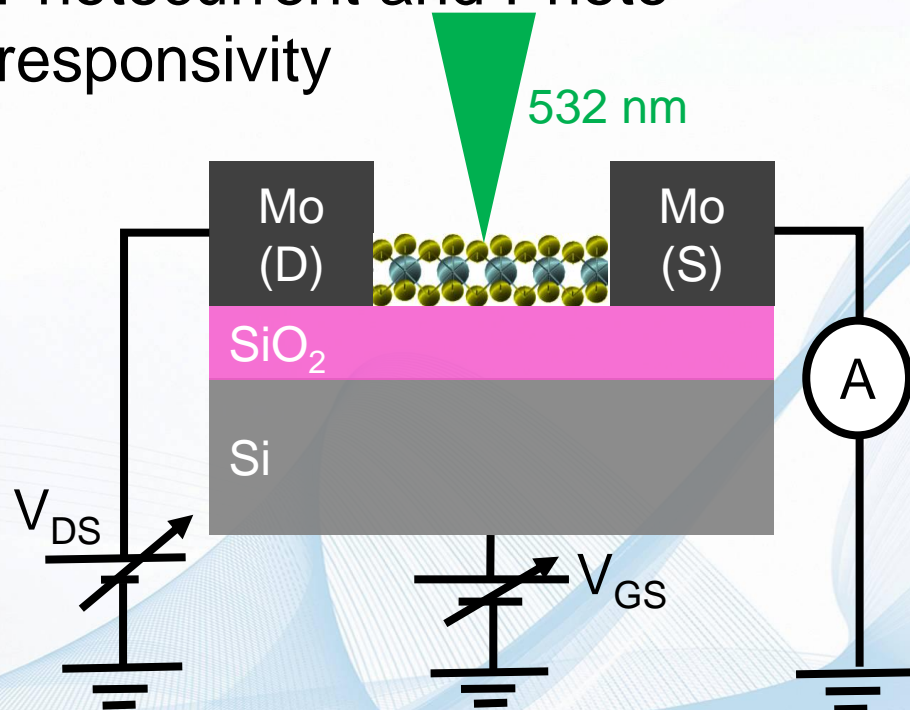
d) IV curves

a.
3D schematic of the as-grown MoS₂ based MSM PD



xy scanning stage

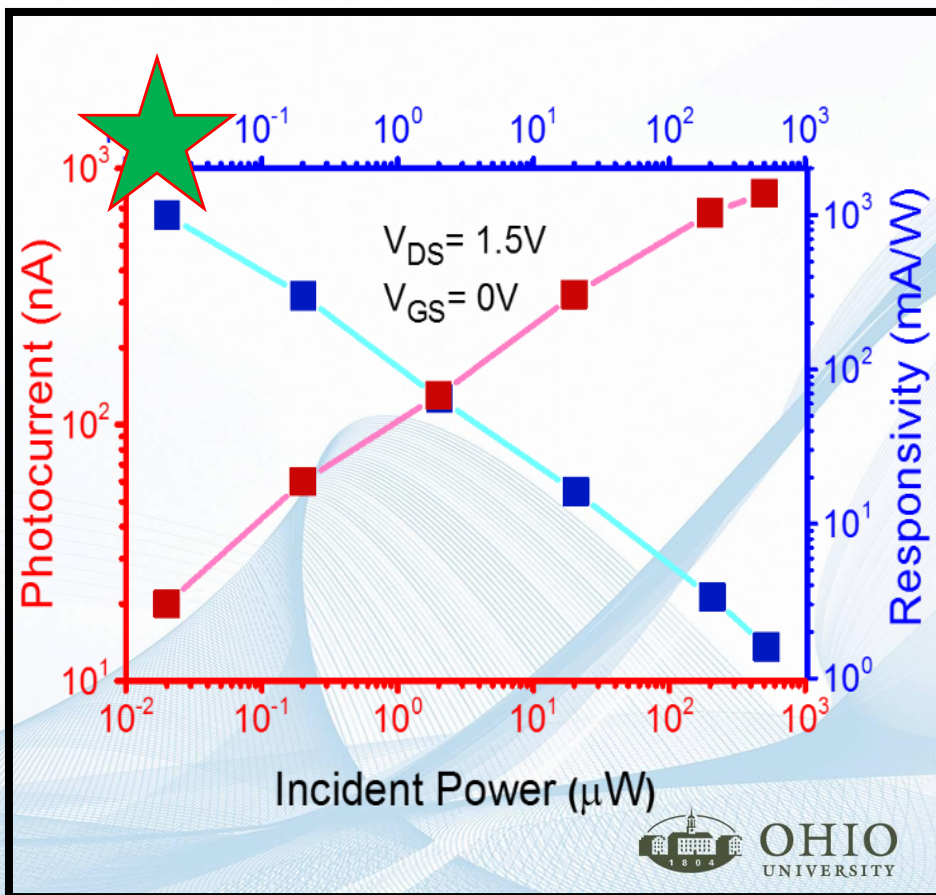
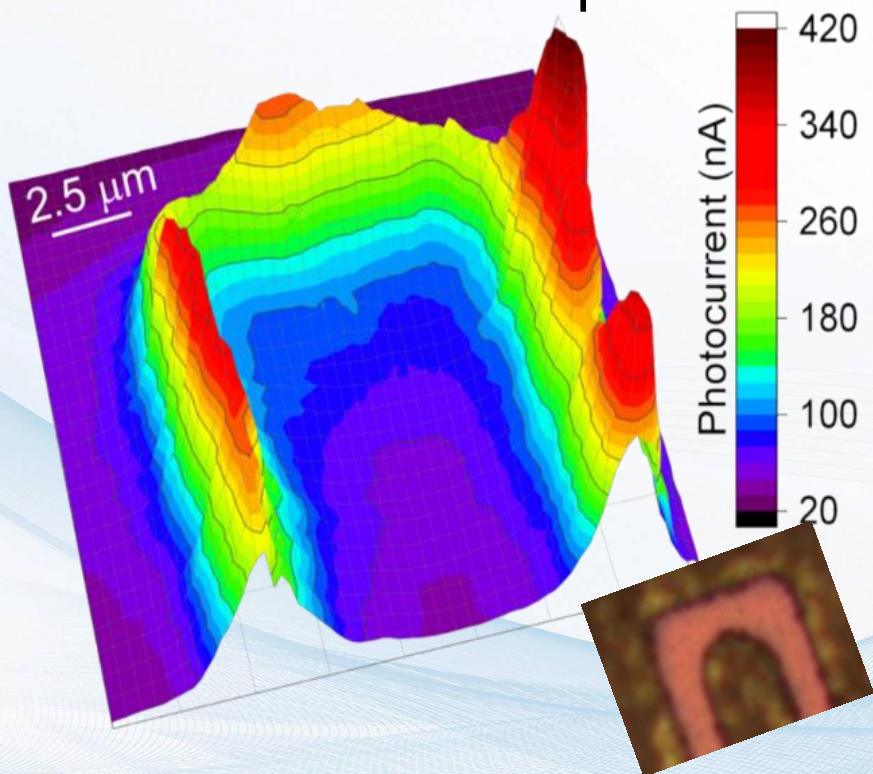
b.
Cross-sectional representation of PD with the electrical contacts used for the measurements of Photocurrent and Photoresponsivity



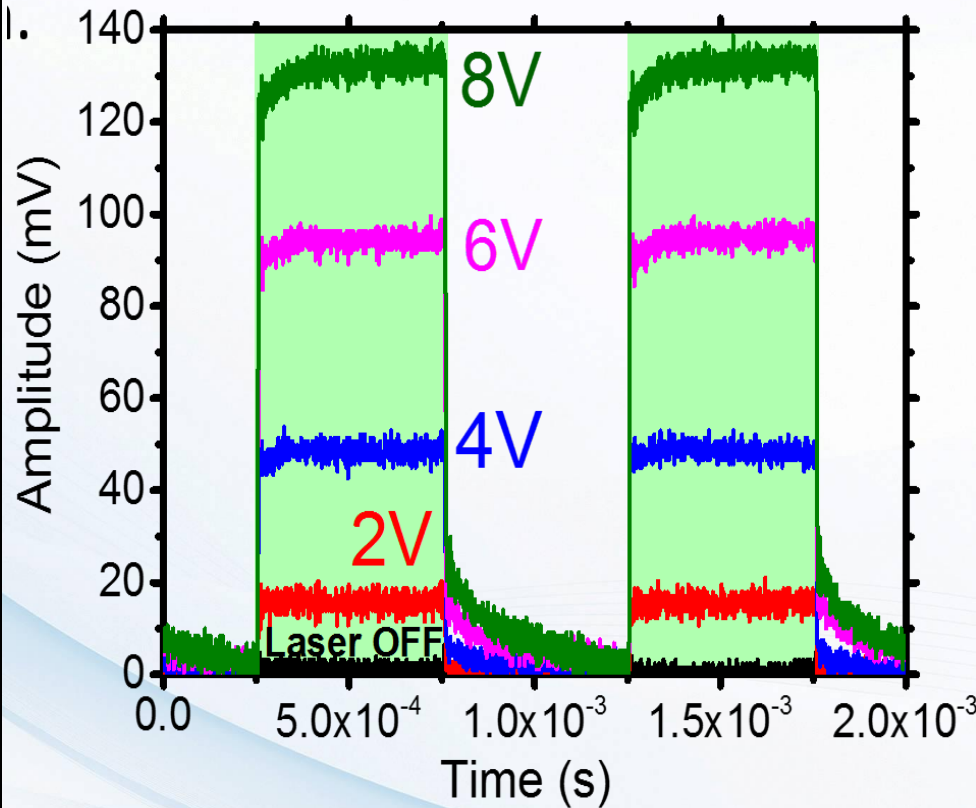
$$\text{Photocurrent} = I_{\text{Illuminated}} - I_{\text{dark}} \text{ (A)}$$

$$\text{Photoresponsivity (R)} = \frac{\text{Photocurrent}}{\text{Incident Power}} \text{ (A/W)}$$

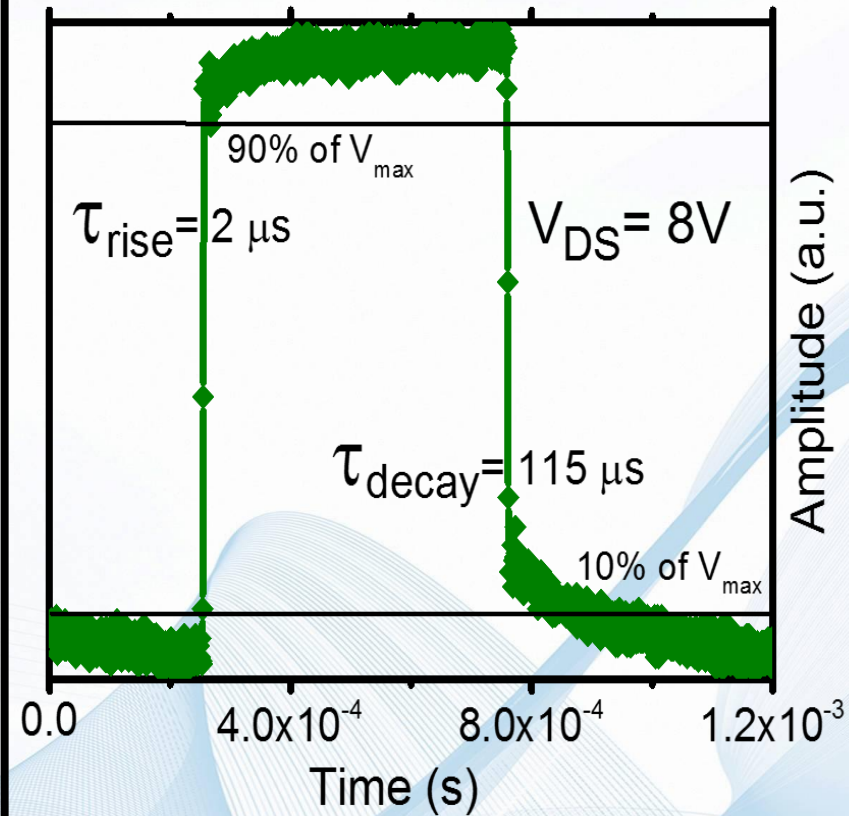
a. Photocurrent Map



a. Time resolved Photoresponse as a function of drain-source Voltage using (1kHz) 405 nm at 100 μ W.



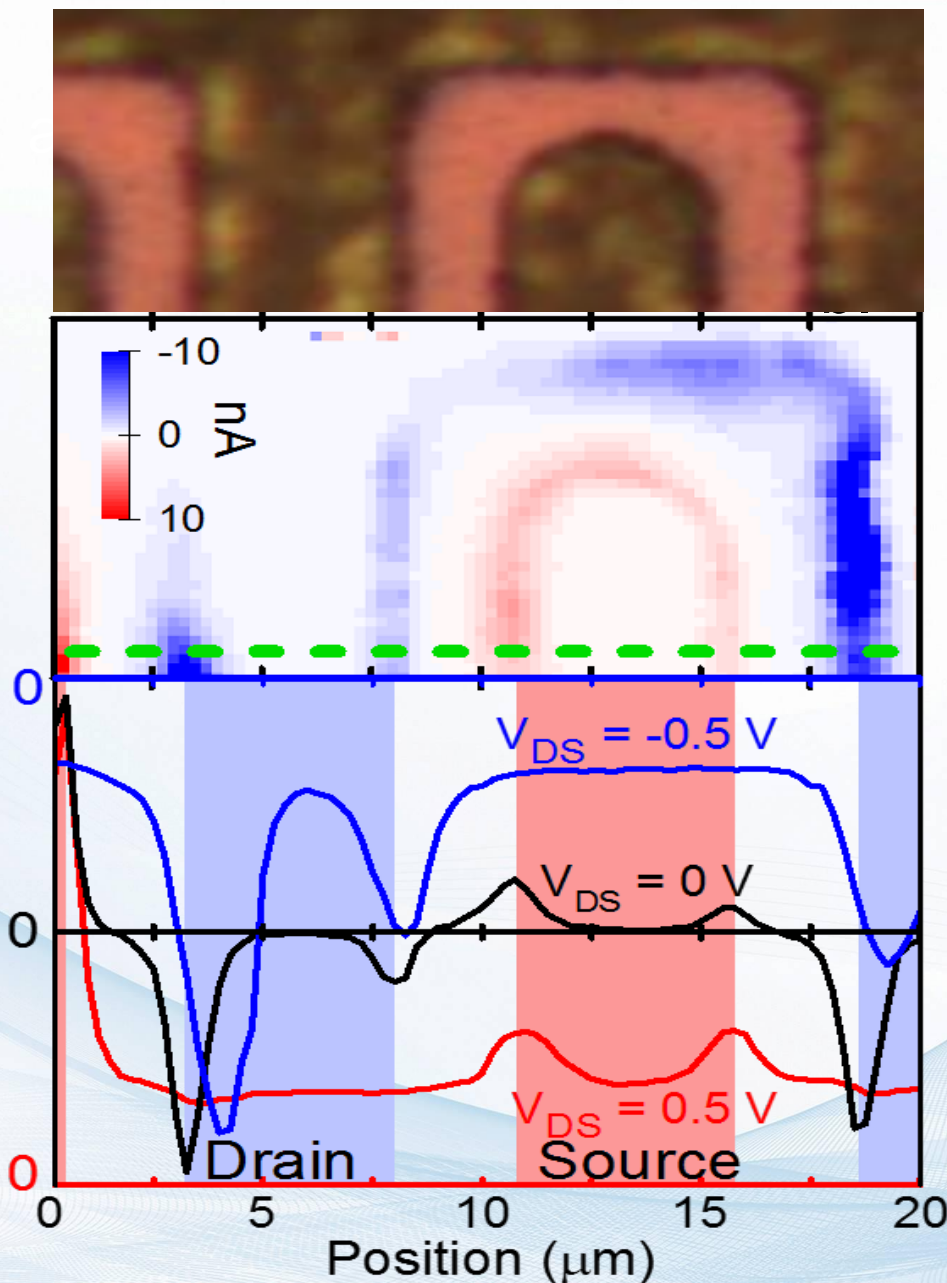
b. Rise and Fall time measured at 8V using the same excitation source.

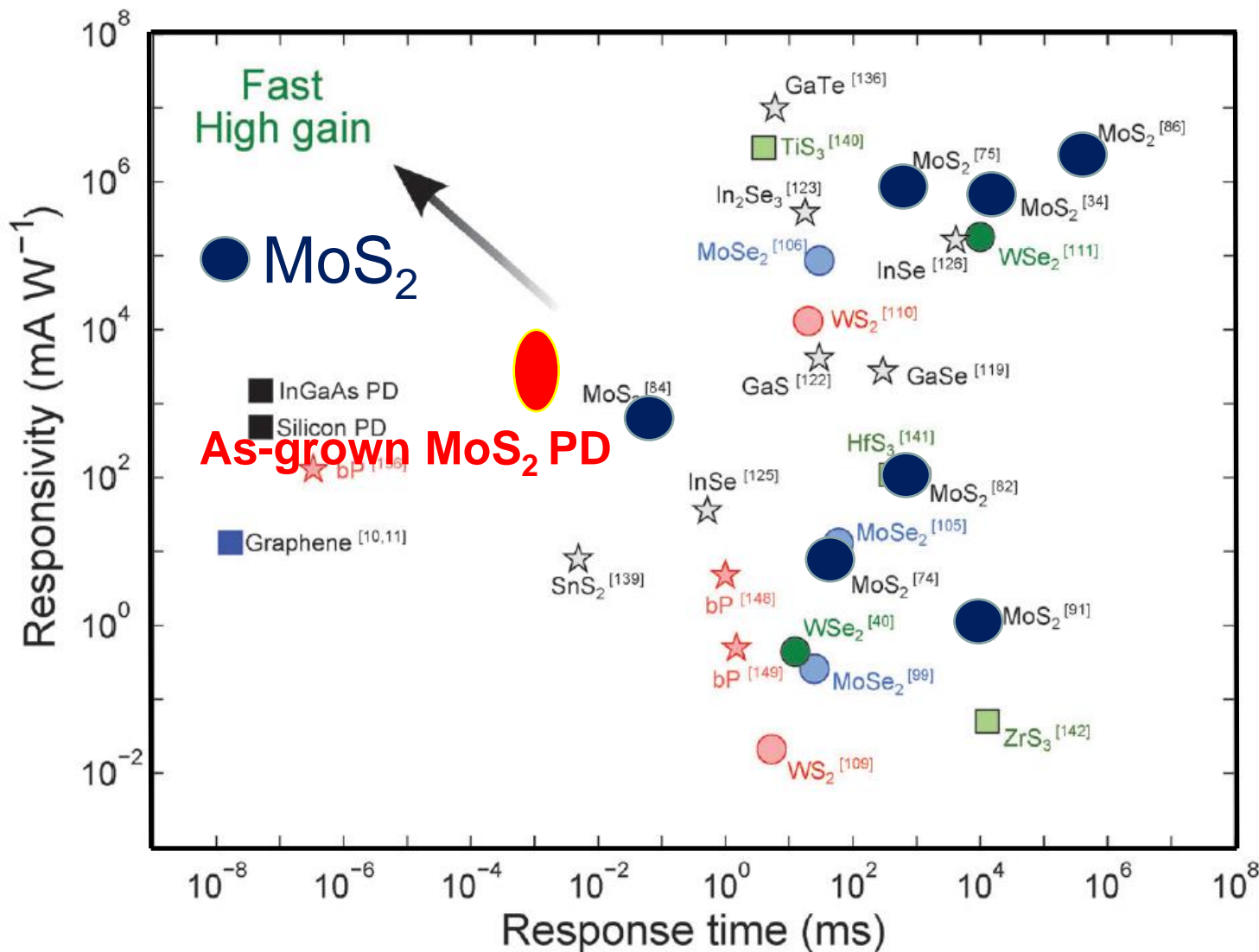


Optical Image

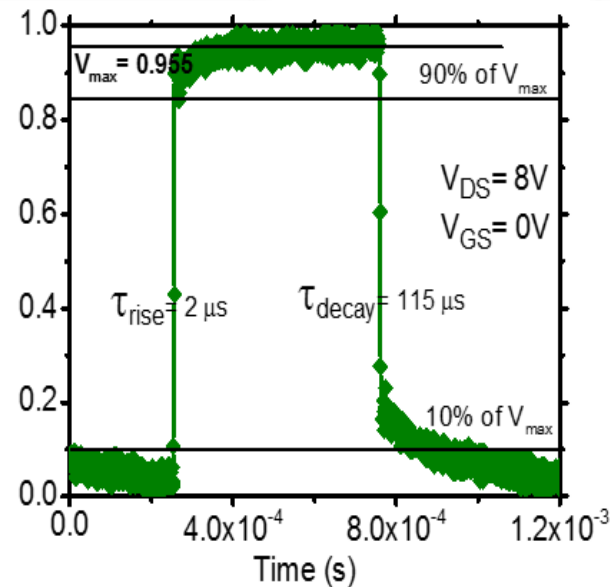
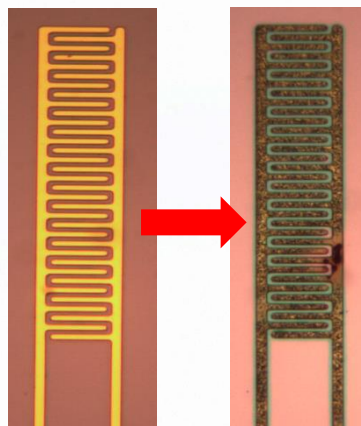
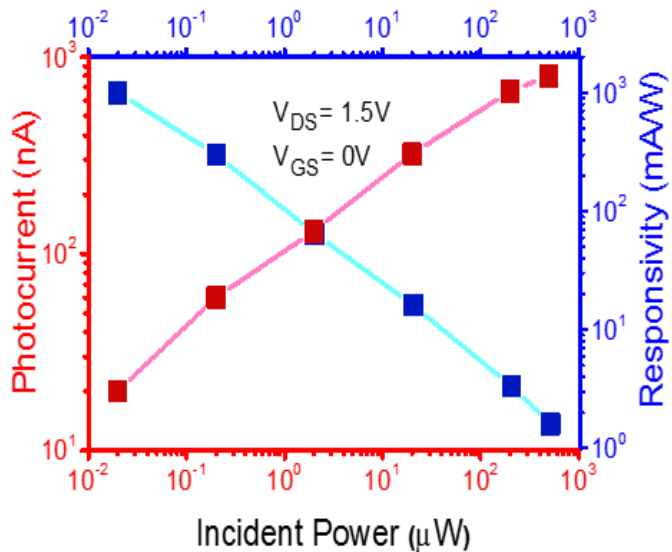
Photocurrent Mapping
at $V_{DS}=0V$

Line profile of Photocurrent
across green line
at $V_{DS}=\pm 0.5, 0V$



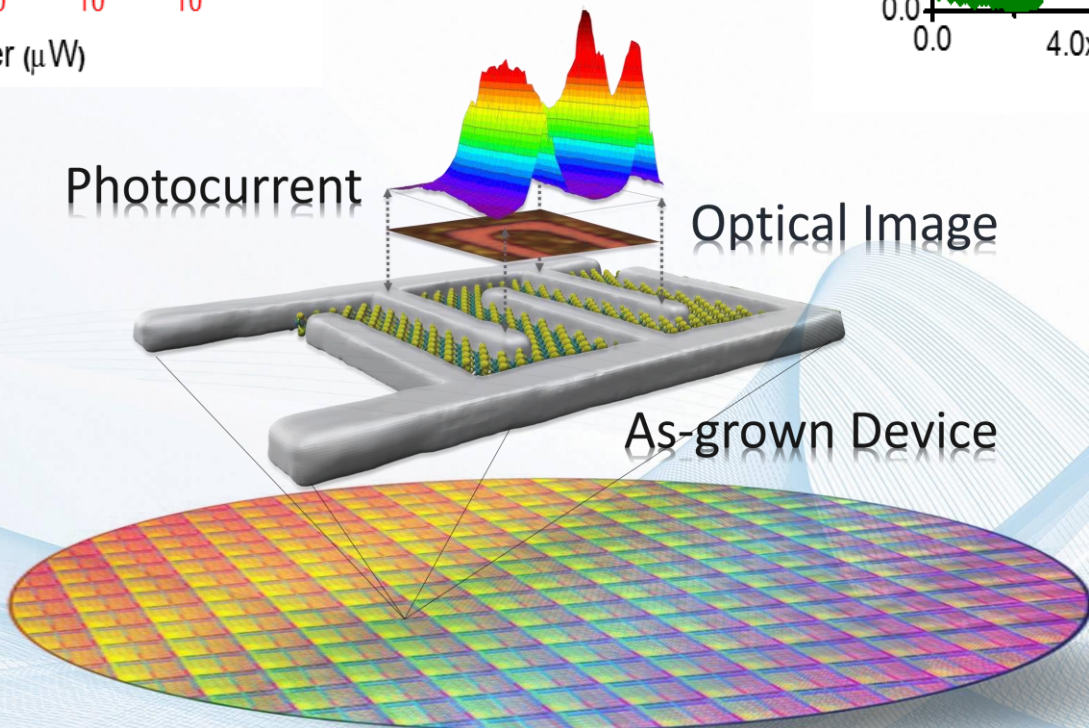


Ref: Buscema, Michele, et al. *Chemical Society Reviews* 44.11 (2015): 3691-3718.

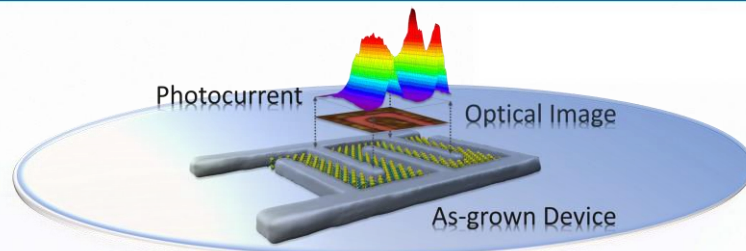


Photocurrent

Optical Image



- Deterministic
- Scalable
- **Compatible with existing silicon processing**
- **Provides concurrent, as-grown, electrical contacts**
- Heterostructures
- Direct on-chip optics?
- Doping?
- Complex geometries?



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